*Original Operating Manual*

# 3- / 4-line active filter LeaXield for leakage current compensation

305/530 V, 50 Hz, 50 A, 50 °C

U.S. Patent No. 10,069,480

| | |
|---|---|
| **Document number:** | **V62187-Z10-C401** |
| **Ordering code:** | **B8423*A1500R000** |
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# Contents

# 1 General important information

## 1.1 Legal notice

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## 1.2 Target audience

This operating manual and the corresponding product LeaXield™ with the ordering codes B84233A1500R000, B84234A1500R000 are intended exclusively for qualified personnel.

“Qualified personnel” is the designation for persons who have the qualifications and experience for a safe installation, start-up and maintenance of this product. The qualified personnel have to detect energy sources which can cause pain or injury and have to execute suitable measures for the protection against injuries.

Please read and comply this operating manual before further steps are taken.

## 1.3 Liability

TDK Electronics AG accepts no liability for any damages which result from an incorrect use of this operating manual or incorrect installation of the product.

## 1.4 Declaration of conformity

**EC-Declaration of Conformity**

We **TDK Electronics AG**
Rosenheimer Straße 141 e, 81671 München

declare under sole responsibility that the product/s

**3-line, 4-line active filter *LeaXield***
**Series B84233A1500R000, B84234A1500R000**

to which this declaration relates is/are in conformity with the following European directives:

LV Directive 2014/35/EU

EMC Directive 2014/30/EU

This is documented by the accordance with the following standard(s):

EN 62368-1:2014
EN 61000-3-2:2006 + A1:2009 + A2(2009)
EN 61000-3-3:2008
EN 61000-4-2:1995 + 2002
EN 61000-4-3:2002 + 2006 + A1:2008 + A2:2010
EN 61000-4-4:2012
EN 61000-4-5:1995 + 2015
EN 61000-4-6:2014
EN 61000-4-11:2004
EN 61000-6-3:2007 + A1:2011

Heidenheim, October 2021

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**Figure 1: EC-Declaration of Conformity**

## UK Declaration of Conformity

We **TDK Electronics AG**
Rosenheimer Straße 141 e, 81671 München

declare under sole responsibility that the product/s

**3-line, 4-line active filter *LeaXield***
**Series B84233A1500, B84234A1500R000**

to which this declaration relates is/are in conformity with the following European directives:

Electrical Equipment (Safety) Regulations 2016

Electromagnetic Compatibility Regulations 2016

This is documented by the accordance with the following standard(s):

EN 62368-1:2014
EN 61000-3-2:2006 + A1:2009 + A2(2009)
EN 61000-3-3:2008
EN 61000-4-2:1995 + 2002
EN 61000-4-3:2002 + 2006 + A1:2008 + A2:2010
EN 61000-4-4:2012
EN 61000-4-5:1995 + 2015
EN 61000-4-6:2014
EN 61000-4-11:2004
EN 61000-6-3:2007 + A1:2011

Our representative in the UK is TDK UK Limited, located at Bridge House, Brants Bridge, Bracknell, Berkshire, RG12 9BG, United Kingdom.

Heidenheim, October 2021

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**Figure 2: UK Declaration of Conformity**

## 2 Product description

LeaXield is designed to reduce the common-mode current resulting from the drive system. It can be added as a stand-alone component to minimize earth leakage currents, consequently improve RCD compatibility and reduce common-mode emissions. Therefore LeaXield brings benefit in several industrial applications e.g. drives, tooling machines, pumps, compressors, conveyer systems.

### 2.1 3-line typical circuit diagram (B84233A1500R000)

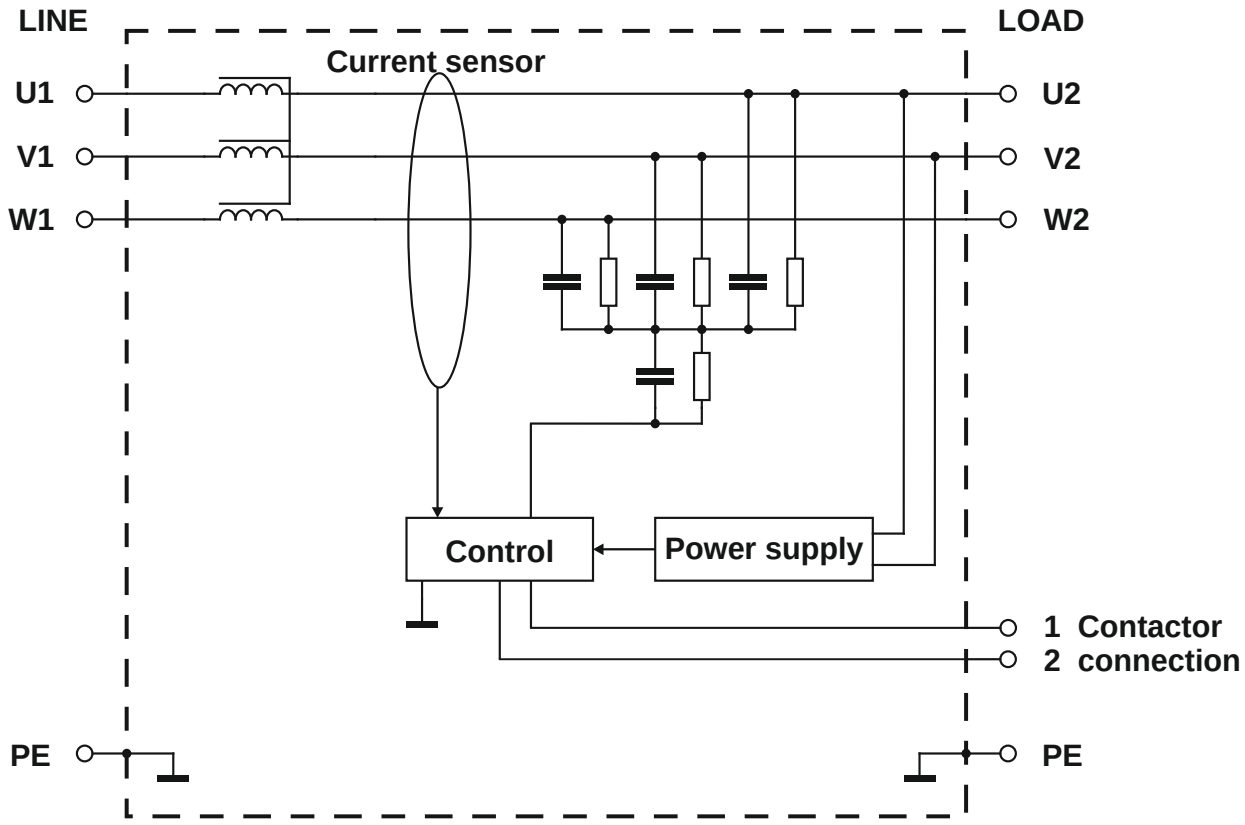



**Figure 3: Typical circuit diagram of B84233A1500R000**

### 2.2 3-line recommended system configuration

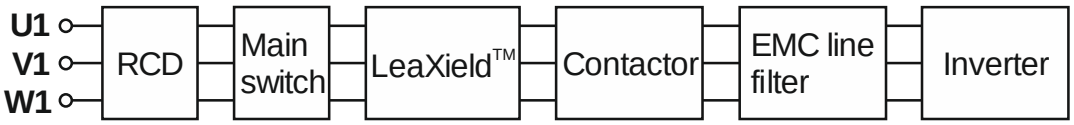



**Figure 4: Recommended system configuration of B84233A1500R000**

The system configuration in Figure 4 must be complied with in order to improve LeaXield performance. A change of the system configuration can lead to a failure of LeaXield and, as a result, to RCD tripping.

