



Original Operating Manual

3-line active filter LeaXield for leakage current compensation

305/530 V, 50 Hz, 50 A, 50 °C

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

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Contents

1	General important information	3
1.1	Legal notice	3
1.2	Target audience	3
1.3	Liability	3
1.4	Declaration of conformity	4
2	Product description	5
2.1	Typical circuit diagram	5
2.2	Recommended system configuration	5
2.3	Functional description	6
2.4	Typical measurements	7
3	Important safety notes	8
3.1	Application	8
3.2	Installation	9
3.3	Product warning notices	10
4	Connections	11
5	Technical data	12
5.1	Electrical and mechanical data	12
5.2	Dimensional drawings	13
6	Analysis of the leakage current	14
6.1	Peak value	14
6.2	Frequency spectrum	15
7	Causes of RCD tripping and remedial actions	16
8	Disposal	16

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 code B84233A1500R000 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 active filter LeaXield
Series B84233A1500R000

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

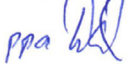
LV Directive 2014/35/EU

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, November 2018



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Figure 1: 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 Typical circuit diagram

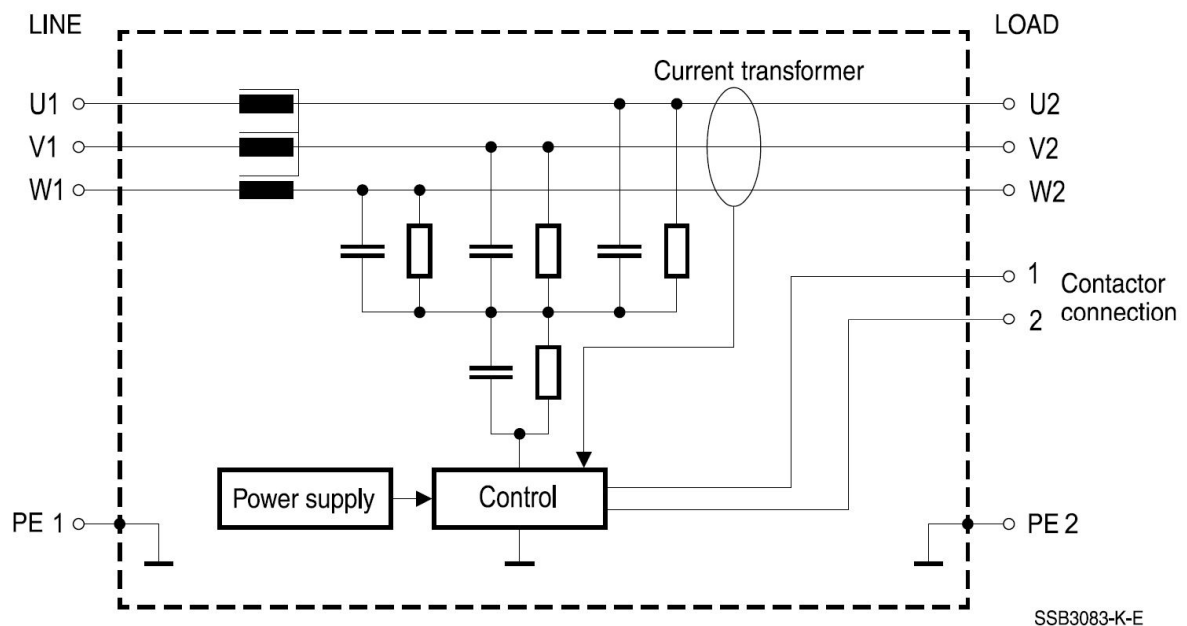


Figure 2: Typical circuit diagram

2.2 Recommended system configuration

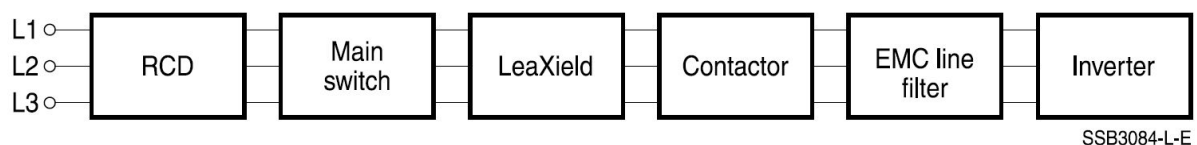


Figure 3: Recommended system configuration

The system configuration in Figure 3 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 Functional description

LeaXield is an active 3-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 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 4. 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 are not compensated by LeaXield. Therefore, a RCD protection regarding dangerous DC and 50 Hz error currents is still provided.

