Manual EN

# ISOMETER® isoBAT425

Insulation monitoring device with coupling impedance ZE420
for batteries up to DC 500 V
Software version: D0560


isoBAT425_D00308_05_M_XXEN/09.2023

## Table of contents

# 1 General information

## 1.1 How to use the manual

**ADVICE**
This manual is intended for qualified personnel working in electrical engineering and electronics! Part of the device documentation in addition to this manual is the enclosed supplement "Safety instructions for Bender products".

**ADVICE**
Read the operating manual before mounting, connecting and commissioning the device. Keep the manual within easy reach for future reference.

## 1.2 Indication of important instructions and information

**DANGER**
Indicates a high risk of danger that will result in death or serious injury if not avoided.

**WARNING**
Indicates a medium risk of danger that can lead to death or serious injury if not avoided.

**CAUTION**
Indicates a low-level risk that can result in minor or moderate injury or damage to property if not avoided.

**ADVICE**
Indicates important facts that do not result in immediate injuries. They can lead to malfunctions if the device is handled incorrectly.

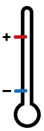
*Information can help to optimise the use of the product.*

## 1.3 Signs and symbols


Disposal


Protect from moisture


Protect from dust


Temperature range


Recycling

RoHS directives

## 1.4 Service and Support

Information and contact details about customer service, repair service or field service for Bender devices are available on the following website: Fast assistance | Bender GmbH & Co. KG.

## 1.5 Training courses and seminars

Regular face-to-face or online seminars for customers and other interested parties:

www.bender.de > know-how > seminars.

## 1.6 Delivery conditions

The conditions of sale and delivery set out by Bender GmbH & Co. KG apply. These can be obtained in printed or electronic format.

The following applies to software products:

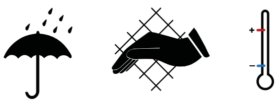
ZVEI: Die Elektroindustrie

'Software clause in respect of the licensing of standard software as part of deliveries, modifications and changes to general delivery conditions for products and services in the electrical industry'

## 1.7 Inspection, transport and storage

Check the shipping and device packaging for transport damage and scope of delivery. In the event of complaints, the company must be notified immediately, see "www.bender.de > service & support.".

The following must be observed when storing the devices:



## 1.8 Warranty and liability

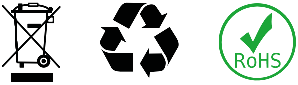
Warranty and liability claims for personal injury and property damage are excluded in the case of:

- Improper use of the device.
- Incorrect mounting, commissioning, operation and maintenance of the device.
- Failure to observe the instructions in this operating manual regarding transport, commissioning, operation and maintenance of the device.
- Unauthorised changes to the device made by parties other than the manufacturer.
- Non-observance of technical data.
- Repairs carried out incorrectly.
- The use of accessories or spare parts that are not provided, approved or recommended by the manufacturer.
- Catastrophes caused by external influences and force majeure.
- Mounting and installation with device combinations not approved or recommended by the manufacturer.

This operating manual and the enclosed safety instructions must be observed by all persons working with the device. Furthermore, the rules and regulations that apply for accident prevention at the place of use must be observed.

## 1.9 Disposal of Bender devices

Abide by the national regulations and laws governing the disposal of this device.




For more information on the disposal of Bender devices, refer to
www.bender.de > service & support.

## 1.10 Safety

If the device is used outside the Federal Republic of Germany, the applicable local standards and regulations must be complied with. In Europe, the European standard EN 50110 applies.

**DANGER** ***Risk of fatal injury due to electric shock!***
*Touching live parts of the system carries the risk of:*

- Risk of electrocution due to electric shock
- Damage to the electrical installation
- Destruction of the device

Before installing the device and before working on its connections, make sure that the installation has been de-energised. The rules for working on electrical systems must be observed.

# 2 Function

## 2.1 Intended use

This ISOMETER® is intended for monitoring the insulation resistance $R_F$ as well as the voltage of a battery during its assembly from individual battery cells. The ISOMETER® monitors the insulation resistance of batteries with nominal system voltages of DC 0…400 V. The maximum permissible system leakage capacitance is 1 µF. Based on the measured values obtained, it is possible to determine the type and location of an insulation fault.

In order to meet the requirements of the applicable standards, customised parameter settings must be made on the equipment in order to adapt it to local equipment and operating conditions. Please heed the limits of the range of application indicated in the technical data.

Any other use or a use that goes beyond this constitutes improper use.

i *If the ISOMETER® is installed inside a control cabinet, the insulation fault message must be audible and/or visible to attract attention.*

## 2.2 Device features

- Monitoring of the insulation resistance $R_F$ to earth
- Monitoring of the battery voltage $U_n$ between the terminals "L+" and "L–"
- Configurable measuring frequency for adjustment to the physical characteristics of the battery
- Measuring the DC residual voltages $U_{L+e}$ (between L+ and earth) and $U_{L-e}$ (between L– and earth)
- Selectable start-up delay, response delay and delay on release
- Alarm output via LEDs ("AL1", "AL2"), display, and alarm relays ("K1", "K2")
- Automatic device self test
- Selectable n/c or n/o relay operation
- Measured value indication via multi-functional LC display
- Activatable fault memory
- Locating the faulty conductor L+/L–, i.e. the distribution of the insulation resistance $R_F$ between terminals "L+" and "L–"
- Monitoring and automatic adjustment to the system leakage capacitance $C_e$ up to 4 µF
- Continuous connection monitoring of terminals "L+", "L–" and "E"
- Two separately adjustable response value ranges from 10 kΩ to 5 MΩ (prewarning, alarm)
- Device supply via wide-range power supply
- RS-485 (galvanically isolated) including the following protocols:
  - BMS (Bender measuring device interface) for the data exchange with other Bender devices
  - Modbus RTU
  - IsoData (for continuous data output)
- Password protection against unauthorised changing of parameters

## 2.3 Functional description

The isoBAT425 ISOMETER® is intended for monitoring the insulation resistance $R_F$ as well as the voltage $U_n$ of a battery during its assembly from individual battery cells. The ISOMETER® measures the insulation resistance $R_F$ and the system leakage capacitance $C_e$ of the battery to earth. Additionally, it measures the battery voltage $U_n$ between L+ and L–, as well as the residual voltages $U_{L+e}$ ($U_{L+}$ to earth) and $U_{L-e}$ ($U_{L-}$ to earth).

In the first step, the battery is assembled in two parallel strings (plus and minus string) which are not interconnected. During the second step, the two strings are connected to form a complete battery by means of another battery.

The resulting measured values allow diagnosing the type and location of the insulation fault. In the LC display, the faulty conductor is displayed with a plus or a minus sign preceding the value $R_F$.

