XKBU / XKBR - Split-core current transformers for power quality applications up to 20 kHz

High-precision harmonic measurements up to 20 kHz

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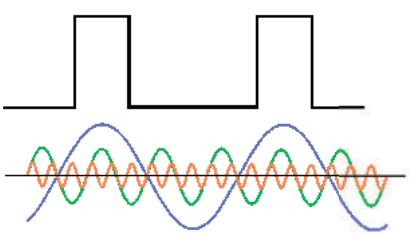
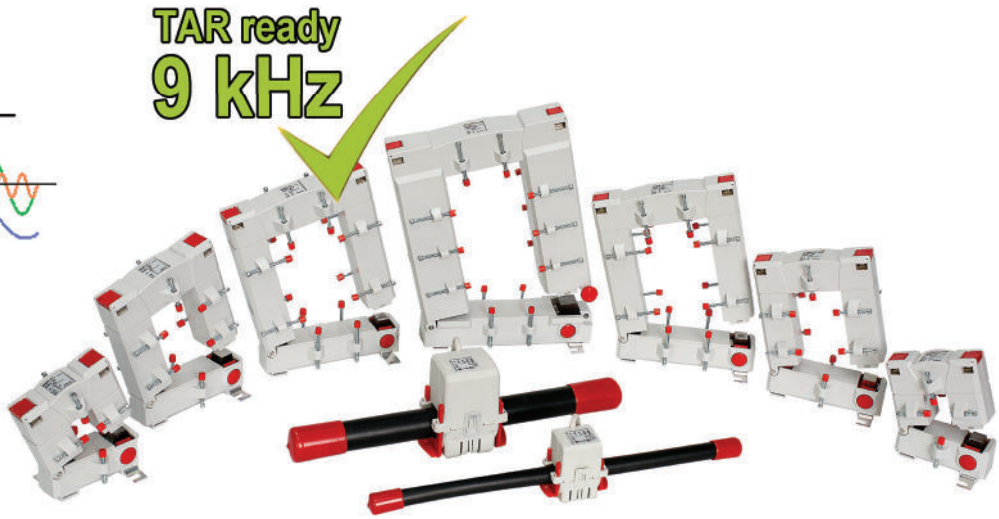




New measuring requirements for inductive current transformers in the low-voltage range

Changes to the structure of generation and consumption

Over the last few years, the proportion of renewable energy in Germany has grown massively. Wind, biomass, photovoltaic and hydroelectric plants now make up approximately 30% of the country's energy mix.
Unlike in conventional nuclear or coal-fired power stations, where all synchronous generators are used to produce electricity, here inverters or frequency converters are used. As such, it is not always possible to achieve a clean sine wave.
The distortions are caused by the switching semiconductor elements in the inverter. Harmonics generated in this way are whole multiples of the first harmonic and can extend far into the single-digit kilohertz range. The total harmonic distortion (THD) factor[1] specifies the undesirable distortion ratio of the 50 Hz sinusoidal oscillation and regularly reaches between 10 and 30%.
In addition to the harmonics produced by inverters on the generator side, there have also been changes on the consumer side in recent years. Non-linear consumers such as LED or energy-saving lamps are pushing linear ones, like traditional incandescent bulbs, out of our daily lives almost completely.
Plug-in power supply units for mobile phones and laptops are no longer made from small transformers either, but from semiconductor circuits known as switched-mode power supplies. It would not be possible to create such small, light power supply units any other way. But these benefits are set against one big disadvantage: the current is drawn from the public grid not as a sinusoidal waveform, but in pulses. The figure below illustrates this:

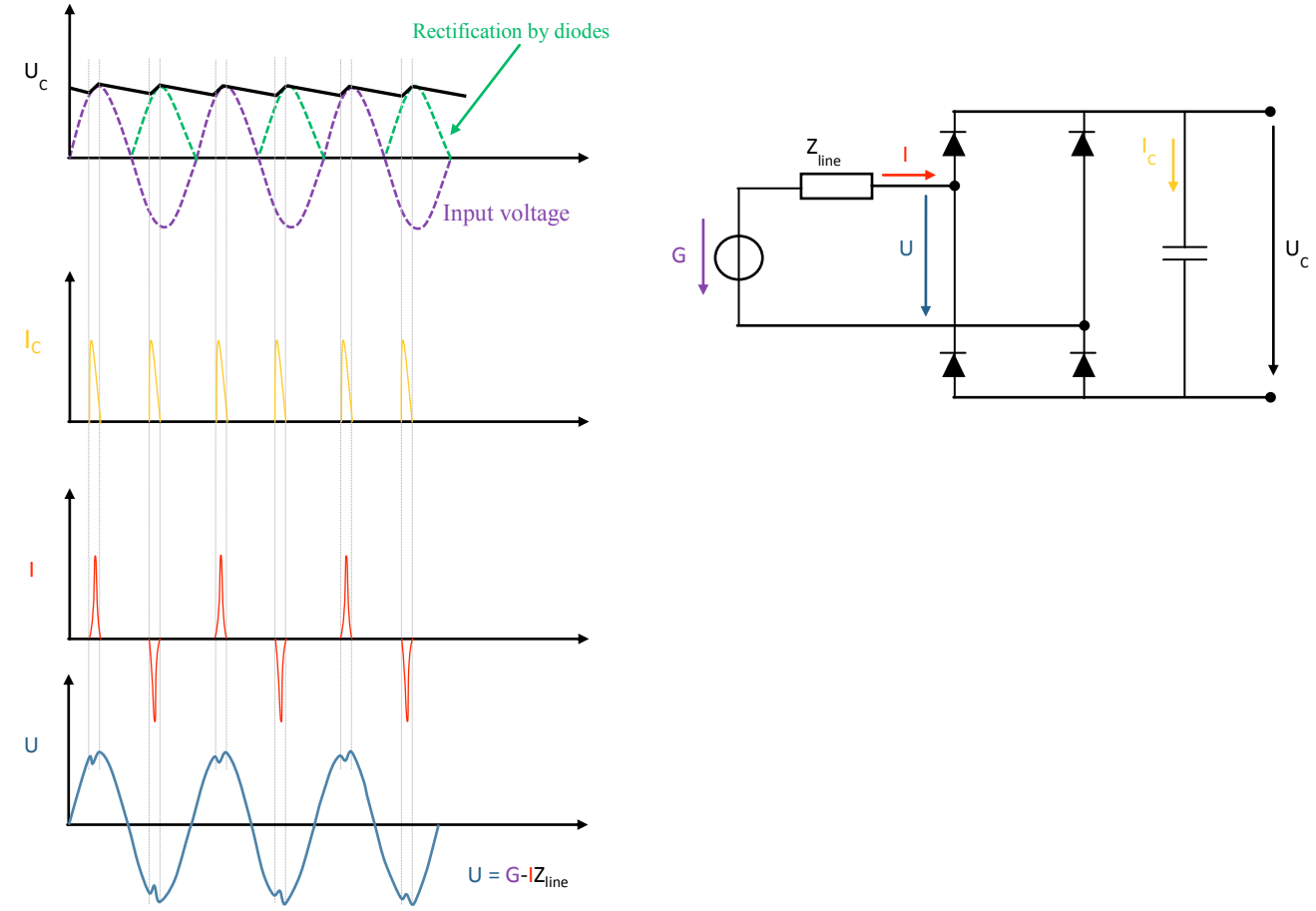


Figure 1: Bridge rectifier with pulsed current draw

The filter capacitor shown in the diagram not only smooths the required output voltage, it is also recharged in pulses by the rectifier diodes. These steep current peaks generate reactive power on the one hand, and harmonics on the other.

[1] The THD is the ratio of the harmonic component to the first harmonic

Standards regulate limit values – but not always!