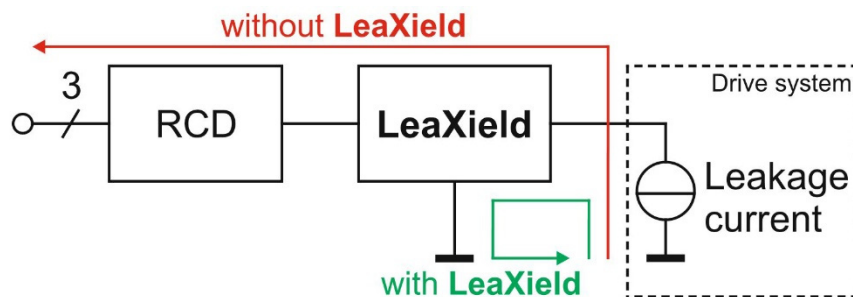


Figure 4: Functional principle of LeaXield

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 5.

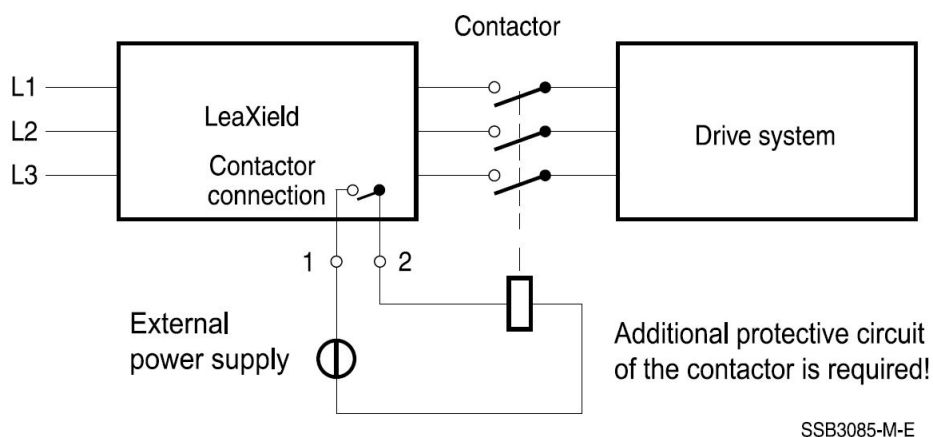


Figure 5: Wiring of the contactor connection

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.

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.

2.4 Typical measurements

Figure 6 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.