The detected fault is assignable to an alarm relay via the menu. If the values $R_F$ or $U_n$ violate the activated response values in "AL" menu, the LEDs and the alarm relays "K1" and "K2" issue an alarm according to the alarm assignment settings in the "out" menu. In addition, the operating mode of the alarm relay can be set and the fault memory "M" can be activated in this menu.

If the values $R_F$ or $U_n$ do not violate their respective release value (response value plus hysteresis) for the period $t_{off}$ without interruption, the alarm relays will switch back to their initial position and the alarm LEDs will go out. If the fault memory is activated, the alarm relays remain in alarm condition and the LEDs light until the reset button "R" is pressed or the supply voltage $U_s$ is interrupted.

The device function can be tested using the test button "T".

Parameters are assigned to the device via the LCD and the control buttons on the front panel; this function can be password-protected. The parameters of the device can be set via Modbus RTU.

## 2.3.1 ZE420 coupling impedance

In the case of open battery strings, the ZE420 coupling impedance provides a low-resistance connection (10 kΩ) between terminals "L+" and "L–", necessary for the measuring functions of the ISOMETER®. In the case of closed batteries, the resistance is optional due to the internal resistance of the battery.

In addition to this resistance, there is also a 1.5 mA current limitation. It starts above $U_n$ = 25 V and increases the internal resistance of the coupling impedance. For this reason, in the event of a cross fault, the system connection monitoring may be additionally triggered but, at the same time, the responsivity of the cross fault detection is increased.

In addition, the coupling impedance contains two capacitances for a necessary minimum leakage capacitance to earth.

## 2.3.2 Measured values

**Parameters measured by the ISOMETER®**

| Parameter | Description | Unit |
|---|---|---|
| $R_F$ | Isolationswiderstand gegen Erde | kΩ |
| $U_n$ | DC system voltage between L+ and L– | V |
| $U_{L+e}$ | DC residual voltage between L+ and earth | V |
| $U_{L-e}$ | DC residual voltage between L– and earth | V |
| Faulty conductor | Distribution of the insulation resistance $R_F$ between terminals "L+" and "L–".<br>In the LC display, the fault location is marked with a plus or a minus sign preceding the value $R_F$. | % |

**Measured value ranges and resolution**

| Value | Interface | Value range | | Resolution |
|---|---|---|---|---|
| *R* | LCD | 1 kΩ | 999 kΩ | 1 kΩ |
| | | 1.0 MΩ | 10.0 MΩ | 0.1 MΩ |
| | BMS | 1 kΩ | 20000 kΩ | 1 kΩ |
| | Modbus, IsoData | 1 kΩ | 20000 kΩ | 1 kΩ |
| *U* | LCD | 0 V | ±99.9 V | 0.1 V |
| | | ±100 V | ±500 V | 1 V |
| | BMS | 0 V | 500 V | 1 V |
| | Modbus, IsoData | 0 V | ±500 V | 0.1 V |
| *C* | LCD | 0 nF | 999 nF | 1 nF |
| | | 1.00 µF | 9.99 µF | 0.01 µF |
| | BMS | 0 nF | 9990 nF | 1 nF |
| | Modbus, IsoData | 0 nF | 9990 nF | 1 nF |

### 2.3.3 Monitoring of the insulation resistance and the system leakage capacitance

The insulation resistance $R_F$ as well as the system leakage capacitance $C_e$ to earth are measured. The results are the total values from the sub-components $R_{F1} \| R_{F2}$ as well as $C_{e1} + C_{e2}$. The system leakage capacitance value $C_e$ is only updated above $R_F = 10$ kΩ.

When the insulation resistance $R_F$ reaches or falls below the threshold values R1 (prewarning) or R2 (alarm), an alarm message is issued. Parameters R1 and R2 can be found in the response value menu "AL" (see "Response values overview", page 28). If by means of the measured voltages the faulty conductor can be assigned to the plus or the minus string, only the corresponding "L+" or "L–" alarm will be issued. Otherwise, both alarms are issued together.

The system leakage capacitance $C_e$ is monitored on its compliance with the maximum permissible value for the ISOMETER®. If the measured value of the system leakage capacitance $C_e$ exceeds 4 µF, the device error "E.07" with the alarm message "Device error" is issued.

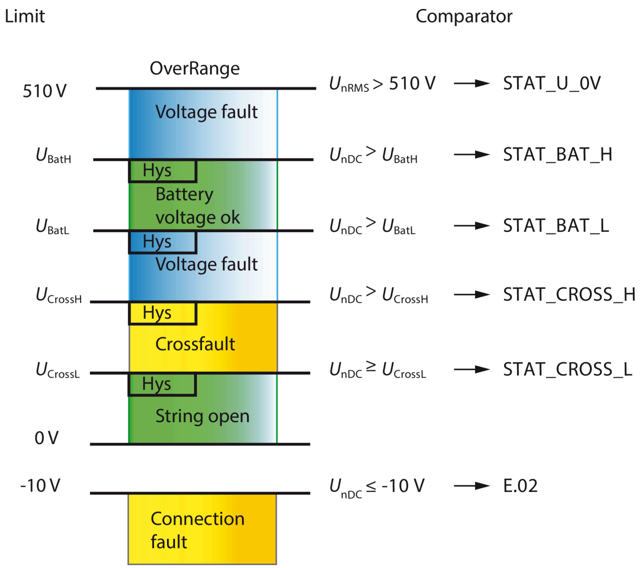
The measurement method requires a low-resistance connection between terminals "L+" and "L–". If the battery strings are still separated from each other, the connection will be established via the coupling impedance ZE420. The 12 kΩ internal resistance of the coupling impedance is included in the measured value $R_F$. If $R_F$ is below 100 kΩ, a measured value deviation of approx. +2 kΩ must be expected. If the battery strings are connected to form a complete battery, the internal resistance of the battery establishes the low-resistance connection and the deviation due to the coupling impedance is omitted.

### 2.3.4 Undervoltage/overvoltage monitoring

The nominal system voltage $U_n$ is 400 V. With an overvoltage of 25 %, a maximum of 500 V are permissible. The DC system voltage $U_n$ is measured in V and $V_{RMS}$. The root-mean-square value is a true RMS value and is only required for overload detection (over range) of the system coupling. In addition, the DC residual voltages $U_{L+e}$ as well as $U_{L-e}$ to earth are determined. The voltage values on the LC display and the interface are averaged to improve the resolution and are time-delayed. The comparators of the system voltage monitoring use the non-delayed, non-averaged system voltage. Therefore, minor deviations between the response of the voltage monitoring and the indicated voltage value are possible.

The parameters (U1<, U1>, U2< and U2>) for monitoring the system voltage $U_n$ can be set in the response value menu "AL" (see "Setting the response values (AL)", page 28). The maximum undervoltage value is limited by the overvoltage value. If the nominal system voltage $U_n$ reaches, falls below or exceeds the limit values (U< or U>), an alarm will be signalled. The alarm will be deleted when the threshold values plus hysteresis are no longer violated.