The use of the contactor on the load side of LeaXield is particularly important for reliable operation when switching on the mains voltage. Further information about the function and the wiring of the contactor is described in the following sections.

## 2.3 4-line typical circuit diagram (B84234A1500R000)

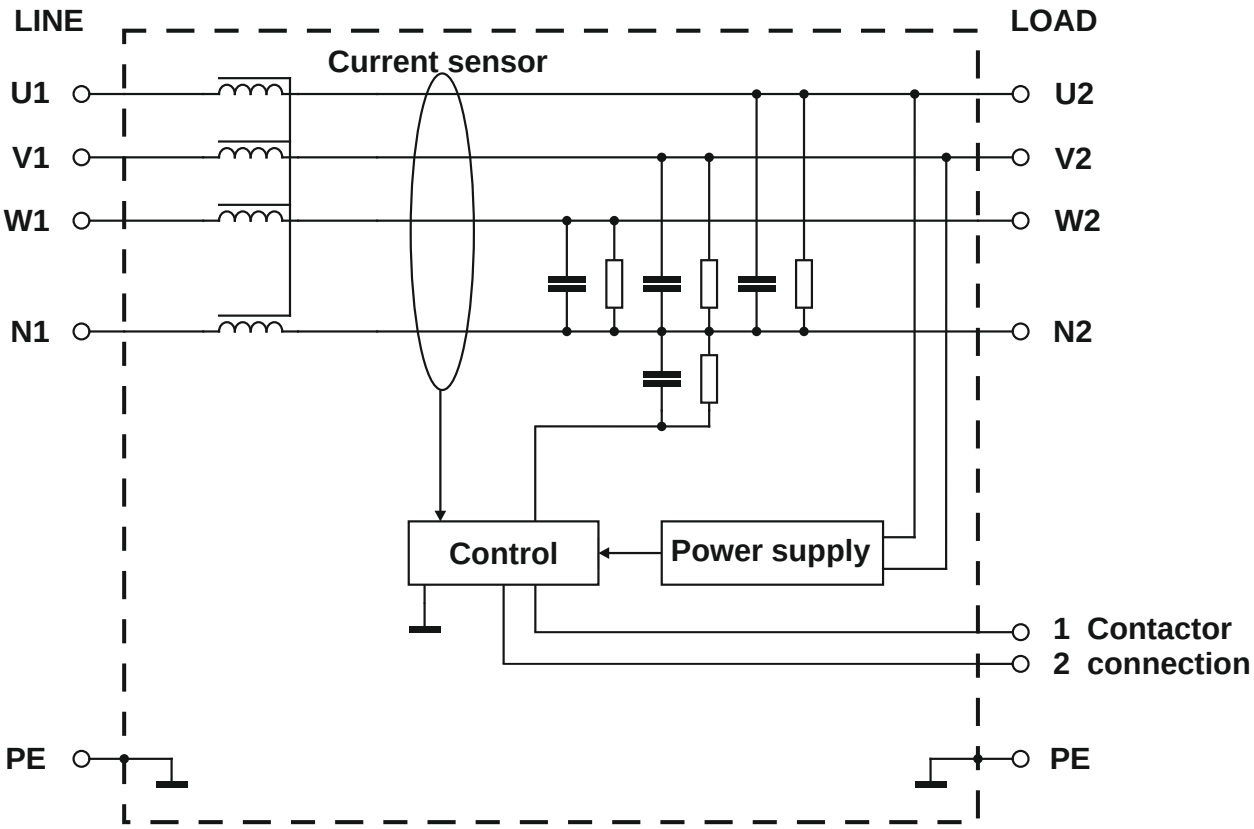



**Figure 5: Typical circuit diagram of B84234A1500R000**

## 2.4 4-line recommended system configuration

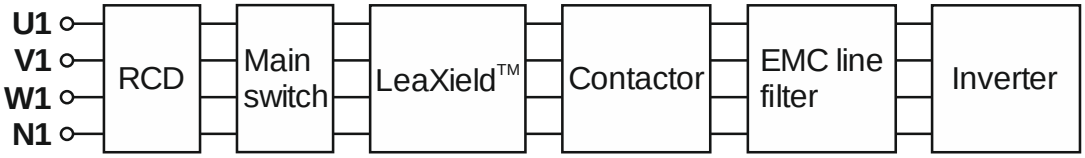



**Figure 6: Recommended system configuration of B84234A1500R000**

The system configuration in Figure 6 must be complied with in order to improve LeaXield performance. A change of the system configuration can lead to a failure of LeaXield and, as a result, to RCD tripping.

The use of the contactor on the load side of LeaXield is particularly important for reliable operation when switching on the mains voltage. Further information about the function and the wiring of the contactor is described in the following sections.

## 2.5 Functional description

LeaXield is an active 3-/4-line filter for the compensation of leakage currents. By minimizing the leakage currents, the RCD compatibility is improved and the common-mode emission in drive systems with inverters is reduced. The product is designed for the use in a 3-phase TN system.

The integrated current sensor detects the residual current of the three phases (+ neutral wire at 4-line LeaXield) and provides the measured value to the amplifier, which generates a corresponding 180° phase-shifted current with the same amplitude. Thus, instead of flowing through the RCD, the leakage current flows through the coupling capacitors back to the source of the leakage current as shown in Figure 7. Hence, undesirable RCD tripping is avoided. Common-mode attenuation up to 35 dB within a frequency range of 150 Hz to 30 kHz is possible. DC and 50 Hz error currents which occur on the drive line side are not compensated by LeaXield. Therefore, a RCD protection regarding dangerous DC and 50 Hz error currents is still provided.

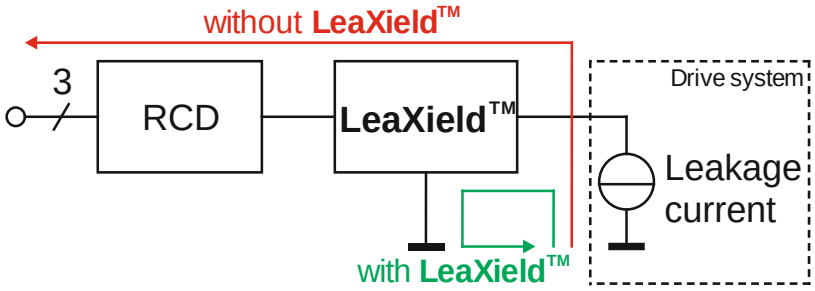



**Figure 7: Functional principle of LeaXield (valid for 4-line LeaXield too)**

### LeaXield contactor connection

The contactor connection allows LeaXield to be in steady state before the leakage current flows. This improves the RCD compatibility, especially during the switch-on of the mains voltage. To achieve this, connect the external power supply with pin 1 of the contactor connection at LeaXield and connect the contactor with pin 2 as shown in Figure 8 and Figure 9.