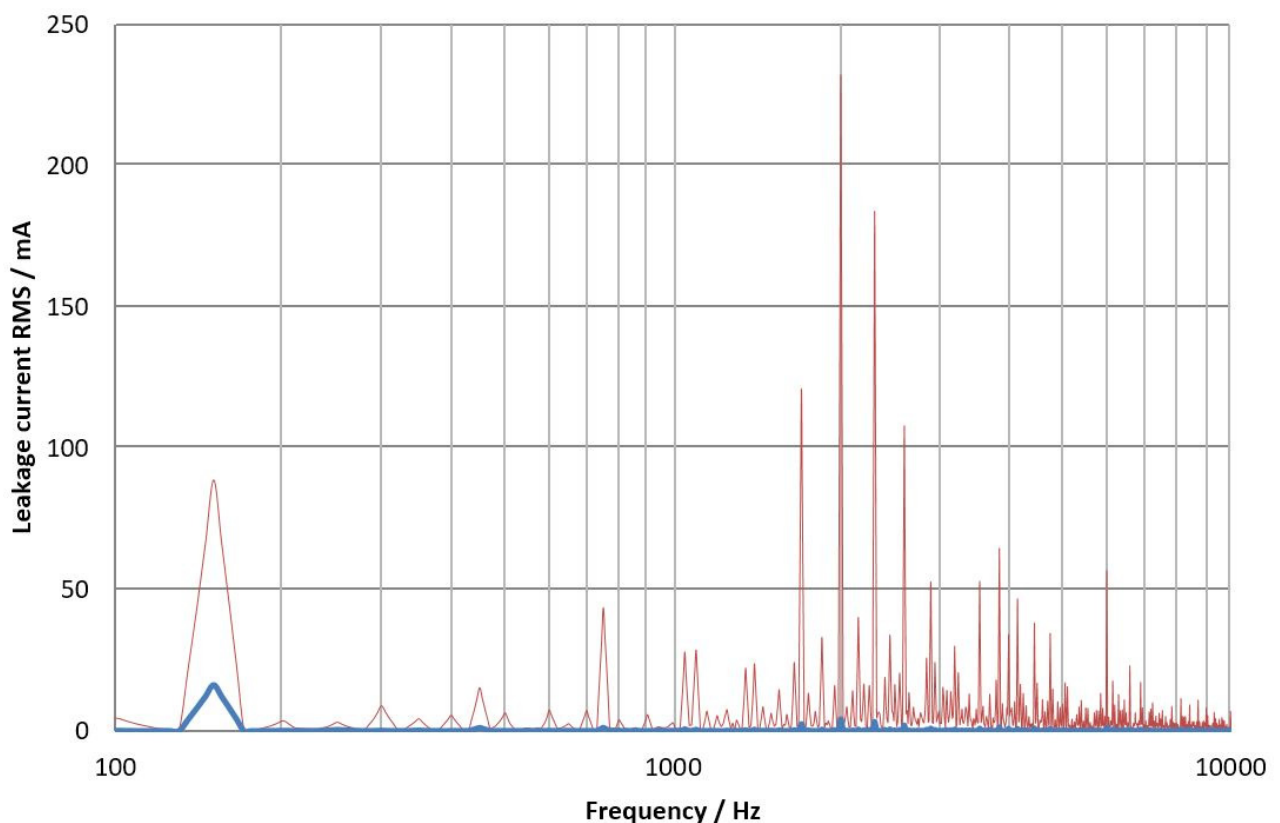


Figure 6: Typical measurements

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:

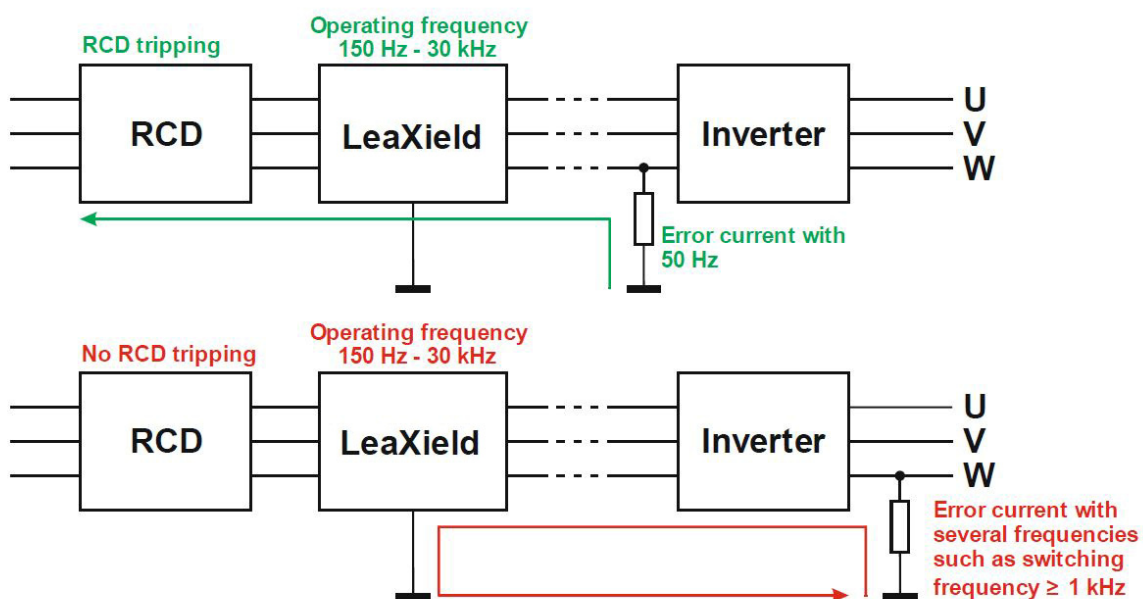


Figure 7: Comparison of error current on the inverter line and load side

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 7 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 dangerous touch currents.

For the case that the error current occurs on the load side of the inverter as shown in the bottom block diagram of Figure 7 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 $\leq 93\%$
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. Electrical charge may be stored for up to 5 minutes after switch off. Discharge the device and make sure it is voltage free. Dangerous leakage current. Can cause severe injury or death. Connect protective earth before commissioning.
	Risk of injury regarding hot surface. Can cause severe burns. Do not touch. Allow to cool before servicing.