The image below shows the operating mode of the voltage comparators with the resulting messages.




| Status | Message |
|---|---|
| STAT_U_0V | Overvoltage Undervoltage |
| STAT_BAT_H | Overvoltage Undervoltage |
| ! STAT_BAT_H & STAT_BAT_L | Battery voltage ok |
| ! STAT_BAT_L & STAT_CROSS_H | Overvoltage Undervoltage |
| ! STAT_CROSS_H & STAT_CROSS_L | Overvoltage |
| ! STAT_CROSS_L | Undervoltage |

Figure 2-1: Voltage monitoring limits

## 2.3.5 Messpulsperiodendauer und Ansprecheigenzeiten

In the "sEt" menu, the measuring pulse period duration TMP can be configured with the parameter "t ⎍". The maximum operating times $t_{ae}$ (see "Measuring and response times", page 17) of the monitoring of the insulation resistance $R_F$, the cross fault $R_C$ as well as the connection to earth (E.01) and the battery (E.02) depend on it. The modifiable measuring pulse period duration allows adjusting the ISOMETER® to the insulation behaviour of the battery.

Measuring pulse period durations which are marked with the "auto" symbol switch automatically to the longest measuring pulse period duration as long as the message "Battery voltage $U_n$ is ok" is indicated. The following table shows the maximum operating times $t_{ae}$ for the different alarms and measuring pulse period durations $T_{MP}$.

| $T_{MP}$ | $R_F$ | $R_C$ | E.01 | E.02 |
|---|---|---|---|---|
| 0.8 s | 3.5 s | 3.0 s | 2.1 s | 6.0 s |
| 2.0 s | 8.0 s | 3.0 s | 2.1 s | 6.0 s |
| 4.0 s | 16.0 s | 3.0 s | 2.1 s | 15.0 s** |
| 8.0 s | 32.0 s | 3.0 s | 2.1 s | 30.0 s* |

* The value only applies to $C_{e1}$ or $C_{e2}$ > 400 nF. Below this value, the absence of just one system connection is not reliably detected.

** The value only applies to one-sided $R_f \leq 1.5$ MΩ. Above this value, the absence of just one system connection is not reliably detected.

## 2.3.6 Fault diagnosis

### 2.3.6.1 Insulation fault to earth

The displayed value $R_F$ of the ISOMETER® is the total insulation resistance $R_F$ to earth. The polarity and the amount of residual voltages $U_{L+e}$ and $U_{L-e}$ are an indicator of insulation fault location.

If the battery strings are not interconnected yet, the residual voltages $U_{L+e}$ and $U_{L-e}$ are almost identical and the nominal battery voltage $U_n$ is about 0 V, it is very likely that the insulation fault is only located in one string. The polarity of the residual voltages marks the affected string. The affected battery cell can be calculated by means of the residual voltages $U_{L+e}$ or $U_{L-e}$ and the ISOMETER® internal resistance $R_i$ = 120 kΩ:

$$U_{cell} = U_{Lxe} \times (1 + R_F / R_i)$$

If there is an additional insulation fault in the other string, determining the cell is almost impossible, since several variables, depending on location and size of the insulation fault, determine the residual voltages. If the battery strings are connected to form a complete battery, the measured value "Fault location%" indicates the fault location. Clear assignment is only possible in the event of a single insulation fault. The value can range between −100 % and +100 %. The sign indicates the string affected. When the fault is located in the middle of the battery, the fault location is 0 %.

### 2.3.6.2 Insulation fault between the battery strings (cross fault)

The insulation fault $R_C$ (cross fault) creates a connection between the unconnected strings and has no connection to earth. It can be detected via the $U_n$ value of the voltage measurement. If $U_n$ reaches or exceeds the comparator value $U_{CrossL}$, the overvoltage alarm is activated.

Depending on the fault location of the insulation fault $R_C$, an unloaded voltage on the same level as the voltage in a battery cell up to the maximum voltage of the series connection of both battery strings can occur. $R_C$ directly at the coupling points is not detectable due to the absence of voltage. Since the coupling impedance contains a current-limited resistance of 10 kΩ, which is connected in parallel to the series internal resistance of 240 kΩ of the ISOMETER®, the nominal system voltage $U_n$ resulting from the insulation fault $R_C$ is loaded with this resistance. For $R_C$ > 10 kΩ, exceeding half the voltage of a battery cell can be considered as lower limit for the fault detection.

Note that the internal resistance of the coupling impedance is only linear up to approx. 1.5 mA and from then on limits the current to this value. In connection with the non-linear internal resistance of the coupling impedance, in case of high-resistance values of $R_C$ the device error / coupling error "E.02" can occur simultaneously with the overvoltage alarm.

#### 2.3.6.3 Battery voltage

The system voltage $U_n$ is monitored with the voltage comparators described above. The insulation fault $R_C$ between the unconnected strings as well as the completion of the battery can be detected via these comparators.

### 2.3.7 Error codes

In the event of a device error the display shows the respective **error code**.

**Overview of some error codes**

| Error code | Meaning |
|---|---|
| E.01 | **PE connection error**<br>The connection of "E" or "KE" to earth is interrupted.<br>**Action:** Check connection, eliminate error. The error code will be erased automatically once the error has been eliminated. |
| E.02 | **System connection error**<br>The internal resistance of the system is too high or the connection of "L+" or "L–" to the system is interrupted. The terminals "L+" and "L–" are connected incorrectly.<br>**Action:** Check connection, eliminate error. The error code will be erased automatically once the error has been eliminated. |
| E.05 | **Measurement error**<br>Due to system interferences or a device error, the insulation measured value is no longer updated. Prewarning and alarm are set for the insulation measured value at the same time.<br>**Calibration invalid after software update**<br>"E.05" appears together with "E.08": The software is not compatible to the calibration of the device.<br>**Action:** Install the previous software version or have the device calibrated at the factory. |
| E.07 | **Permissible system leakage capacitance $C_e$ exceeded**<br>The device is not suitable for the present network leakage capacitance $C_e$.<br>**Action:** Uninstall the device. |
| E.08 | **Calibration error**<br>**Action:** Check connection, eliminate error. If the error is still present, there is a device error. |

Internal device errors "E.xx" can be caused by external disturbances or internal hardware errors. If the error message occurs again after the device has been restarted or after a reset to the factory settings (menu item "FAC"), the device must be repaired. After the fault has been eliminated, the alarm relays switch back either automatically or when the reset button is pressed. The self test can take a few minutes.

### 2.3.8 Connection monitoring

#### E-KE monitoring

The E-KE monitoring checks the connection between terminals "E" and "KE" and thereby ensures the connection to earth of the ISOMETER® and the battery enclosure. An error is reported with the code **E.01** and device error. It operates constantly in the background and does not affect the measuring function of the device.