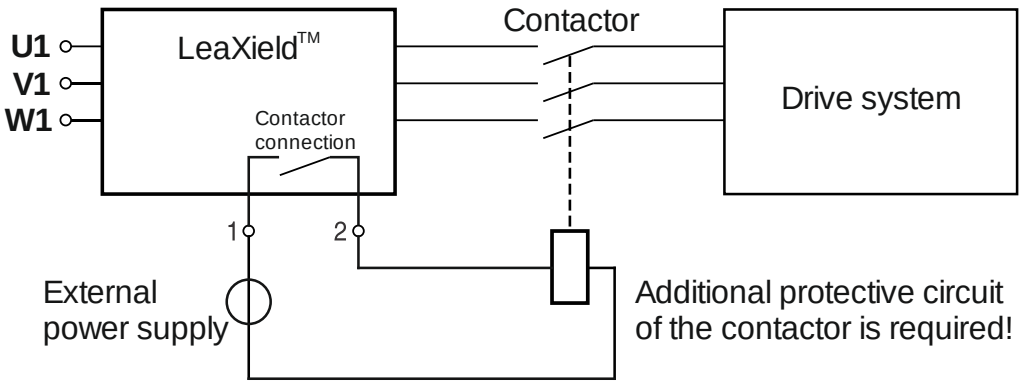



**Figure 8: Wiring of the contactor connection (for 3-line version)**

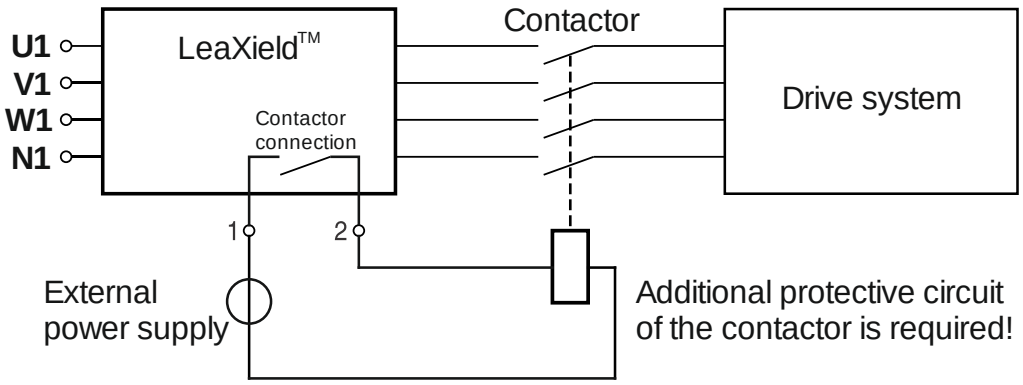



**Figure 9: Wiring of the contactor connection (for 4-line version)**

The contactor connection allows LeaXield to control the external power supply and hence the contactor. When the mains voltage is applied the contactor closes after approx. 2 s, therefore there is enough time for the device to attain a steady state.

### EMC line filter as pre-attenuator

The EMC line filter, which has to be connected to the load side of LeaXield, functions as a pre-attenuator and reduces the high leakage currents of the inverter coming from the switching of the power semiconductors. Therefore, using an EMC line filter is recommended, as it allows LeaXield to work properly in the specified frequency range.

### Systems with three-phase drives and single-phase loads

Additional single-phase loads, such as power supplies or fans, are sometimes used in systems with three-phase drives. They also use the neutral wire. Figure 10 shows an example of a system with three-phase drives and single-phase loads.

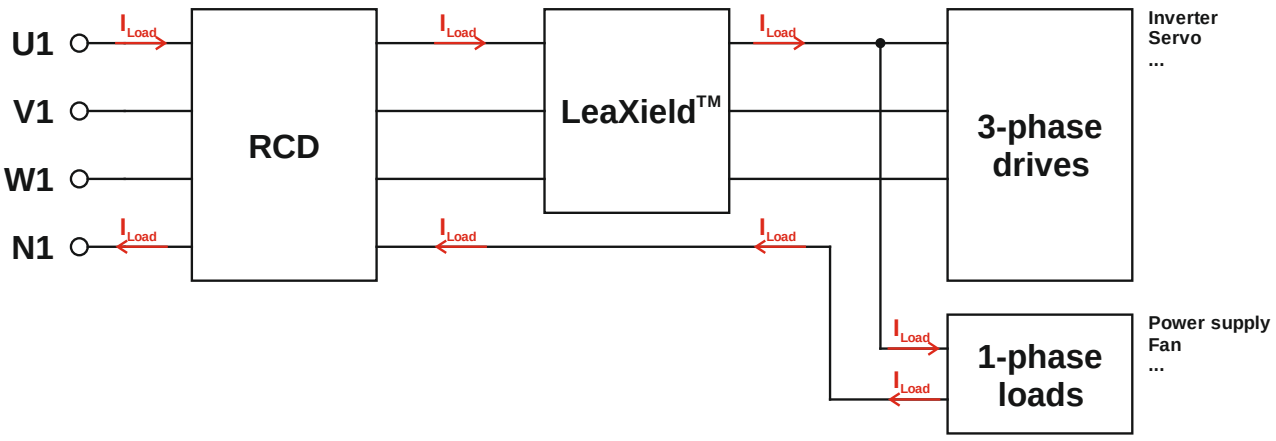



**Figure 10: Three-phase drives and single-phase loads**

This type of configuration can lead to a malfunction of the 3-line LeaXield because the additional neutral wire can't be connected to it. Without the connected neutral wire, the 3-line LeaXield treats the load current of the single-phase components as a leakage current.

In this cases the **4-line LeaXield** has to be used to avoid RCD tripping.

## 2.6 Typical measurements

Figure 11 shows sample measurements of the leakage current in the frequency domain. The red spectrum shows the leakage current without LeaXield and the blue spectrum shows the leakage current with LeaXield. The high attenuation up to 35 dB and the large operating frequency from 150 Hz to 30 kHz leads to an effective leakage current compensation.