There is already a corresponding set of international norms that limits harmonic currents in end devices with a power consumption > 75 W. Devices under 75 W are not currently covered by standards. In the interests of keeping costs down, manufacturers do not usually implement filter measures or complex power factor correction. The EN 61000-3-2 set of standards does not come into play until the 25 W mark for lamps either; for example, where energy-saving lamps are concerned, THD_I values of 30 to 70% and higher are not uncommon during warm-up and in continuous duty. It should also be noted that, even when they do kick in, the standards only define limit values up to 2 kHz. As a result, manufacturers have hardly taken interference suppression into account at all when developing electronic products for the frequency range > 2 kHz in the past.
In addition, more and more electrical motors with variable-frequency drive technology are being used in the industrial sector. Today already, the percentage of electrical motors sold that have a frequency-controlled drive stands at around 40%. The majority of these motors utilise pulse width modulation technology, which can generate THD_I values in the range from 100 to 120%. Clean sine waves are almost impossible to identify at these values.

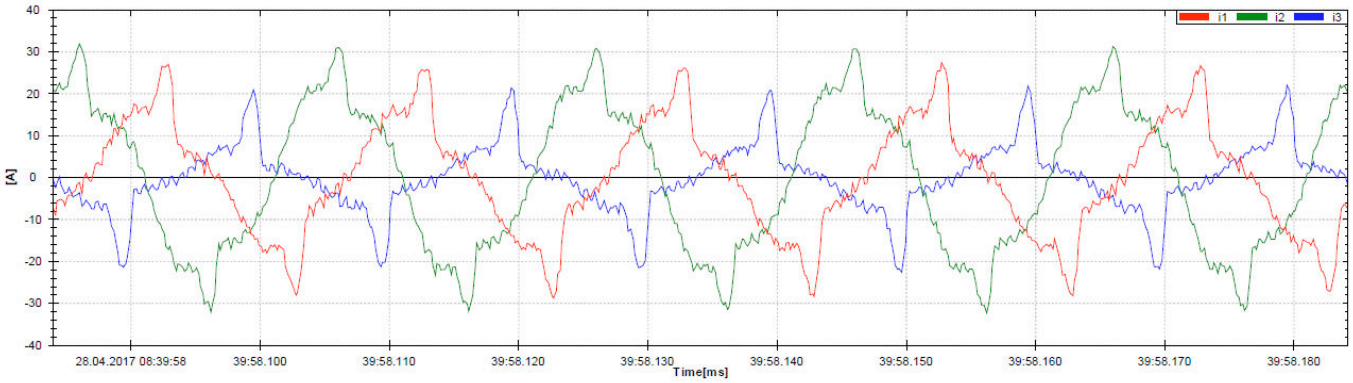


Figure 2: Flow of current for an industrial customer on the low-voltage grid

Power electronics have so many benefits that we can categorically state there will be no return to linear consumers such as the traditional incandescent bulb. In fact, we can expect harmonic loads to increase even further in European grids, due to the development of alternative sources of energy and the growth of non-linear consumers. We should also bear in mind that having lots of consumers that are not regulated by standards could cause considerable interference overall.
Filter systems have already had to be installed in office buildings where just computers, telephone systems and energy-efficient bulbs are used, in order to bring problems with harmonics under control.

Effects of harmonics

Grid operators are primarily interested in the economic effects of harmonics. When it comes to harmonic **currents**, the most important phenomena are as follows[2]:

- Overloading of neutral conductors
- Overheating of transformers
- False tripping of circuit breakers/miniature circuit breakers
- Overstressing of power-factor correction capacitors
- Skin effects

If the distortion level in the supply **voltage** reaches a value > 10%, this shortens the lifetime of devices considerably. This reduction is estimated as follows:

- 32.5% for 1-phase machines
- 18% for 3-phase machines
- 5% for transformers.

To maintain the lifetime expected from the nominal load, the devices named above must be over-dimensioned.