**System connection monitoring**

The system connection monitoring monitors the connection of terminals “L+” and “L–” to the battery by means of the coupling impedance ZE420. An error is reported with the code **E.02** and device error. The monitoring requires a resistance smaller than 12 kΩ and a system leakage capacitance $C_e$ larger than 80 nF between terminals “L+” and “L–”. In the case of separated battery strings, the coupling impedance ensures that these minimum requirements are fulfilled. In the case of closed battery strings, the battery provides the required connection between “L+” and “L–” with its low-ohmic internal resistance. The system connection monitoring operates constantly in the background and does not influence the measuring function of the ISOMETER®.

Above a measuring pulse period duration of 2 s, a missing connection to “L+” or “L–” is only reliably detected under the conditions specified in chapter “Messpulsperiodendauer und Ansprecheigenzeiten”, page 12.

The system connection monitoring can be deactivated with the “nEt” parameter in the “SEt” menu. See chapter “Setting device control parameters (SEt)”, page 31.

## 2.3.9 Reset and test

### 2.3.9.1 External test/reset input and stop mode

The fault memory (“M”) is deleted by briefly connecting (0.2 s < t < 1.5 s) the terminal “T/R” to earth (terminal “E”). If the connection time exceeds 1.5 s, the manual self test starts. If the terminal “T/R” is still connected to earth after the device self test has been completed, the ISOMETER® changes to stop mode (“StP” indication on the display) and the measuring function is deactivated.

### 2.3.9.2 Reset

The following options trigger a reset:

- Briefly pressing (0.2 s < t < 1.5 s) the external “T/R” button.
  If the button is held (t > 1.5 s), a test follows the reset.
- Pressing and holding (t > 1.5 s) the “R” button.
- Sending a reset command via the interface.
- Activating stop mode.

In doing so, alarms that are no longer active are deleted from the fault memory.

### 2.3.9.3 Manual self test

During a manual self test (duration approx. 30 s), the measuring functions of the ISOMETER® are deactivated.

During the test, the “AL1” and “AL2” LEDs are lit, the message “tES” appears on the display and all self-test functions described in the self-test section are carried out. An alarm which makes the LEDs flash overrides the lighting of the LEDs.

The manual self test can be triggered as follows:

Holding the external “T/R” button (>1.5 s):

- A reset is carried out before the test so that alarms which are no longer active are deleted from the fault memory.
- The LCD shows “tES” and “CAL”.

Holding the “T” button (>1.5 s):

- The LCD shows all elements as long as this button is pressed, afterwards “tES” flashes.
- A reset is carried out after the test.

Sending a test command via the interface (COM):

- The LCD shows “tES” and “CAL”.
- A reset is carried out after the test.

If triggering via the “T/R” button, the alarms remain active during the test (except the “Device fault” alarm). In addition, the message “test” switches the alarm relays if it is assigned to the alarm relays in the “out” menu. After the manual self test, which can only be exited when exiting the stop mode, the message “test”, which may be displayed, will also be deleted from the fault memory.

### 2.3.9.4 Automatic self test

During an automatic test (duration approx. 30 s), the measuring functions of the ISOMETER® are deactivated. In the “t” menu (see chapter 4.6) the parameter “test” can be used to set the repetition time for an automatic test. If this timer is the trigger, only the message “tES” will be indicated on the display. No alarm is issued via the LEDs, the alarm relays or the interface. No reset is carried out.

A manual self test resets the timer for the automatic self test.

### 2.3.9.5 Self test

The ISOMETER® has the following self test functions:

- Checking the operating system (background test)
- Checking the connection of terminals “E” and “KE” to earth (background test, continuous)
- System connection monitoring (background test, continuous)
- Checking the function of the measuring equipment

Some of the self-test functions are executed constantly or time-controlled in the background, others are only executed on request.

The following sources can request a self-test:

- “T” button on the ISOMETER®
- External “T/R” button
- Serial interface
- Timer for automatic self test, configurable with the “test” parameter in the “t” menu
- Device start when “S.Ct” parameter = on (in the “SEt” menu)

During a self test started by one of the sources named above, the measuring function is temporarily deactivated. The background tests do not influence the measuring function.

### 2.3.9.6 Checking the operating system

The operating system check includes:

- Check sum verification of the program memory
- Error-free program sequence with stack check
- Parameter values check
- µC initialisation check

The µC initialisation check is run at least every 5 min. The data RAM memory, the check sum of the program memory and the content of the parameter memory are checked at least once an hour. These tests run in the background and do not influence the measuring function of the ISOMETER®.

## 2.3.10 Stop mode

The stop mode stops the measuring functions of the ISOMETER®. The measuring pulse voltage is 0 V and the input resistance of the system coupling has a high resistance. The LCD displays the message “StP”. The message “test” is set and all other messages are deleted.

The stop mode can be started by permanently closing the external “T/R” button or via the interface and ends when opening the “T/R” button or by releasing it via the interface. The control of the stop mode via the “T/R” button and the interface is an OR operation.

When the stop mode ends, a waiting time (2 s) starts so that the measured value recording settles before new threshold value comparisons are allowed.

If the ISOMETER® starts with an alarm (“out” menu, alarm assignment “S.AL” set to “on”) the released alarms are set and the measured resistance values are reset to their initial value. **The alarm assignment S.AL (i.e. Start with an alarm) should be set identically for both alarm relays.** When operating without “S.AL”, no alarms are set and the ISOMETER® starts with the maximum measured resistance value.

## 2.3.11 Start with alarm (S.AL)

The S.AL function allows a device start with set alarm messages. This function is activated in the “out” menu, in the alarm relay alarm assignments “r1” and “r2” by means of the parameter “S.AL”. For useful operation with this function, both alarm relays should have “S.AL” activated and operate in n/c mode.

If “S.AL” is activated during device start, all alarms of the released threshold value comparisons are set and the measured resistance values are initialised with 0 Ω. The alarms of the individual threshold value comparisons remain set until the respective measured value has reached the GO-state. No hysteresis is taken into account and the alarms do not remain stored in the fault memory.

A measured value that reaches the GO-state after the device has started triggers the history memory in case of a previous threshold value violation and the alarm remains stored in the fault memory.

## 2.3.12 Measuring and response times

The measuring time is the period essential for the detection of the measured value. The measuring time is reflected in the operating time $t_{ae}$. For the insulation resistance measured value, it is mainly determined by the necessary measuring pulse duration, which depends on the insulation resistance $R_F$ and the system leakage capacitance $C_e$ of the system to be monitored. The measuring pulse is generated by the measuring pulse generator integrated in the ISOMETER®. The measuring times for $C_e$, $U_{L+e}$, $U_{L-e}$ and R % are synchronous.

System disturbances may lead to extended measuring times. In contrast, the time for the system voltage measurement $U_n$ is independent and considerably shorter.