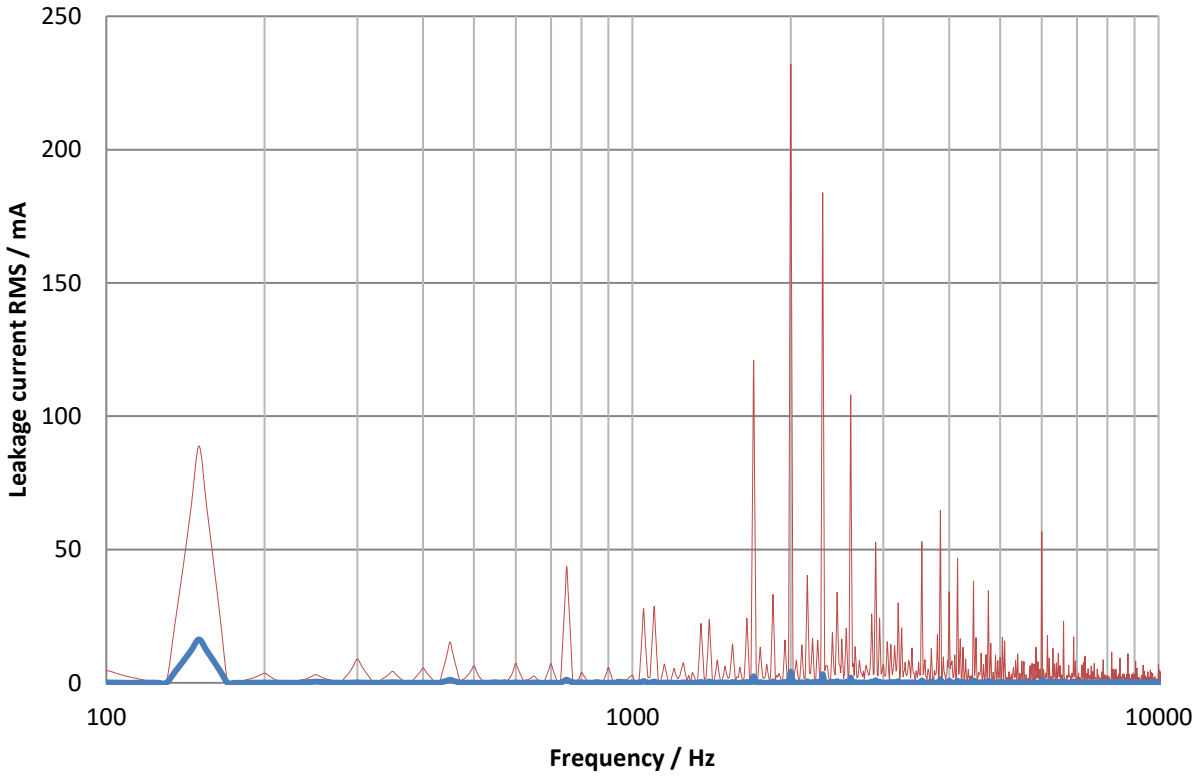



**Figure 11: Typical measurements**

# 3 Important safety notes

## 3.1 Application

- LeaXield is designed for variable-speed drive systems in a 3-phase TN system.
- The maximum leakage current on the load side of LeaXield is 1 A. Higher leakage currents can lead to malfunctions or damages of the product.
- The product LeaXield compensates leakage currents in an operating frequency range of 150 Hz to 30 kHz.
- According to EN 50178 / VDE 0160 only type B/B+ RCDs are allowed in variable-speed drive systems.
- In general, no security against failure exists for electronic devices. The operator of the machine is responsible for bringing the machine to a safe state on malfunction of the device or the tripping of the RCD.
- **Attention:** LeaXield cannot be used for RCDs which are requested according the fire protection guidelines such as VDE 0100-530.
- **Attention:** Error currents which are caused on the inverter load side can consist of several frequency portions, such as the switching frequency or motor frequency. The error currents in the range of the switching frequency are compensated by LeaXield intentionally. Therefore, it cannot be ensured that there is operator protection on the inverter load side.

  Note:
  An electrical insulated protection against touch such as a cover is recommended to get an operator protection on the inverter load side. Corresponding engineering standards have to be considered.

  Detailed description of the error current on the inverter load side:

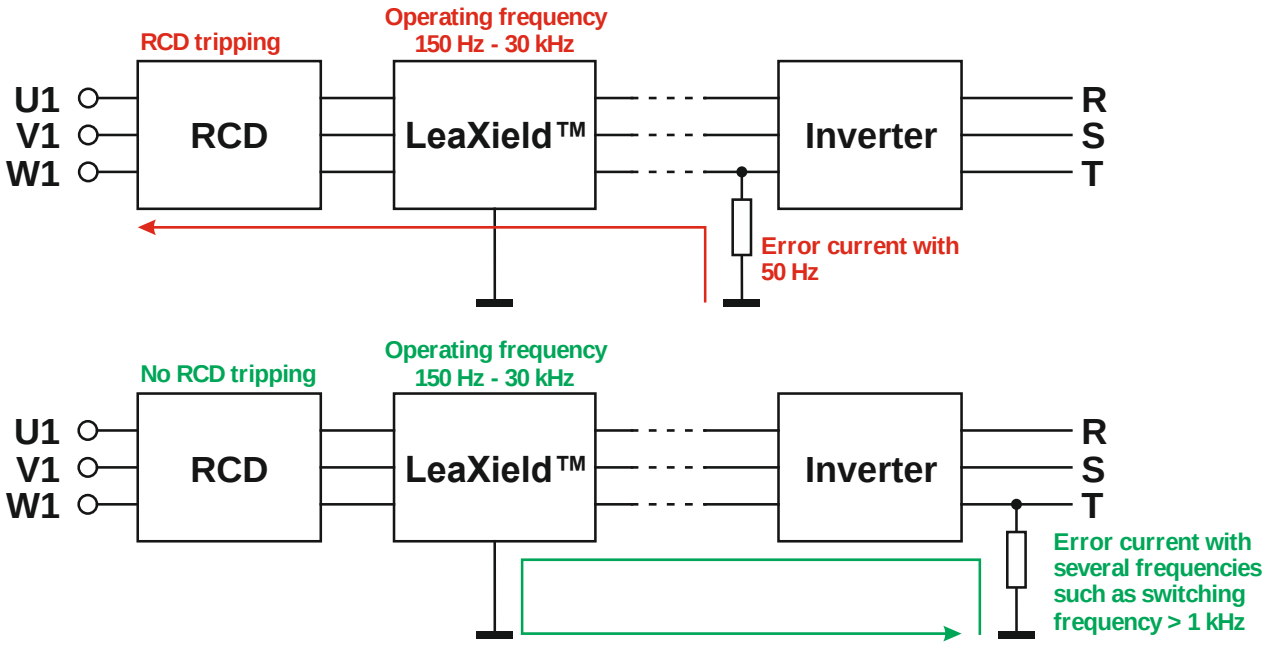



**Figure 12: Comparison of error current on the inverter line and load side (valid for 4-line LeaXield too)**

An error current occurs by indirect or direct touch of a live part or an insulation fault which can lead to dangerous touch currents or to fire. Unlike to a leakage current the RCD has to be tripped for the case that an error current occurs.

The top block diagram of Figure 12 shows the situation if an error current (shown as a resistor) occurs on the line side of the inverter. Error currents which are caused on the line side of the inverter have a dominant frequency of 50 Hz. The attenuation of LeaXield starts at 150 Hz. Therefore, the error current is not compensated and the RCD can be tripped to avoid a dangerous 50 Hz touch current.

For the case that the error current occurs on the load side of the inverter as shown in the bottom block diagram of Figure 12 the error current consists of several frequency portions, such as the switching frequency which is the dominant portion of the error current. The switching frequency of common inverters is in the range ≥ 1 kHz. As a result, LeaXield compensates this portion of the error current and it is possible that the RCD can’t be tripped. No operator protection exists anymore.