4 Connections

Table 3: LeaXield connections

Mains connection		Function	Measurement and compensation of leakage current																					
<table border="1" style="width: 100%; text-align: center;"> <tr> <td style="width: 15%;">U1</td> <td style="width: 70%;">EPCOS</td> <td style="width: 15%;">U2</td> </tr> <tr> <td></td> <td>B84233A1500R000</td> <td></td> </tr> <tr> <td></td> <td>LeaXield™</td> <td></td> </tr> <tr> <td>V1</td> <td>305/530 V 50Hz 50A</td> <td>V2</td> </tr> <tr> <td>W1</td> <td>$T_r = 50\text{ °C}$ 25/100/21</td> <td>W2</td> </tr> <tr> <td></td> <td>U.S. Patent No. 10,069,480 CE</td> <td></td> </tr> <tr> <td>LINE</td> <td>XXXXX</td> <td>LOAD</td> </tr> </table>	U1	EPCOS	U2		B84233A1500R000			LeaXield™		V1	305/530 V 50Hz 50A	V2	W1	$T_r = 50\text{ °C}$ 25/100/21	W2		U.S. Patent No. 10,069,480 CE		LINE	XXXXX	LOAD	Connection description		
	U1	EPCOS	U2																					
		B84233A1500R000																						
	LeaXield™																							
V1	305/530 V 50Hz 50A	V2																						
W1	$T_r = 50\text{ °C}$ 25/100/21	W2																						
	U.S. Patent No. 10,069,480 CE																							
LINE	XXXXX	LOAD																						
	U1/V1/W1	Phases on line side																						
	U2/V2/W2	Phases on load side																						
Contactor connection		Function	Improvement of the switch-on behavior																					
<p style="text-align: center;">Contactor connection</p> <p style="text-align: center;">$V_{MAX} 24\text{ V DC} / 250\text{ V AC}$</p> <p style="text-align: center;">$I_{MAX} 2\text{ A}$</p> <table border="1" style="margin: auto; text-align: center;"> <tr> <td style="width: 30px; height: 30px;">1</td> <td style="width: 30px; height: 30px;">2</td> </tr> </table>		1	2	Connection description																				
		1	2																					
		1	Control of the external connector (see Figure 5)																					
2																								