### Operating time $t_{ae}$

The operating time $t_{ae}$ is the time required by the ISOMETER® to determine the measured value. The insulation resistance measured value depends on the insulation resistance $R_F$ and the system leakage capacitance $C_e$.

### Response delay $t_{on}$

The response delay $t_{on}$ is set uniformly for all alarm messages in the “t” menu using the parameter “ton”, while each alarm message specified in the alarm assignment has its own timer for $t_{on}$. This delay can be used for interference suppression in the case of short measuring times.

An alarm message will only be signalled when a limit value of the respective measured value is violated for the duration of $t_{on}$. Each time the limit value is violated within the time $t_{on}$, the response delay “ton” restarts.

### Total response time $t_{an}$

The total response time $t_{an}$ is the sum of the operating time $t_{ae}$ and the response delay $t_{on}$.

### Delay on release $t_{off}$

The delay on release $t_{off}$ can be set uniformly for all alarm messages using the parameter “toff”, while each alarm message specified in the alarm assignment has its own timer for $t_{off}$.

An alarm message will be signalled until the limit value of the respective measured value is no longer violated (including hysteresis) for the duration of $t_{off}$ without interruption. Each time a limit value is no longer violated during $t_{off}$, the delay on release “toff” restarts.

### Start-up delay *t*

After connecting the supply voltage $U_S$, the alarm output is suppressed for the time set in parameter “t” (0…10 s).

## 2.3.13 Password protection (on, OFF)

If password protection is activated (on), settings can only be made after entering the password (0...999). For its activation, see chapter 4.7.

## 2.3.14 Fault memory

### Disabled (OFF)

The LEDs and relays signal the fault as long as it is detected.

### Enabled (ON)

The LEDs and relays signal the fault until a reset is performed or the supply voltage $U_s$ is disconnected.

## 2.3.15 History memory HiS

The history memory saves exclusively the measured values for the first fault. The history memory must first be cleared before new measured values can be saved.

The values checked in the table in section “Displaying measured values”, page 27 can be saved.

## 2.3.16 Digital interface

The ISOMETER® uses the serial hardware interface RS-485 with the following protocols:

- **BMS**
  The BMS protocol is an essential component of the Bender measuring device interface (BMS bus protocol). Data transmission generally makes use of ASCII characters.
- **Modbus RTU**
  Modbus RTU is an application layer messaging protocol, and it provides master/slave communication between devices that are connected via bus systems and networks. Modbus RTU messages have a 16-bit CRC (cyclic redundant checksum), which guarantees reliability.

- **IsoData**
  The ISOMETER® sends an ASCII data string with a cycle of approximately 1 second. Communication with the ISOMETER® in this mode is not possible, and no additional sender may be connected via the RS-485 bus cable. The ASCII data string for the ISOMETER® is described in chapter 5.4.

  *The IsoData protocol can be terminated by sending the command “Adr3” during a transmission pause of the ISOMETER®.*

The parameter address, baud rate and parity for the interface protocols are configured in the “out” menu.

*With “Adr = 0”, the menu entries baud rate and parity are not shown in the menu and the IsoData protocol is activated.*
*With a valid bus address (i.e. not equal to 0), the menu item “baud rate” is displayed in the menu. The parameter value “---” for the baud rate indicates the activated BMS protocol. In this case, the baud rate for the BMS protocol is set to 9600 baud. If the baud rate is set unequal to “---”, the Modbus protocol with configurable baud rate is activated.*

# 3 Installation, connection and commissioning

## 3.1 Dimensions

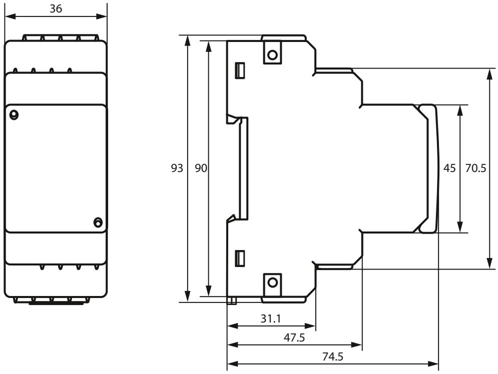



Figure: Dimension diagram (in mm)

## 3.2 Installation

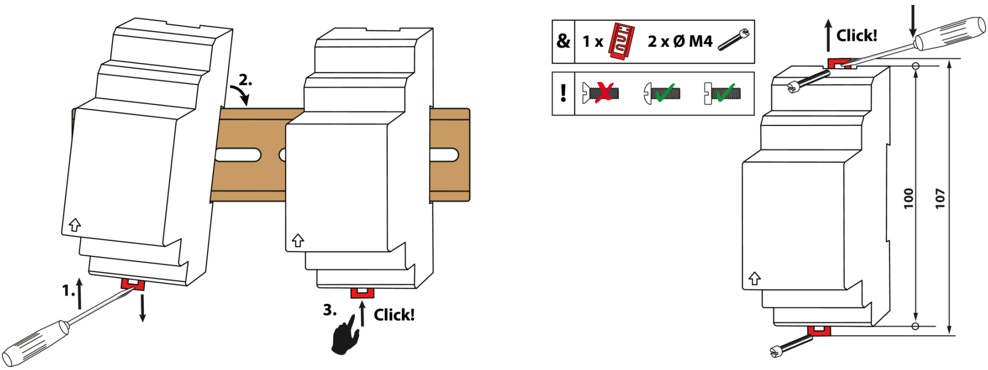



Figure: DIN rail mounting (left) or screw mounting (right)

## 3.3 Connection

**DANGER** ***Risk of fatal injury due to electric shock!***

*Touching live parts of the system carries the risk of:*

- Risk of electrocution due to electric shock
- Damage to the electrical installation
- Destruction of the device

Before installing the device and before working on its connections, make sure that the installation has been de-energised. The rules for working on electrical systems must be observed.

For details about the conductor cross sections required for wiring, refer to chapter "6 Technical data".