## 3.2 Installation

- The mounting and installation has to be executed only by qualified personnel who are conversant with the safety regulations.
- During the mounting and the installation, it has to be ensured that the machine is voltage free.
- During the mounting and the installation, the accident prevention regulations for electrical machines and equipment have to be observed.
- Connect LeaXield with the provided earth conductors on the line and load side.
- Connect the product with a wide area (low impedance) to functional earth to get a better EMC performance
- The housing of LeaXield must not be opened. Repairs are not permitted.
- Please notice the labeling on the product for the correct connection of the terminals “Line,” “Load” and “Contactor connection.”
- The terminals of LeaXield have protection class IP20 and are safe against touch. But this applies only if the correct conductor cross-section is used and all terminals are connected.
- Regarding heating, a minimum distance of 10 mm between LeaXield and the adjacent components must be observed.
- Consider the environmental conditions for the product.

**Table 1: Environmental conditions**

| | |
|---|---|
| Ambient temperature | +50 °C |
| Humidity stress | without condensation, rel. air humidity ≤ 93% |
| Altitude | ≤ 2000 m over mean sea level |
| Overvoltage category | III |
| Degree of pollution | 2 |

## 3.3 Product warning notices

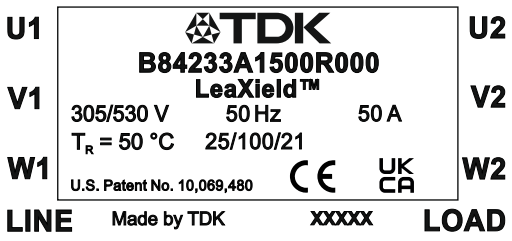
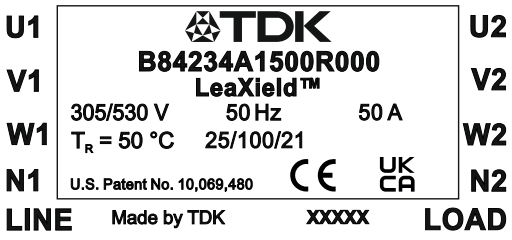
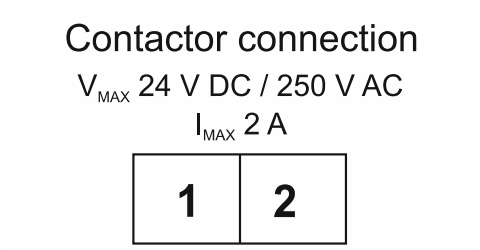
Table 2 shows warning notices with the corresponding descriptions which are pictured on the product, too. Please take care of the possible risks and follow the descriptions to avoid accidents.

**Table 2: Product warning notices**

| Symbol | Description |
|---|---|
|  | Hazardous voltages.<br>Electrical charge may be stored for up to 5 minutes after switch off.<br>Discharge the device and make sure it is voltage free. |
| | Dangerous leakage current.<br>Can cause severe injury or death.<br>Connect protective earth before commissioning. |
|  | Risk of injury regarding hot surface.<br>Can cause severe burns.<br>Do not touch. Allow to cool before servicing. |

## 4 Connections

**Table 3: LeaXield connections**

| | | |
|---|---|---|
| **Mains connection of B84233A1500R000** | | |
|  | **Function** | Measurement and compensation of leakage current |
| | **Connection description** | |
| | U1/V1/W1 | Phases on line side |
| | U2/V2/W2 | Phases on load side |
| **Mains connection of B84234A1500R000** | | |
|  | **Function** | Measurement and compensation of leakage current |
| | **Connection description** | |
| | U1/V1/W1/N1 | Phases and neutral on line side |
| | U2/V2/W2/N2 | Phases and neutral on load side |
| **Contactor connection** | | |
|  | **Function** | Improvement of the switch-on behavior |
| | **Connection description** | |
| | 1 | Control of the external connector (see Figure 8 and Figure 9) |
| | 2 | |

# 5 Technical data

## 5.1 Electrical and mechanical data

**Table 4: Electrical and mechanical data**

**Electrical data**

| | | |
|---|---|---|
| Rated voltage | $V_{R\ [L–PE\ /\ L–L]}$ | 305/530 V AC (50 Hz) |
| Minimum operating voltage | $V_{min\ [L–PE\ /\ L–L]}$ | 208/360 V AC (50 Hz) |
| Rated current | $I_R$ | 50 A (Referred to 50 °C rated temperature) |
| Rated temperature | $T_R$ | 50 °C |
| Test voltage:<br>- line to line for 2 s<br>- line to case for 2 s | <br>$V_{test\ [L-L]}$<br>$V_{test\ [L-Case]}$ | <br>1770 V DC<br>1500 V DC |
| Overload capability (thermal) | | 1.5 x $I_R$ for 3 min per hour or<br>2.5 x $I_R$ for 30 s per hour |
| Peak load side leakage current<br>Load side leakage current frequency range | $I_{LK-LOAD}$<br>$f_{LK-LOAD}$ | up to 1 A<br>150 Hz … 30 kHz |
| Contactor connection:<br>- Maximum voltage<br>- Maximum current | <br>$V_{max}$<br>$I_{max}$ | <br>24 V DC / 250 V AC<br>2 A |
| Typical contact resistance | $R_{typ}$ | 1.0 mΩ |