5 Technical data

5.1 Electrical and mechanical data

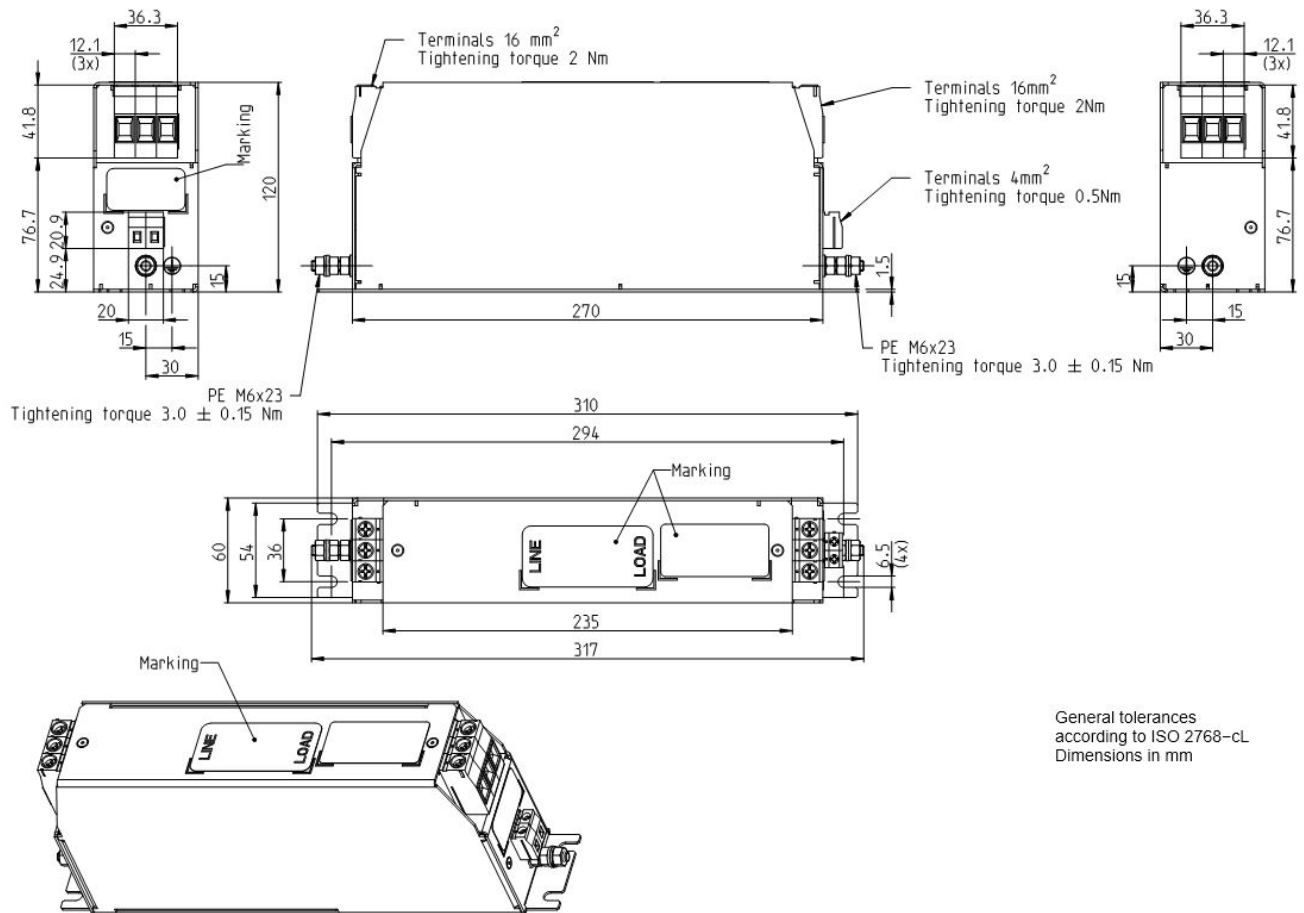
Table 4: Electrical and mechanical data

Electrical data	
<i>Mains connection</i>	
Rated voltage V_R	305/530 V AC (50 Hz)
Minimum operating voltage V_{min}	208/360 V AC (50 Hz)
Rated current I_R	50 A
Rated frequency f_R	50 Hz
Typical contact resistance R_{typ}	1.0 m Ω
Overload capability (thermal)	1.5 • I_R for 3 min per hour or 2.5 • I_R for 30 s per hour
Test voltage line to line for 2 s V_{test}	1770 V DC
Test voltage line to case for 2 s V_{test}	1500 V DC
<i>Contactor connection</i>	
Maximum voltage V_{max}	24 V DC / 250 V AC
Maximum current I_{max}	2 A
<i>Leakage current compensation</i>	
Maximum leakage current $I_{LK-LOAD}$ (Peak value)	1 A
Frequency range	150 Hz to 30 kHz
General data	
Rated temperature T_R	50 °C
Degree of protection (IEC 60529)	IP 20
Climatic category (IEC 60068-1)	25/100/21
Mechanical data	
Terminal mains connection	16 mm ² / 2 Nm
Terminal contactor connection	4 mm ² / 0.5 Nm
PE connection	Ring cable lug M6 / 3 Nm
Weight	ca. 1.63 kg

3-line active filter LeaXield
for leakage current compensation

B84233A1500R000

5.2 Dimensional drawing



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 8 to measure the leakage current.

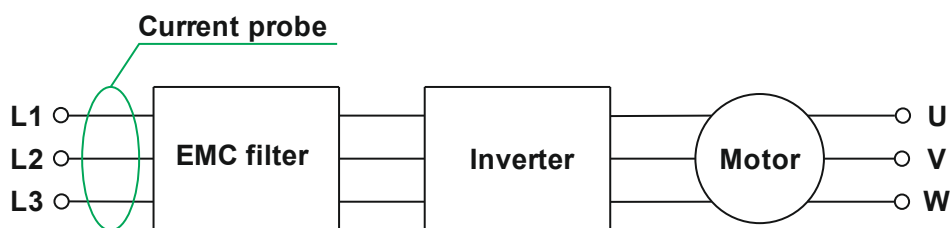


Figure 8: Measurement of the leakage current

Figure 9 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.