### Wiring diagram

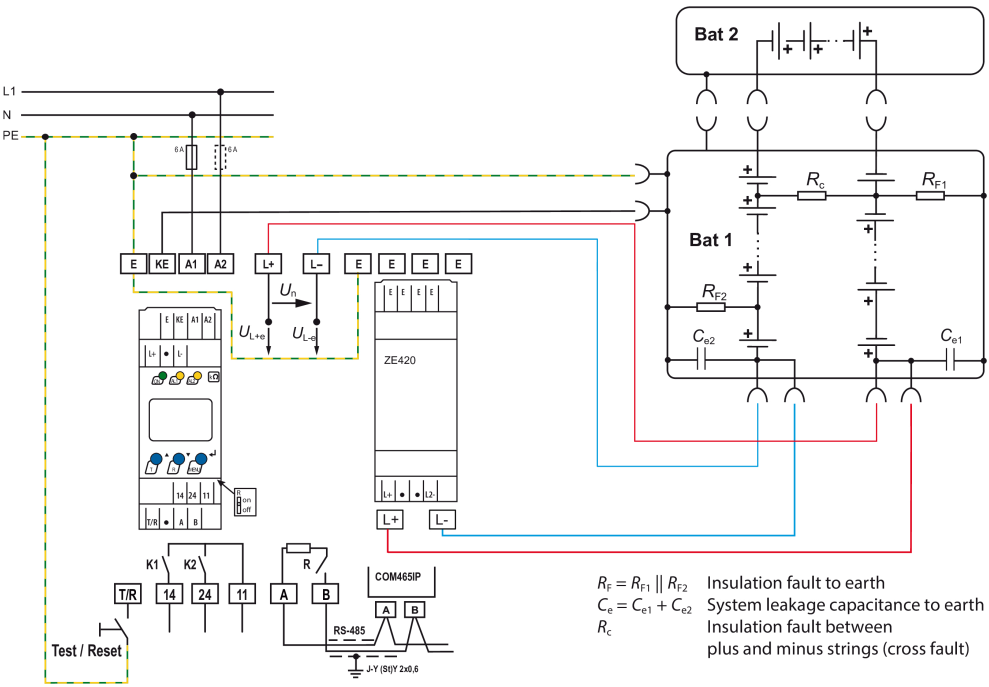



Figure: Anschlussbild

**Legend to wiring diagram**

| Terminal | Connections |
|---|---|
| **A1, A2** | Connection to the supply voltage $U_s$ via fuse (line protection):<br>If supplied from an IT system, protect both lines by a fuse.* |
| **E** | Connection to PE: Use same wire cross section as for "A1", "A2". |
| **KE** | Connection to the battery enclosure |
| **L+, L–** | Connection to the battery to be monitored<br>Indication in display: "L1" for L+; "L2" for L- |
| **T/R** | Connection for the external combined test and reset button |
| **11, 14** | Connection to alarm relay "K1" |
| **11, 24** | Connection to alarm relay "K2" |
| **A, B** | RS-485 communication interface with connectable terminating resistor<br>Example: Connection of a BMS Ethernet gateway COM465IP |

**** For UL applications:***

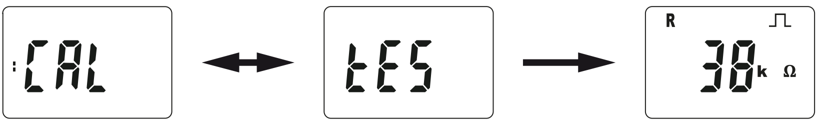
*Use 60/75 °C copper lines only!*

*For UL and CSA applications, connect the supply voltage $U_S$ via 5 A fuses.*

## 3.4 Commissioning

1. **Check that the ISOMETER® is properly connected to the system to be monitored.**
2. **Connect supply voltage $U_S$ to the ISOMETER®.**

   The device carries out a calibration, a self test and adjusts itself to the IT system to be monitored. With high system leakage capacitances this process may take up to 30 s. The standard display then appears showing the present insulation resistance, e.g.:

   The pulse symbol ⎍ signals an error-free update of the resistance and capacitance measured values. If the measured value cannot be updated due to disturbances, the pulse symbol will be blanked.
3. **Start a manual self test** by pressing the test button "T" > 1.5 s. While holding the test button all available display elements are shown. After releasing the button, the test starts and "tES" flashes for the duration of the test. Detected malfunctions are displayed as error codes (see chapter 2.3.7).

   *The alarm relays are not checked during the test (factory setting). The setting can be changed in the "out" menu so that the relays switch to the alarm state during the manual self test.*
4. **Check if the settings are suitable for the system being monitored.**

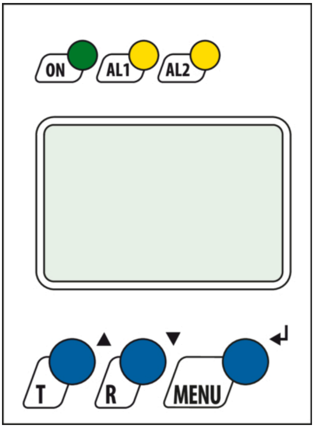
   The list of factory settings is shown in the tables from chapter 4.4.

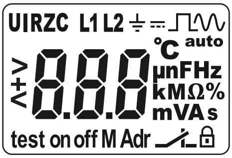
5. **Check the functionality by a real insulation fault.**

   Use a suitable resistor to check the ISOMETER® against earth in the system being monitored.

# 4 Operation

## 4.1 Operating and display elements

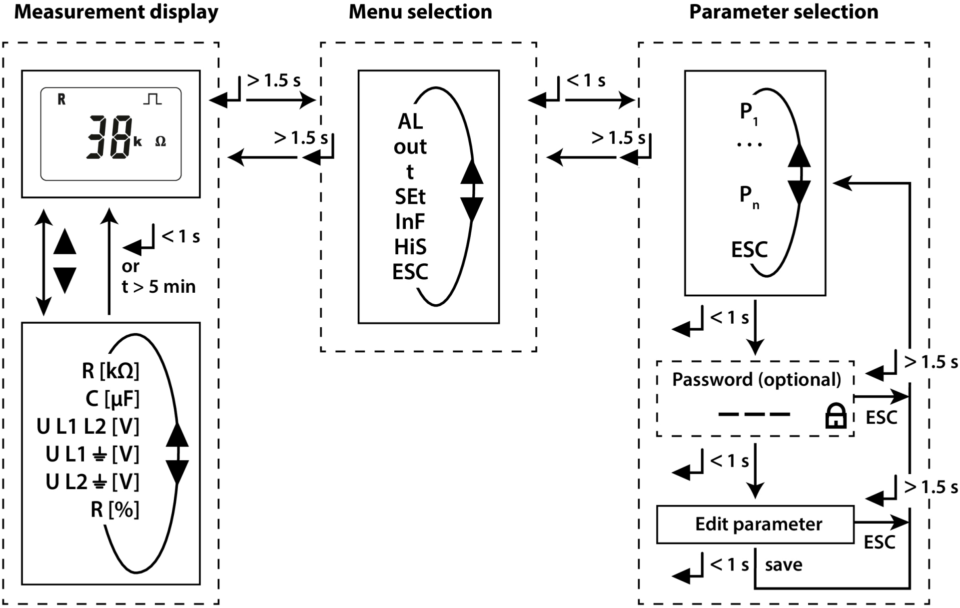
| Device front | Operating elements | Function |
|---|---|---|
|  | **ON** | Power LED |
| | **AL1 AL2** | Alarm LEDs (For codes see “Assigning the alarm messages to the relays”, page 29.) |
| | **▲▼** | Up and down buttons<br>– For navigating up or down in the menu settings.<br>– For increasing or decreasing values. |
| | **T** | Test button (press > 1.5 s) |
| | **R** | Reset button (press > 1.5 s) |
| | **↲** | Enter button<br>– Select menu item.<br>– Save value. |
| | **MENU** | MENU button (press > 1.5 s)<br>– Starts menu mode.<br>– Exits menu item without saving changes. |