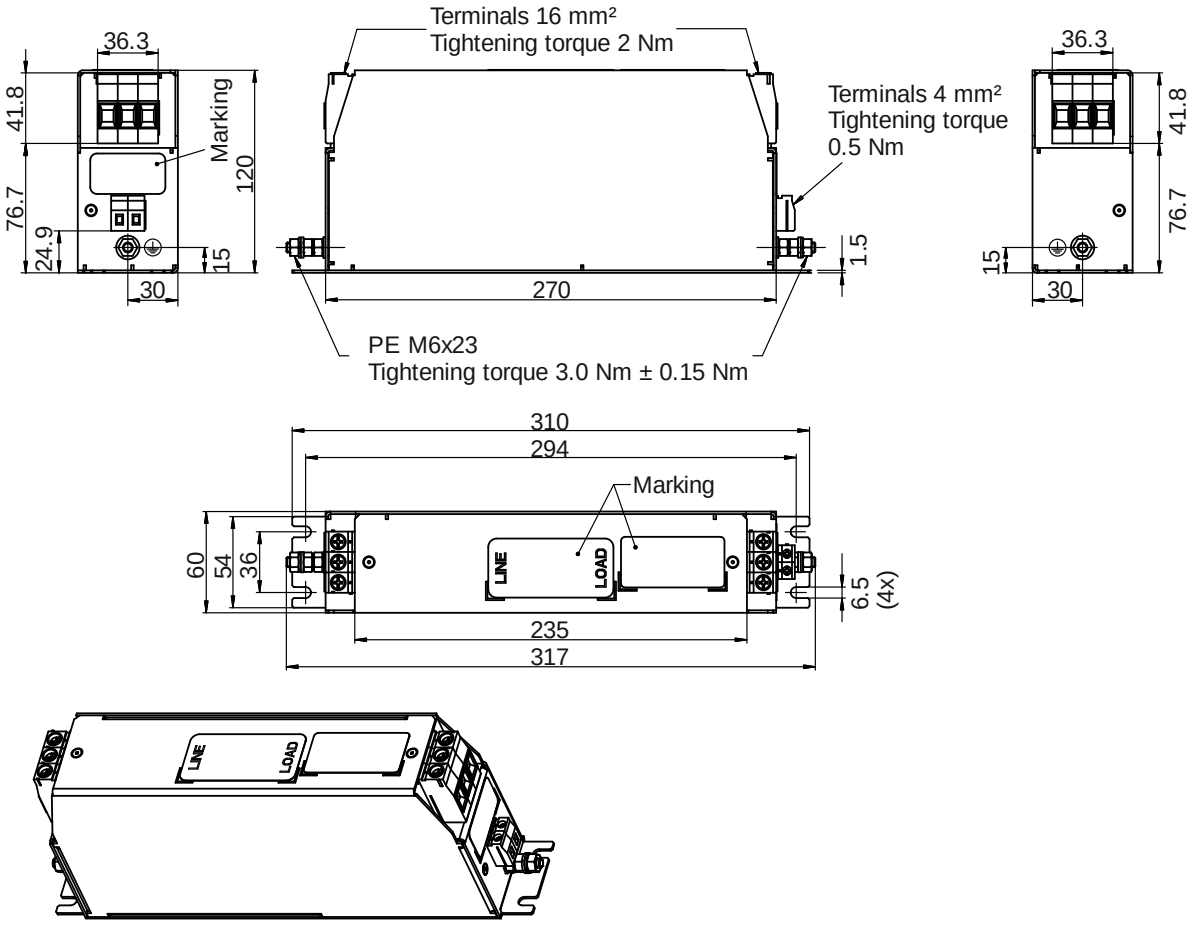
**General data**

| | |
|---|---|
| Climatic category (IEC 60068-1: 2013) | 25/100/21 |
| Degree of protection (IEC 60529: 2015) | IP 20 |

**Mechanical data**

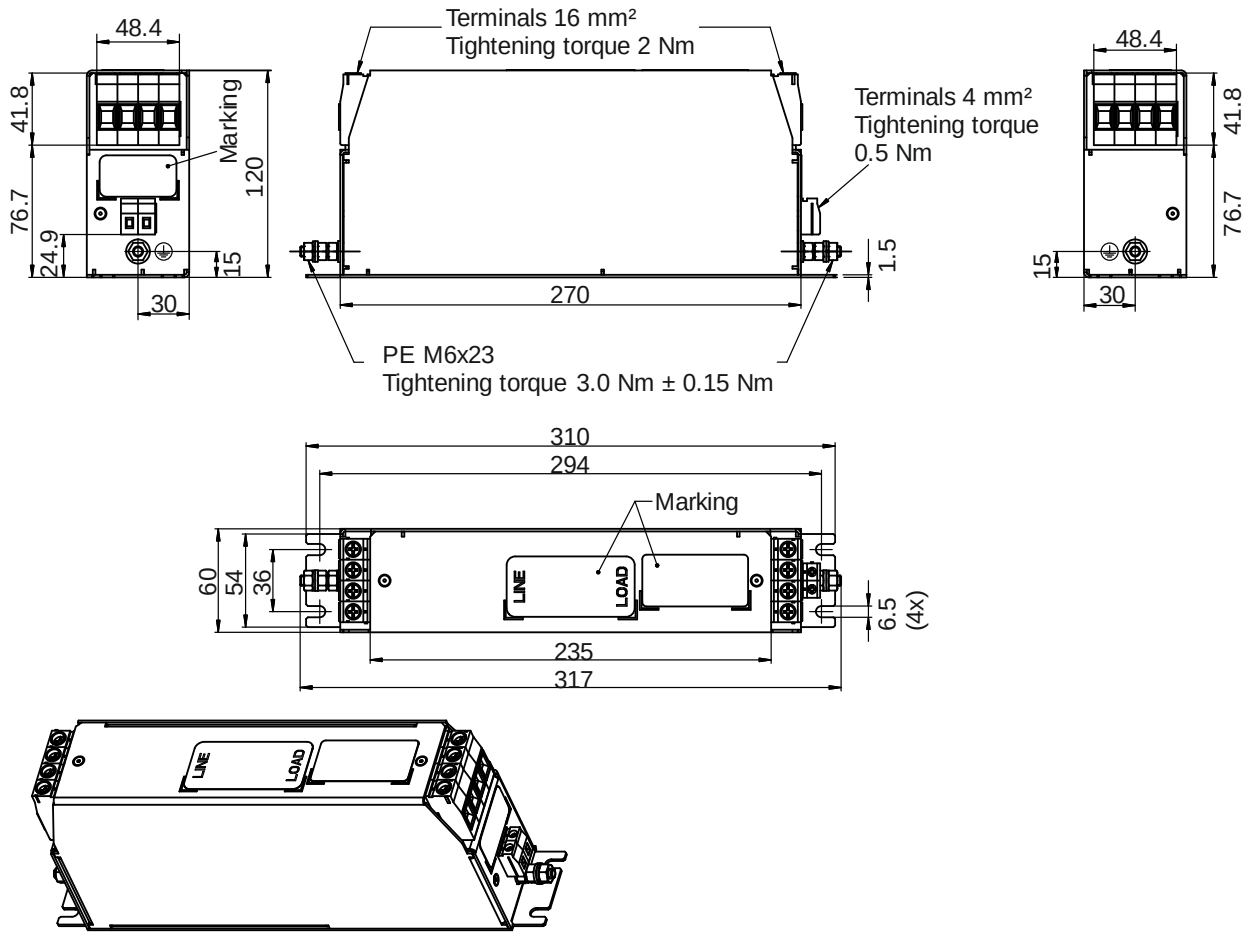
| | |
|---|---|
| Terminal mains connection | 16 mm² / 2 Nm |
| Terminal contactor connection | 4 mm² / 0.5 Nm |
| PE connection | Ring cable lug M6 / 3 Nm ± 0.15 Nm |
| Weight B84233A1500R000 | ca. 1.7 kg |
| Weight B84234A1500R000 | ca. 1.9 kg |

## 5.2 Dimensional drawing B84233A1500R000




General tolerances
according to ISO 2768−cL
Dimensions in mm

## 5.3 Dimensional drawing B84234A1500R000




General tolerances
according to ISO 2768−cL
Dimensions in mm

# 6 Analysis of the leakage current

## 6.1 Peak value

In general, it is recommended that the leakage current of the machine is measured before implementing LeaXield in the system. On the basis of the measurement, it is possible to verify whether the specified leakage current peak value is below the defined LeaXield limit of 1 A. If not, measures are necessary as described in Section 7.