[2] Schneider Electric Wiki (accessed 09/01/2018) http://de.electrical-installation.org/dewiki/Wirtschaftliche_Auswirkungen#St.C3.B6rungsausl.C3.B6sung_und_Anlagenausfall

Standard regulation for distribution network operators

The latest draft of VDE-AR-N 4100[1] deals with this matter. Point 5.4.4.3 of this regulation refers to harmonic currents of up to **9 kHz** that need to be monitored and covers not only **generating plants**, but also **receiving plants** and **storage systems**. The customer should liaise with the grid operator and take action to reduce harmonic currents – particularly by constructing filter circuits. In future we can assume, therefore, that current measurements up to 9 kHz will be taken continuously across the whole low-voltage network.
Looking at the overall picture of the rise in distributed energy generation plants and non-linear consumers, we can see this is a very sensible move. Grid operators and their customers will need measuring equipment that can accurately record harmonic currents of up to 9 kHz.

Current transformers up to 20 kHz

MBS AG offers the full series of XCTB plug-in current transformers for measurements up to 20 kHz. These products guarantee high-precision transmission up to 20 kHz on the one hand, and are designed to withstand the thermal demands of running in networks subject to harmonics on the other.
Additional to the mentioned plug-in current transformers the split-core current transformers series XKBU and XKBR are also designed for the high-precision transmission up to 20 kHz and are perfect for subsequent assembly into already existing installations.

Output signals are 1 or 5 A, just like with the familiar inductive current transformer to IEC 61869-2. Performance data corresponds to standard values too. As a result, these transformers can also be used in conventional 50 Hz applications. An additional rating plate defines the frequency transmission behaviour.

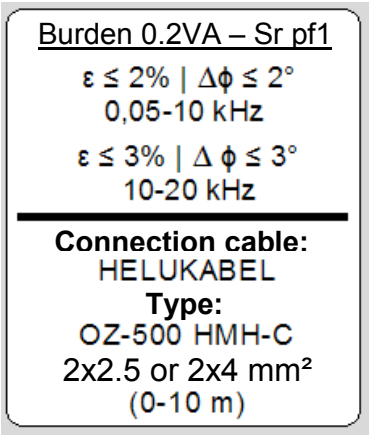


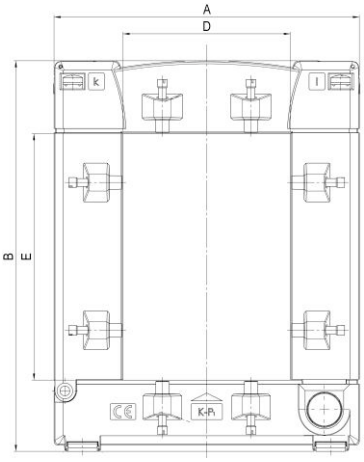
Figure 3: Frequency transmission behaviour

Since the connecting cable affects the load and the transmission behaviour more if it is long, we recommend the OZ-500 HMH-C cable from Helukabel GmbH (2 x 2.5 mm^2 or 2 x 4 mm^2 version) for harmonic measurements up to 20 kHz.
MBS AG carries out its accuracy tests using this type of cable too. The customer can now benefit from a consistent measuring chain and reliable measured values in the frequency range up to 20 kHz.
The connection cabels integrated in the split-core current transformers type XKBR can also be used in the mentioned lengths, because they are also considered in the accuracy tests performed by MBS AG.

[1] TAR low voltage (E VDE-AR-N 4100): draft published 28/04/2017

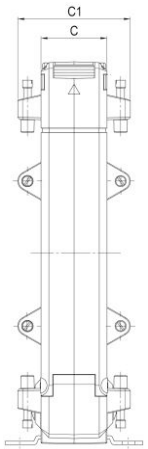
Split-core current transformer, type XKBU

Features / benefits
- Perfect for subsequent assembly into already existing installations
- Easy and safe mounting, due to hearable locking system
- Available in nominal current ranges 250…2500 A
- Deliverable with secondary current 5 A / 1 A
- Accuracy classes @ 50 Hz: 1 and 0.5
- Four different construction types
- **Connecting cable for harmonic measurements: HELUKABEL type: OZ-500 HMH-C with 2x2.5 or 2x4 mm² (0-10m)**
- Harmonic measurements with load 0.2 VA – Sr pf1 (power factor 1)
- Suitable for networks subject to harmonics with fundamental frequency of 50 Hz