| Display | Display elements | Function |
|---|---|---|
|  | **U** | System voltage $U_n$ |
| | **R** | Insulation resistance $R_F$ |
| | **C** | System leakage capacitance $C_e$ |
| | **L1 L2** ⏚ | Monitored conductors<br>L1 = L+<br>L2 = L– |
| | ⎓ | Voltage type DC |
| | ⎍ | Pulse symbol: error-free measured value update |
| | ∿ | Voltage type AC |
| | **°C**<br>**µ n F Hz**<br>**k M Ω %**<br>**m V A s** | Measured values and units |
| | 🔒 | Password protection is activated |
| | ⟋ | In the menu mode, the operating mode of the respective alarm relay is displayed. |
| | **Adr** | Communication interface with measured value: isoData operation |
| | **M** | Fault memory is activated |
| | **test on off** | Condition symbols |
| | ><br>+<br>< | Identification for response values and response value violation |

**i** *The display parameters that can be configured flash.*

*Depending on the ISOMETER®'s scope of functions, not all display elements are used.*

## 4.2 Menu overview




| Menu item | Parameter |
|---|---|
| **AL** | Querying and setting response values |
| **out** | Configuring fault memory, alarm relays and interface |
| **t** | Setting delay times and self test cycles |
| **SEt** | Setting device control parameters |
| **InF** | Querying software version |
| **HiS** | Querying and clearing the history memory |
| **ESC** | Going to the next-higher menu level |

## 4.3 Displaying measured values

### Overview

| HiS | Display | Description |
|---|---|---|
| ✓ | ± R kΩ ⎍ | **Insulation resistance** $R_F$<br>1 kΩ … 10 MΩ<br>For $R_F$ < 5 MΩ, "+" or "–" $R_F$ indicate as mainly on L+ or L– when \|fault location\| > 20 % or strings are open and $\|U_{L+e} + U_{L-e}\| \geq 5$ V. |
| ✓ | C µF ⎍ | **System leakage capacitance** $C_e$<br>1 nF ... 9.99 µF<br>No update when $R_F$ is < 10 kΩ. |
| ✓ | ± U L1 L2 V | **System voltage** $U_n$ (L+ - L–)<br>DC 0…500 V |
| ✓ | ± U L1 ⏚ = V | **Residual voltage** $U_{L+e}$ (L+ - PE)<br>DC 0…500 V |
| ✓ | ± U L2 ⏚ = V | **Residual voltage** $U_{L-e}$ (L– - PE)<br>DC 0…500 V |
| ✓ | ± R % | **Fault location in %**<br>–100 % … +100 %<br>This value is indicated in the range of the correct total battery voltage and is only valid for external errors which are directly applied to the plus or minus connections of the complete battery.<br>$R_{f+} = (200\,\% \times R_f) / (100\,\% + x\,\%)$<br>$R_{f-} = (200\,\% \times R_f) / (100\,\% - x\,\%)$ |

✓ The measured value is displayed in the history memory.

### Displaying the current measured values

The standard display shows the currently measured value for $R_F$ . Press the up or down buttons to display the other measured values. After 5 min at the latest the display switches back to the standard display.

⚠ **ADVICE**
The pulse symbol indicates a currently measured value. If this symbol does not appear, the measurement is still ongoing and the latest valid measured value will be displayed. The symbols "<" or ">" will be displayed additionally to the measured value when a response value has been reached or violated, or the measured value is below or above the measuring range.

## 4.4 Setting the response values (AL)

### 4.4.1 Setting the response values for monitoring the insulation resistance

**How to proceed**

1. Open menu “AL”.
2. Select parameter “R1” for prewarning or parameter “R2” for alarm.
3. Set value and confirm with Enter.

### 4.4.2 Setting the response values for undervoltage and overvoltage

**How to proceed**

1. Open menu “AL”.
2. Select parameter “U<” for undervoltage or parameter “U>” for overvoltage.
3. Set value and confirm with Enter.

### 4.4.3 Response values overview

| Display | Activation | | Setting value | | | Description |
|---|---|---|---|---|---|---|
| | FAC | Cs | Range | FAC | Cs | |
| R1 < | **on** | not adjustable | R2 … 5000 | **1500** | kΩ | Prewarning value $R_{an1}$<br>Hys. = 25 % / min. 1 kΩ |
| R2 < | **on** | not adjustable | 10 … R1 | **1000** | kΩ | Alarm value $R_{an2}$<br>Hys. = 25 % / min. 1 kΩ |
| U1 < | **on** | not adjustable | U1> … 500 | **450** | V | Battery voltage ok $U_{BatH}$<br>Hys. = 5 % / min. 5 V |
| U1 > | **on** | not adjustable | 3 … U1< | **385** | V | Battery voltage ok $U_{BatL}$<br>Hys. = 5 % / min. 5 V |
| U2 < | **on** | not adjustable | U2> … 500 | **385** | V | Cross fault $U_{CrossH}$<br>Hys. = 5 % / min. 2 V |
| U2 > | **on** | not adjustable | 3 … U2< | **3** | V | Cross fault $U_{CrossL}$<br>Hys. = 5 % / min. 2 V |

FAC Factory settings
Cs Customer settings

## 4.5 Configuring fault memory, alarm relays, and interfaces (out)

Call up menu „out“ to configure fault memory, alarm relays, and interfaces.

### 4.5.1 Configuring the relays

| Relay K1 | | | Relay K2 | | | Description |
|---|---|---|---|---|---|---|
| Display | FAC | Cs | Display | FAC | Cs | |
| 1 | **n/c** | | 2 | **n/c** | | Relay operating mode n/c or n/o |

FAC Factory settings
Cs Customer settings

### 4.5.2 Assigning the alarm messages to the relays

The “on” setting assigns an alarm message to the respective relay. The LED indication is directly assigned to the alarm message and is not related to the relays.