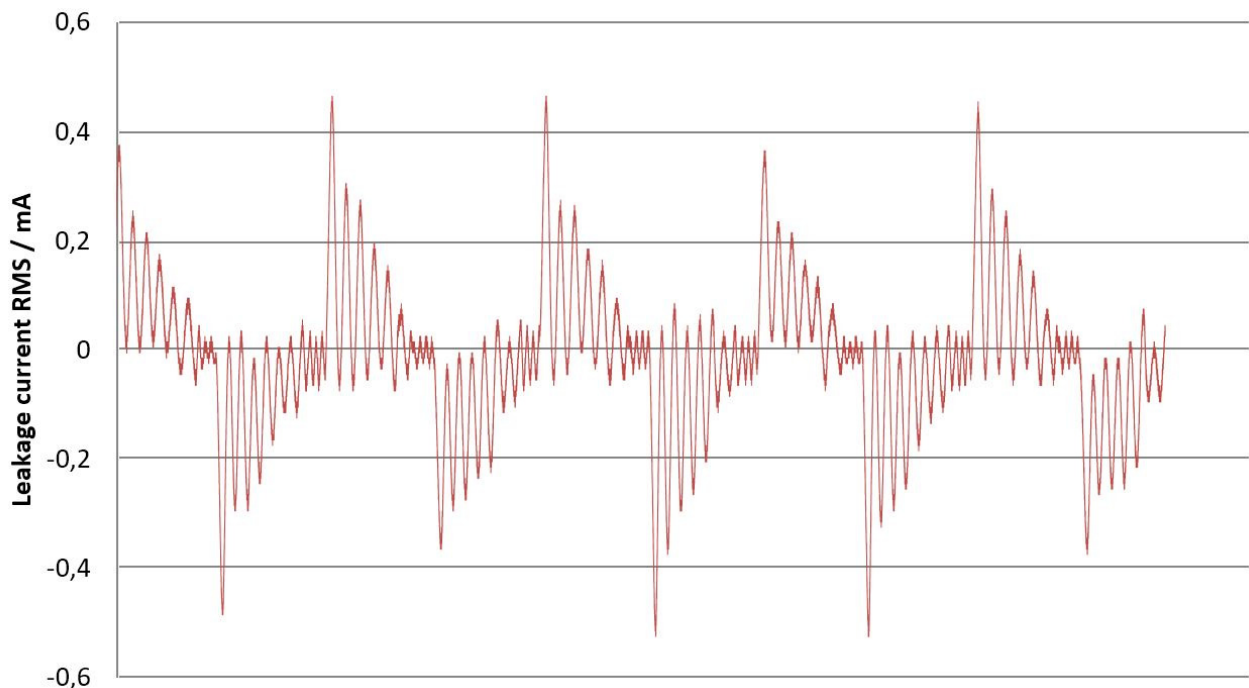


Figure 9: Typical leakage current measurement in the time domain

6.2 Frequency spectrum

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

Figure 10 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 10.

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.