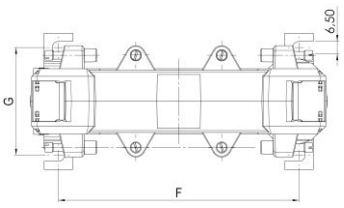
General technical specifications
- Operating temperature: -5°C < T < +40°C
- Storage temperature: -25°C < T < +70°C
- Therm. nominal continuous rated current I_{cth}: 1.0 x I_N
- Therm. nominal short-time current I_{th}: 60 x I_N, 1 sec.
- Max. operating voltage U_m: 0.72 kV
- Isolation test voltage: 3 kV, U_{eff}, 50 Hz, 1 min.
- Rated frequency: 50 Hz
- Isolation class: E
- Applicable technical standard: DIN EN 61869, part 1 + 2

Accuracy classes for harmonic measurements
- Measuring accuracy up to 20 kHz: $\Delta\phi \leq 1°$ @ 0.05-20 kHz
  $\varepsilon \leq 2\%$ @ 0.05-10 kHz
  $\varepsilon \leq 3\%$ @ 10-20 kHz



Dimensions

Type	A (width) [mm]	B (height) [mm]	C / C1 (depth) [mm]	D [mm]	E [mm]	F [mm]	G [mm]
XKBU 23	93	106	34 / 58	23	33	64	56
XKBU 58	125	158	34 / 58	55	85	96	56
XKBU 812	155	198	34 / 58	85	125	126	56
XKBU 816	195	243	64 / 79	85	165	156	62



Order list XKBU 23

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1	0.5	1	0.5
		Art.-no.	Art.-no.	Art.-no.	
250	1.5	11-6004		11-1004	
300	3.75	11-6005		11-1005	
400	1		11-6007		11-1007
	5	11-6006		11-1006	

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Order list XKBU 58

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1	0.5	1	0.5
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
250	1.5	11-6101		11-1101	
300	2.5	11-6102		11-1102	
400	1		11-6107		11-1107
	2.5	11-6103		11-1103	
500	2.5		11-6108		11-1108
	5	11-6104		11-1104	
600	2.5		11-6109		11-1109
	5	11-6105		11-1105	
750	2.5		11-6110		11-1110
	5	11-6106		11-1106	
800	2.5		11-6111		11-1111
1000	5		11-6112		11-1112

Order list XKBU 812

Secondary current		5A		1A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1	0.5	1	0.5
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
250	1.5	11-6201		11-1201	
300	2.5	11-6202		11-1202	
400	2.5	11-6203		11-1203	
500	2.5		11-6207		11-1207
	5	11-6204		11-1204	
600	2.5		11-6208		11-1208
	5	11-6205		11-1205	
750	2.5		11-6209		11-1209
	5	11-6206		11-1206	
800	2.5		11-6210		11-1210
1000	5		11-6211		
1200	5		11-6212		
1250	5		11-6213		
1500	5		11-6214		

Order list XKBU 816

Secondary current		5A	
Primary current [A]	Burden [VA]	Accuracy class	
		1	0.5
		Art.-no.	Art.-no.
1000	5	11-6301	11-6307
1200	5	11-6302	11-6308
1500	5	11-6303	11-6309
1600	5	11-6304	11-6310
2000	5	11-6305	11-6311
2500	5	11-6306	11-6312

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Split-core current transformer, type XKBR

Features / benefits
- Perfect for subsequent assembly into already existing installations
- Easy and safe mounting
- Due to the „click“-system even a one-hand mounting is possible
- Available in nominal current ranges 100…1000 A
- Deliverable with secondary current 5 A / 1 A
- In total 8 different construction types of series XKBR
- UL-certification in preparation and sealable (XKBR 18S; XKBR 18L; XKBR 28; XKBR 42; XKBR42L)
- Harmonic measurements with load 0.2 VA – Sr pf1 (power factor 1)
- Suitable for networks subject to harmonics with fundamental frequency of 50 Hz