A digital oscilloscope and a current probe with a band width of at least 30 kHz and amplitude > 1 A is recommended for measuring the peak value. The current probe has to enclose all phases as shown in Figure 13 to measure the leakage current. **Please consider that for the 4-line LeaXield the neutral wire has to be measured too.**

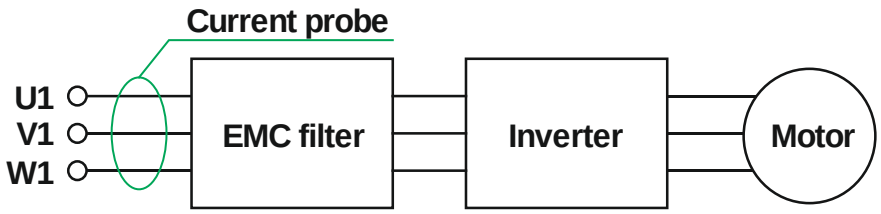



**Figure 13: Measurement of the leakage current (system with unused neutral wire)**

Figure 14 shows a typical measurement of the leakage current in the time domain. In this measurement example, the maximum leakage current is approx. 500 mA and is below the maximum peak value as specified in Section 5.

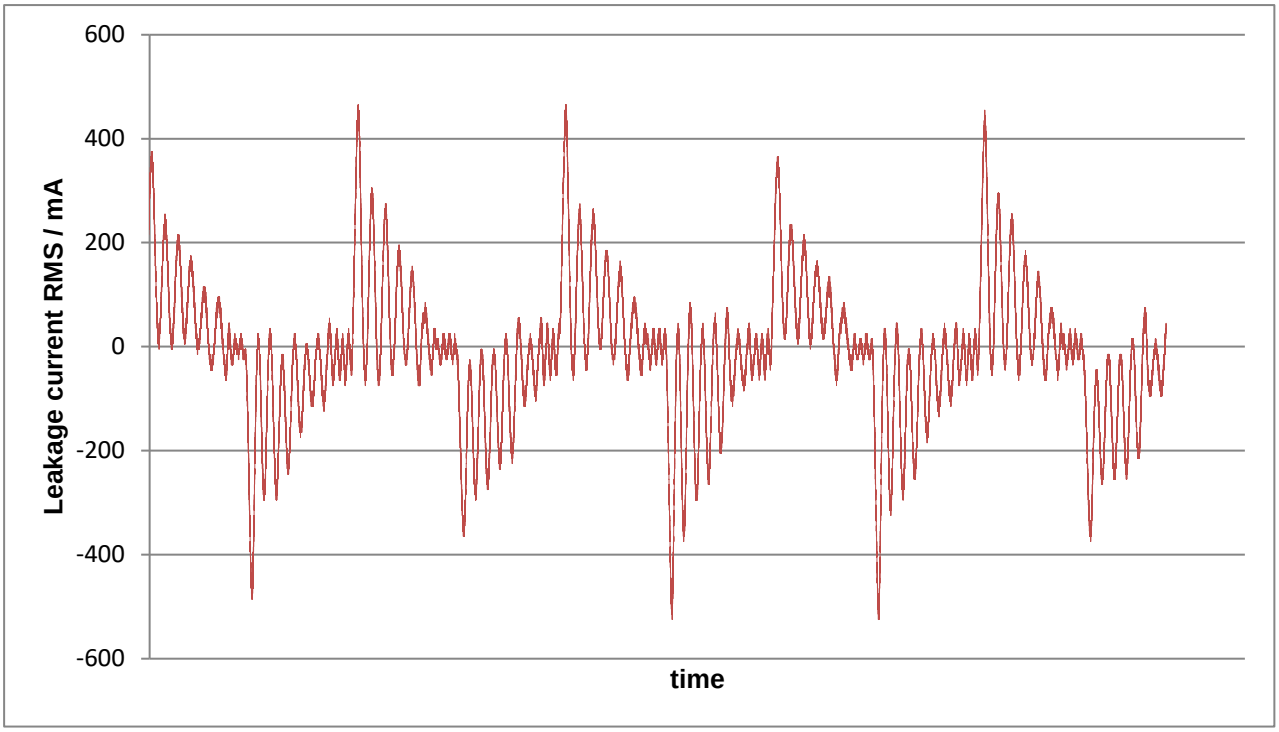



**Figure 14: Typical leakage current measurement in the time domain**

## 6.2 Frequency spectrum

In addition to the peak value of the leakage current, the frequency spectrum provides helpful information.

Figure 15 shows the leakage current in the frequency spectrum which is relevant as the RCD tripping limit of a typical RCD type B/B+ depends on the frequency. Furthermore, the spectrum shows whether the leakage currents are in the operating range of LeaXield as indicated with the green line in Figure 15.

The FFT function of the oscilloscope can be used for the measurement. But the application of a residual current analyzer is recommended. The advantage of a residual current analyzer is that the tripping characteristics of various RCDs can be shown.

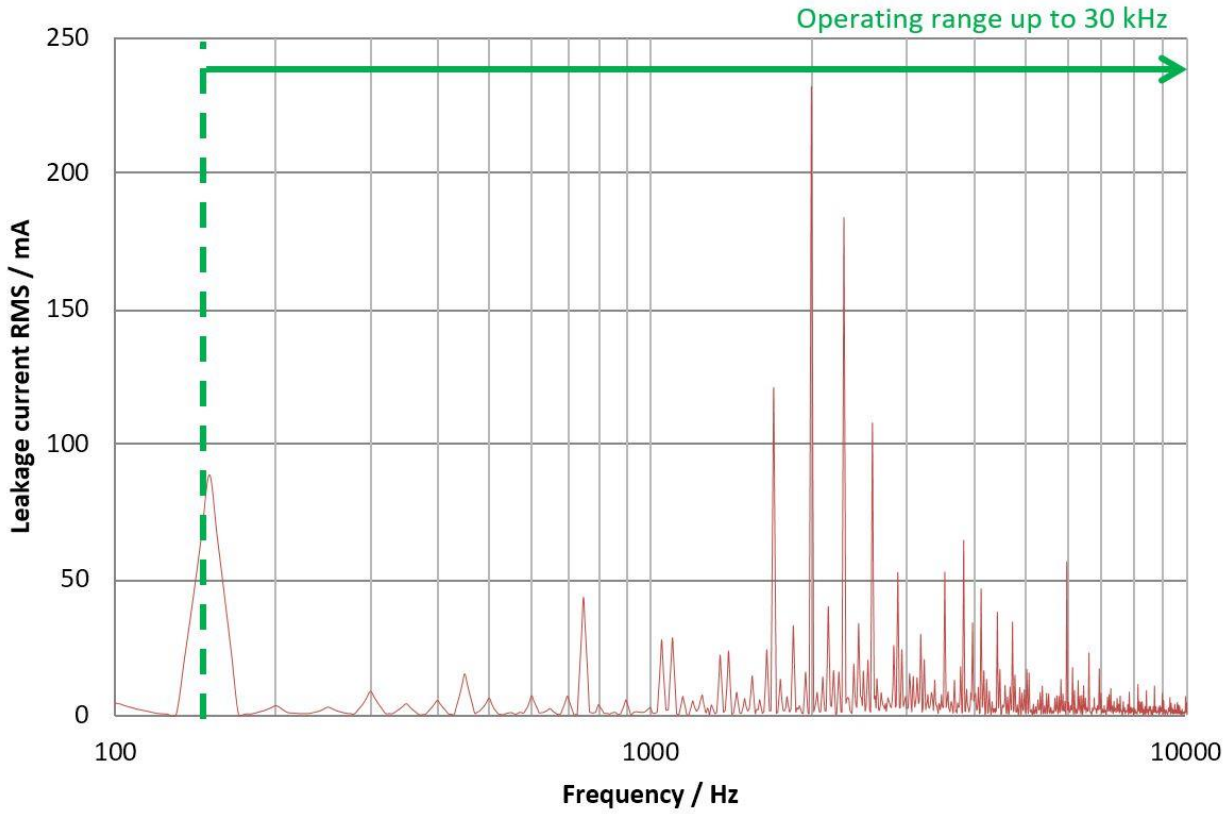



**Figure 15: Measurement of the frequency spectrum**

## 7 Causes of RCD tripping and remedial actions

The following table shows possible causes and the corresponding remedial actions in the event that the RCD trips.