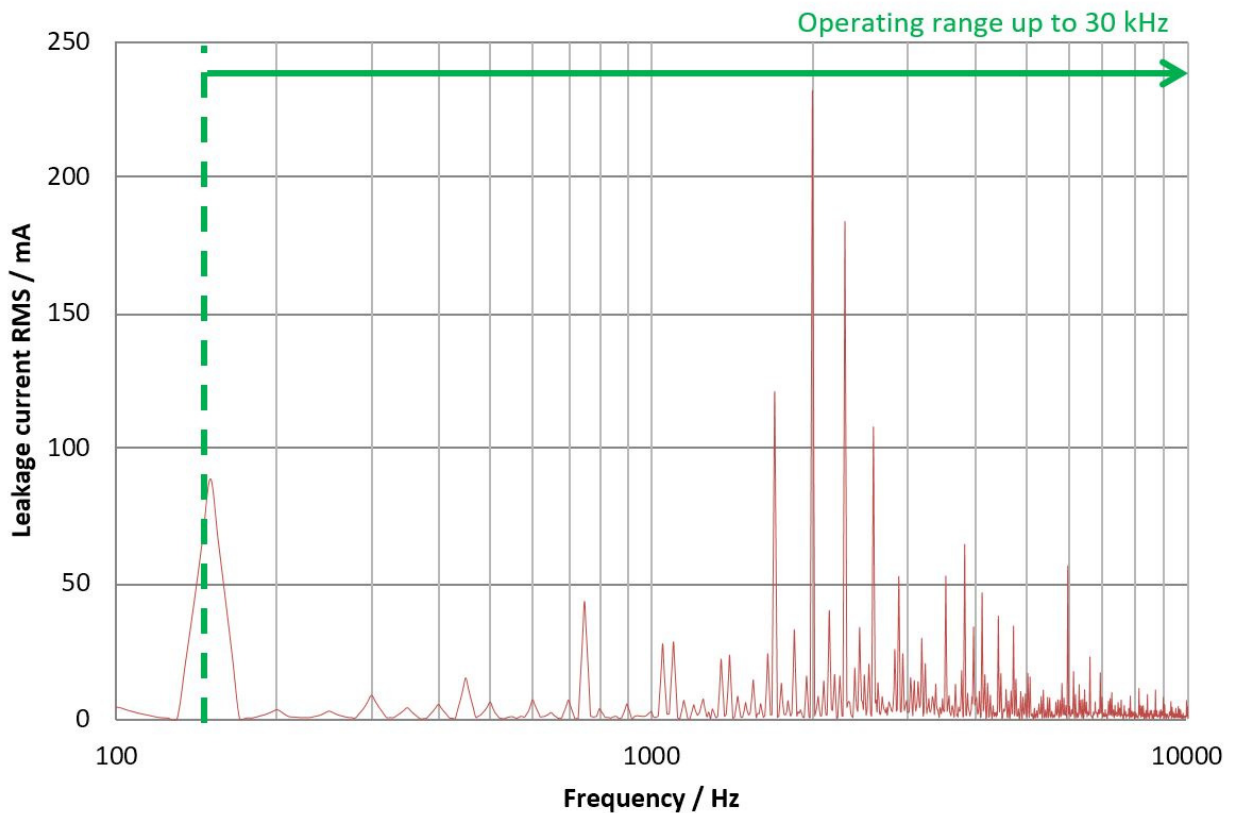


Figure 10: Measurement of the frequency spectrum

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	Set the rated voltage to a value 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 5
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 5
Maximum leakage current > 1 A	Use EMC line filter with higher insertion loss at 10 kHz (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)

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 the advices in our data book “EMC Filters” (latest edition); attention should be paid to the chapter “General safety notes”.
- 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: Filters contain components that store an electric charge. Dangerous voltages can continue to exist at the filter 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 filter is installed and the last to be disconnected. Depending on the magnitude of the leakage currents, the particular specifications for making the protective–earth connection must be observed.
- Impermissible overloading of the filter, 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 filter housing).
- Filters must be protected in the application against impermissible exceeding of the rated currents by overcurrent protective devices.
- In case of leakage currents $> 3.5 \text{ mA}$ you shall mount the PE conductor stationary with the required cross section before beginning of operation and save it against disconnecting. For leakage currents $I_L^a) \leq 10 \text{ mA}$ the PE conductor must have a KU value $^b)$ of 4.5; for leakage currents $I_{LK} > 10 \text{ mA}$ the PE conductor must have a KU value of 6.
- Output chokes and output filters must be protected in the application against impermissible exceeding of the component temperature.
- The converter output frequency must be within the specified range to avoid resonances and uncontrolled warming of the output chokes and output filters.
- Because the product 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!

a) I_L = Leakage current let-go

b) The KU value (symbol KU) is a classification parameter of safety-referred failure types designed to ensure protection against hazardous body currents and excessive heating.(DIN VDE 0800-1, 0800-8, 0800-9)

A value of KU = 4.5 with respect to interruptions is attained:

- with a permanently connected protective earth connections $\geq 1.5 \text{ mm}^2$
- with a protective earth connection $\geq 2.5 \text{ mm}^2$ via connectors for industrial equipment (IEC 60309-2).

KU = 6 with respect to interruptions is achieved for fixed-connection lines $\geq 10 \text{ mm}^2$, where the type of connection and installation is conform to the specification for PEN conductors according to DIN VDE 0100-540.

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2. 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.
3. **The warnings, cautions and product-specific notes must be observed.**
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7. **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.

Important notes

8. The trade names EPCOS, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, ExoCore, FilterCap, FormFit, LeaXield, MiniBlue, MiniCell, MKD, MKK, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, ThermoFuse, WindCap are **trademarks registered or pending** in Europe and in other countries. Further information will be found on the Internet at www.tdk-electronics.tdk.com/trademarks.

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