General technical specifications
- Length of connection cable (color coded): Sec. 1A: 2.5 m, cross section 2x0.75 mm² (XKBR 18; XKBR 32; XKBR 44)
  2.5 m, cross section 2x0.5 mm² (XKBR 18S; XKBR 18L; XKBR 28; XKBR 42; XKBR 42L)
  Sec. 5A: 0.5 m, cross section 2x1.5 mm² (XKBR 18L; XKBR 28; XKBR 32; XKBR 44; XKBR 42; XKBR 42L)
  Connection cables suitable for harmonic measurements in the mentioned accuracy classes
- Operating temperature: -5°C < T < +50°C
- Storage temperature: -25°C < T < +70°C
- Therm. nominal continuous rated current I_{cth}: 1.2 x I_N
- Therm. nominal short-time current I_{th}: 60 x I_N, 1 sec.
- Max. operating voltage U_m: 0.72 kV
- Isolation test voltage: 3 kV, U_{eff}, 50 Hz, 1 min.
- Rated frequency: 50 Hz
- Isolation class: E
- Applicable technical standard: DIN EN 61869, part 1 + 2

Accuracy classes
- XKBR 18S / XKBR 18 / XKBR 18L / XKBR 28
  Measuring accuracy up to 20 kHz: $\Delta\phi$ ≤ 1° @ 0.05-20 kHz
  ε ≤ 2% @ 0.05-1.5 kHz
  ε ≤ 5% @ 1.5-9 kHz
  ε ≤ 10% @ 9-20 kHz

- XKBR 32 / XKBR 42 / XKBR 44 / XKBR 42L
  Measuring accuracy up to 20 kHz: $\Delta\phi$ ≤ 1° @ 0.05-20 kHz
  ε ≤ 2% @ 0.05-1.5 kHz
  ε ≤ 5% @ 1.5-3 kHz
  ε ≤ 10% @ 3-9 kHz
  ε ≤ 20% @ 9-20 kHz

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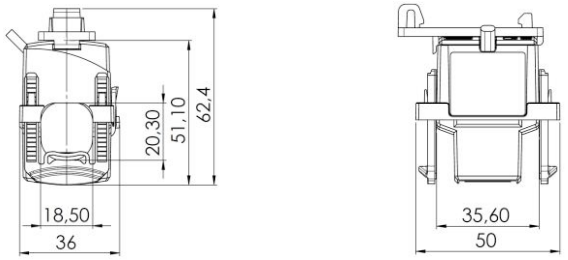
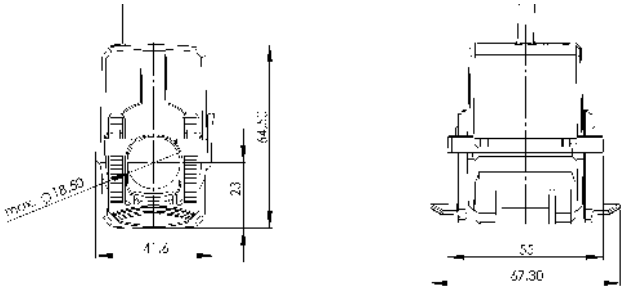
Dimension drawings:

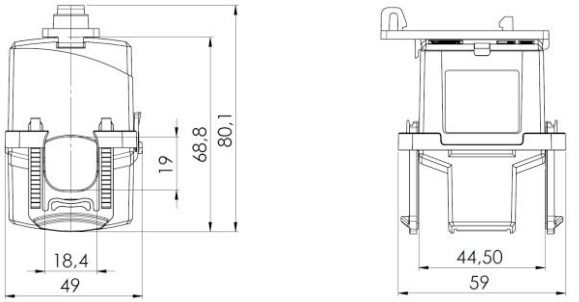
XKBR 18S



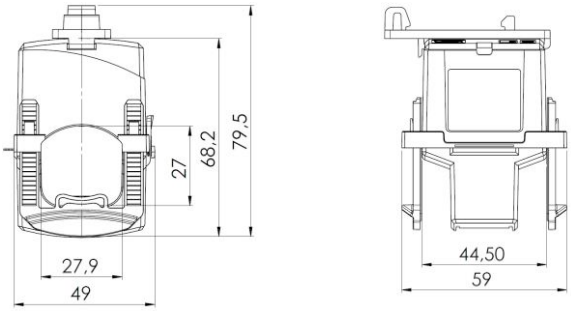
XKBR 18



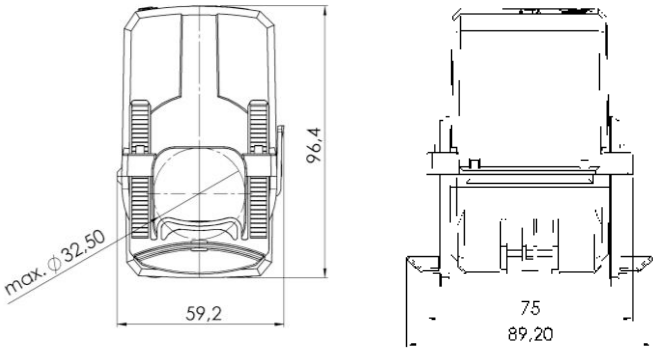
XKBR 18L



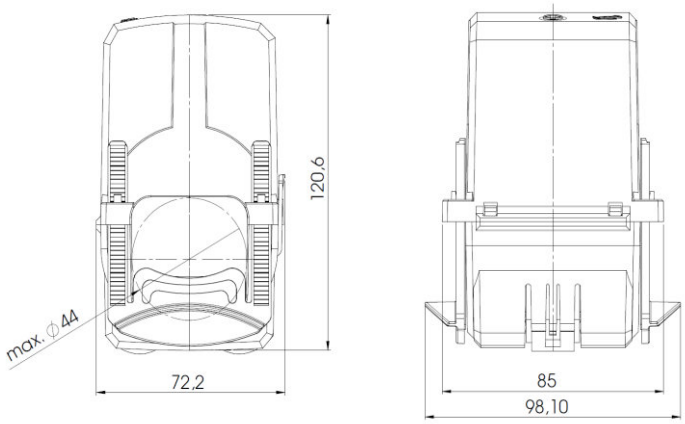
XKBR 28



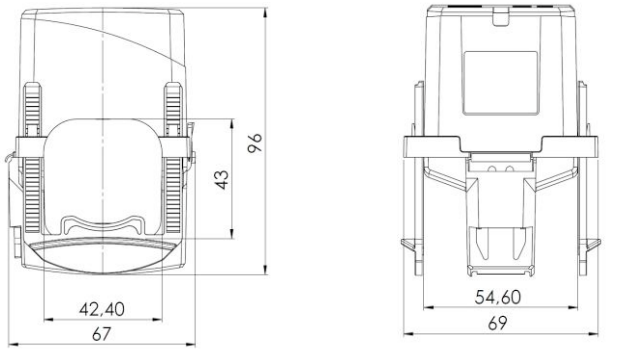
XKBR 32



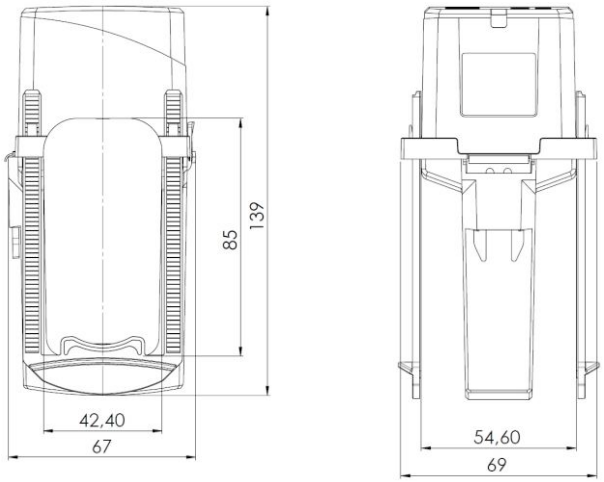
XKBR 44



XKBR 42



XKBR 42L



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Order list XKBR 18S

Secondary current		1 A
Primary current [A]	Burden [VA]	Accuracy class
		1FS5
		Art.-no.
200	0.4	18S-1006
250	0.5	18S-1008