**Table 5: Remedial actions**

| Cause | Recommended action |
|---|---|
| Rated voltage too low | The rated voltage has to be between 360 V AC and 530 V AC |
| LeaXield not ready for operation during switch-on of the mains voltage | Use contactor on LeaXield load side and connect it like in Figure 8 and Figure 9 |
| High 50 Hz transient leakage current due to asymmetrical connection of the phases, e.g. by manual plugging of the grid connector | Use a main switch which contacts as much as possible symmetrically → no high 50 Hz transient leakage current occurs |
| | Use contactor on LeaXield load side and connect it like in Figure 8 and Figure 9 |
| Maximum leakage current > 1 A | Use EMC line filter with higher insertion loss (EMC line filter works as pre-attenuator for LeaXield) |
| | Increase the switching frequency of the inverter |
| High transient leakage currents → RCD trips during switch-on of the mains voltage | Use EMC line filter with low Y capacitance (low leakage filter) |
| | Do not switch on all drives simultaneously. Switch on the drives sequentially. |
| Systems with used neutral wire (for single-phase loads) | Use 4-line LeaXield |

## 8 Disposal

Due to the commercial application of LeaXield, the device must not be disposed at communal collection stations. Professional waste disposal must be implemented.

## Cautions and warnings

- Please note further advice in our website www.tdk-electronics.tdk.com/**pemc_filters_gti**
- It shall be ensured that only qualified persons (electricity specialists) are engaged on work such as planning, assembly, installation, operation, repair and maintenance. They must be provided with the corresponding documentation.
- Danger of electric shock: The products contain components that store an electric charge. Dangerous voltages can continue to exist at the product terminals for longer than five minutes even after the power has been switched off.
- The protective earth connections shall be the first to be made when the product is installed and secured against loosening by defined tightening torque. Remove them at last, when uninstalling. Depending on the magnitude of the leakage currents, the particular specifications for making the protective−earth connection must be observed.
- Impermissible overloading of the product, such as with circuits able to cause resonances, impermissible voltages at higher frequencies etc. can lead to bodily injury and death as well as cause substantial material damages (e.g. destruction of the product housing).
- The Products must be protected in the application against impermissible exceeding of the rated currents by overcurrent protective devices.
- For leakage currents >10 mA, a fixed connection of the protective earth conductor to the public power grid is required. This means that connection via plug connectors is not permitted. The protective conductor must have a minimum cross-section of 10 $mm^2$ Cu or 16 $mm^2$ Al over its entire length. Alternatively, two separate protective conductors with the minimum cross-section specified in each case can also be connected.
- For leakage currents 3.5 mA < $I_{LK}$ [a)] ≤ 10 mA, the following solutions are possible:
  - Stationary device with fixed connection
  - Stationary device with type B plug-in connection (industrial plug-in connection according to IEC 60309) and cross-section ≥ 2.5 $mm^2$
  - Stationary device with type A plug-in connection (non-industrial plug-in device) and additional second protective earth connection
  - Movable equipment with type A plug-in connection and additional second protective earth connection in premises with restricted access
- The products must be protected in the application against impermissible exceeding of the specification parameter.
- The converter output frequency must be within the specified range to avoid resonances and uncontrolled warming of the output chokes and output filters.
- The components can become very hot during operation, there is the risk of burns if touched. The product can remain hot for some time after the power is switched off!
- The products are only to be attached to the fixings or mounting holes provided for this purpose in accordance with the data sheet. It is not permitted for the product specified in the data sheet to assume a mechanical function in the final application, in particular any type of tension or pressure on the product must be prevented.

[a)] $I_{LK}$ = Leakage current

## Display of ordering codes for TDK Electronics products

The ordering code for one and the same product can be represented differently in data sheets, data books, other publications, on the company website, or in order-related documents such as shipping notes, order confirmations and product labels. **The varying representations of the ordering codes are due to different processes employed and do not affect the specifications of the respective products**. Detailed information can be found on the Internet under www.tdk-electronics.tdk.com/orderingcodes.

## Important notes

The following applies to all products named in this publication:

Some parts of this publication contain **statements about the suitability of our products for certain areas of application**. These statements are based on our knowledge of typical requirements that are often placed on our products in the areas of application concerned. We nevertheless expressly point out **that such statements cannot be regarded as binding statements about the suitability of our products for a particular customer application.** As a rule we are either unfamiliar with individual customer applications or less familiar with them than the customers themselves. For these reasons, it is always ultimately incumbent on the customer to check and decide whether a product with the properties described in the product specification is suitable for use in a particular customer application.

We also point out that **in individual cases, a malfunction of electronic components or failure before the end of their usual service life cannot be completely ruled out in the current state of the art, even if they are operated as specified.** In customer applications requiring a very high level of operational safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health (e.g. in accident prevention or life-saving systems), it must therefore be ensured by means of suitable design of the customer application or other action taken by the customer (e.g. installation of protective circuitry or redundancy) that no injury or damage is sustained by third parties in the event of malfunction or failure of an electronic component.

**The warnings, cautions and product-specific notes must be observed.**

In order to satisfy certain technical requirements, **some of the products described in this publication may contain substances subject to restrictions in certain jurisdictions (e.g. because they are classed as hazardous)**. Useful information on this will be found in our Material Data Sheets on the Internet (www.tdk-electronics.tdk.com/material). Should you have any more detailed questions, please contact our sales offices.

We constantly strive to improve our products. Consequently, **the products described in this publication may change from time to time**. The same is true of the corresponding product specifications. Please check therefore to what extent product descriptions and specifications contained in this publication are still applicable before or when you place an order.

We also **reserve the right to discontinue production and delivery of products**. Consequently, we cannot guarantee that all products named in this publication will always be available. The aforementioned does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

Unless otherwise agreed in individual contracts, **all orders are subject to our General Terms and Conditions of Supply.**

**Our manufacturing sites serving the automotive business apply the IATF 16949 standard.** The IATF certifications confirm our compliance with requirements regarding the quality management system in the automotive industry. Referring to customer requirements and customer specific requirements (“CSR”) TDK always has and will continue to have the policy of respecting individual agreements. Even if IATF 16949 may appear to support the acceptance of unilateral requirements, we hereby like to emphasize that **only requirements mutually agreed upon can and will be implemented in our Quality Management System.** For clarification purposes we like to point out that obligations from IATF 16949 shall only become legally binding if individually agreed upon.



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