Snap-on mounting for mounting on DIN rail: Art.-no.: 55016

Order list XKBR 18

Secondary current		1 A
Primary current [A]	Burden [VA]	Accuracy class
		1FS5
		Art.-no.
200	1	18-1027
250	1.5	18-1032

Order list XKBR 18L

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1FS5	0.5FS10	1FS10	0.5FS10
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
100	0.3			18L-1001	
125	0.5			18L-1002	
150	1	18L-6001		18L-1003	
200	0.2				18L-1004
	1.5	18L-6002		18L-1005	
250	0.5				18L-1006
	1		18L-6003		
	2	18L-6004			
	2.5			18L-1007*	

* FS5

Snap-on mounting for mounting on DIN rail: Art.-no.: 55017

Order list XKBR 28

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1FS5	0.5FS5	1FS5	0.5FS10
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
200	0.3			28-1001*	
250	1	28-6001		28-1002	
300	1.5	28-6002		28-1003	
400	0.5				28-1004
	2.5	28-6003		28-1005	
500	1		28-6004		28-1006
	3	28-6005		28-1007	

* FS10

Snap-on mounting for mounting on DIN rail: Art.-no.: 55017

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Order list XKBR 32

Secondary current		5 A	1 A
Primary current [A]	Burden [VA]	Accuracy class	Accuracy class
		1FS5	1FS5
		Art.-no.	Art.-no.
300	2.5	32-6035	
	5		32-1035
400	5	32-6037	32-1037
500	5	32-6039	32-1039
600	5	32-6041	32-1041

Order list XKBR 42

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1FS5	0.5FS5	1FS5	0.5FS5
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
250	2.5			42-1001	
300	2.5	42-6001		42-1002	
400	2.5				42-1003
	5	42-6002		42-1004	
500	2.5				42-1005
	5	42-6003		42-1006	
600	2.5		42-6004		42-1007*
	5	42-6005		42-1008	
750	2.5		42-6006*		42-1009*
	5	42-6007		42-1010	
800	2.5		42-6008*		42-1011*
	5	42-6009		42-1012	
1000	2.5		42-6010*		42-1013*
	5	42-6011		42-1014*	

* FS10

Order list XKBR 42L

Secondary current		5 A		1 A	
Primary current [A]	Burden [VA]	Accuracy class		Accuracy class	
		1FS5	0.5FS5	1FS5	0.5FS5
		Art.-no.	Art.-no.	Art.-no.	Art.-no.
250	2.5			42L-1001	
300	2.5	42L-6001		42L-1002	
400	2.5				42L-1003
	5	42L-6002		42L-1004	
500	2.5				42L-1005
	5	42L-6003		42L-1006	
600	2.5		42L-6004		42L-1007*
	5	42L-6005		42L-1008	
750	2.5		42L-6006*		42L-1009*
	5	42L-6007		42L-1010	
800	2.5		42L-6008*		42L-1011*
	5	42L-6009		42L-1012	
1000	2.5		42L-6010*		42L-1013*
	5	42L-6011		42L-1014*	

* FS10

Order list XKBR 44

Secondary current		5A	1A
Primary current [A]	Burden [VA]	Accuracy class	Accuracy class
		1FS5	1FS5
		Art.-no.	Art.-no.
250	1.5	44-6001	
	2.5		44-1001
300	2.5	44-6006	44-1006
400	5	44-6011	44-1011
500	5	44-6016	44-1016
600	5	44-6021	44-1021
750	5	44-6026	44-1026
800	5	44-6031	44-1031
1000	5	44-6036	44-1036

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