In the event of an unsymmetrical insulation fault, only the alarm message corresponding to the assigned conductor (L+ or L–) will be displayed.

| K1 „r1“ | | | K2 „r2“ | | | LEDs | | | Description |
|---|---|---|---|---|---|---|---|---|---|
| Display | FAC | Ke | Display | FAC | Ke | ON | AL1 | AL2 | |
| 1 Err | **on** | | 2 Err | **off** | | ◎ | ◎ | ◎ | Device error E.xx |
| r1<br>+R1 < Ω | **off** | | r2<br>+R1 < Ω | **on** | | ● | ○ | ● | Prewarning R1<br>Fault $R_F$ at L+ |
| r1<br>–R1 < Ω | **off** | | r2<br>–R1 < Ω | **on** | | ● | ○ | ● | Prewarning R1<br>Fault$R_F$ at L– |
| r1<br>+R2 < Ω | **off** | | r2<br>+R2 < Ω | **on** | | ● | ○ | ● | Alarm R2<br>Fault $R_F$ at L+ |
| r1<br>–R2 < Ω | **off** | | r2<br>–R2 < Ω | **on** | | ● | ○ | ● | Alarm R2<br>Fault $R_F$ at L– |
| r1<br>U < V | **off** | | r2<br>U < V | **off** | | ● | ○ | ○ | Alarm $U_n$<br>Undervoltage |
| r1<br>U > V | **off** | | r2<br>U > V | **on** | | ● | ◎ | ○ | Alarm $U_n$<br>Overvoltage |
| r1<br>U V | **off** | | r2<br>U V | **off** | | ● | ● | ○ | Message battery voltage<br>$U_n$ is ok |
| r1<br>test | **off** | | r2<br>test | **off** | | ● | ● | ● | Manually started device test |

| K1 „r1“ | | | K2 „r2“ | | | LEDs | | | Description |
|---|---|---|---|---|---|---|---|---|---|
| Display | FAC | Ke | Display | FAC | Ke | ON | AL1 | AL2 | |
| r1<br>S.AL | **off** | | r2<br>S.AL | **off** | | ● | ● | ● | Device start with alarm |

FAC Factory settings
Ke Customer settings
○ LED off
◎ LED flashes
● LED on

### 4.5.3 Activating or deactivating fault memory

| Display | FAC | Cs | Description |
|---|---|---|---|
| M | **off** | | Memory function for alarm messages (fault memory) |

FAC Factory settings
Cs Customer settings

### 4.5.4 Configuring interface

| Display | Setting value | | | Description | |
|---|---|---|---|---|---|
| | Range | FAC | Cs | | |
| Adr | 0 / 3…90 | **3** | ( ) | Bus Adr. | Adr = 0 deactivates BMS as well as Modbus and activates isoData with continuous data output (115k2, 8E1) |
| Adr 1 | ---<br>1.2k…115k | **115k** | ( ) | Baud rate | “---”: BMS bus (9k6, 7E1)<br>“1.2k” … “115k”: Modbus (variable) |
| Adr 2 | 8E1<br>8o1<br>8n1<br>8n2 | **8E1** | ( ) | Modbus | **8E1** - 8 data bits, even parity, 1 stop bit<br>**8o1** - 8 data bits, odd parity, 1 stop bit<br>**8n1** - 8 data bits, no parity, 1 stop bit<br>**8n2** - 8 data bits, no parity, 2 stop bits |

FAC Factory settings
Cs Customer settings
( ) Customer setting that is not modified by FAC.

## 4.6 Setting delay times and self test cycles (t)

Open menu "t" to configure the times.

| Display | Setting value | | | Description |
|---|---|---|---|---|
| | Range | FAC | Cs | |
| t | 0…10 | **0** | **s** | Start-up delay when starting the device |
| ton1 | 0…99 | **0** | **s** | Response delay K1 |
| ton2 | 0…99 | **0** | **s** | Response delay K2 |
| toff | 0…99 | **0** | **s** | Delay on release K1 and K2 |
| test | OFF/1/24 | **OFF** | **h** | Repetition time for device test |

FAC Factory settings
Cs Customer settings

## 4.7 Setting device control parameters (SEt)

Open menu "SEt" to configure the device control.

| Display | Activation | | Setting value | | | Description |
|---|---|---|---|---|---|---|
| | FAC | Cs | Range | FAC | Cs | |
|  | **off** | | 0. . .999 | **0** | | Password for parameter setting |
|  | | | auto 0.8<br>auto 2.0<br>0.8<br>2.0<br>4.0<br>8.0 | **2.0** | **s** | Measuring pulse period duration<br>**auto:** change to the period duration 8.0 s with the message "Battery voltage $U_n$ is ok". |
| nEt | **on** | | | | | System connection test |
| S.Ct | **on** | | | | | Device test at device start |
| FAC | | | | | | Restore factory settings |
| SYS | | | | | | For Bender Service only |

FAC Factory settings
Cs Customer settings

## 4.8 Reset to factory settings

All settings with the exception of the interface parameters are reset to the factory settings.

1. Press MENU button (> 1.5 s).
2. Go to “SEt” and confirm with Enter.
3. Go to “FAC” and confirm with Enter.

## 4.9 Showing and deleting the history memory

⚠ **ADVICE**
The history memory saves the measured values for the first fault only. To this end, the history memory must be empty.

**Show history memory**

Call up “HiS” menu and go up or down.

**Delete history memory**

Call up “HiS” menu, go to “Clr” and confirm.

## 4.10 Querying software version (InF)

The software version is displayed as a ticker. Afterwards it can be output step by step using the up or down buttons.

**How to proceed**

1. Press MENU button (> 1.5 s).
2. Go to “InF” and confirm with Enter.
3. If necessary, use up or down buttons to display it step by step.

# 5 Data access via RS-485 interface

## 5.1 Data access using the BMS protocol

The BMS protocol is an essential component of the Bender measuring device interface (BMS bus protocol). Data transmission generally makes use of ASCII characters.

| BMS channel no. | Operation value | Alarm |
|---|---|---|
| 1 | $R_F$ | Prewarning R1 |
| 2 | $R_F$ | Alarm R2 |
| 3 | $C_e$ | |
| 4 | $U_n$ | Undervoltage |
| 5 | $U_n$ | Overvoltage |
| 6 | | Connection fault, earth (E.01) |
| 7 | | Connection fault, system (E.02) |
| 8 | | All other device faults (E.xx) |
| 9 | Fault location [%] | |
| 10 | $U_{L+e}$ | $U_n$ battery voltage ok |
| 11 | $U_{L-e}$ | |
| 12 | Update counter | |
| 13 | | |
| 14 | | |
| 15 | | |

## 5.2 Data access using the Modbus RTU protocol

Requests to the ISOMETER® can be made using the function code 0x03 (read multiple registers) or the command 0x10 (write multiple registers). The ISOMETER® generates a function-related answer and sends it back.

### 5.2.1 Reading out the Modbus register from the ISOMETER®

The required Words of the process image can be read out from the ISOMETER® “Holding Registers” using function code 0x03. For this purpose, the start address and the number of the registers to be read out must be entered. Up to 125 Words (0x7D) can be read out with one single request.

### Command of the master to the ISOMETER®

In the following example, the master of the ISOMETER® requests the content of register 1003 using address 3. The register contains the channel description of measuring channel 1.

| Byte | Name | Example |
|---|---|---|
| Byte 0 | ISOMETER® Modbus address | 0x03 |
| Byte 1 | Function code | 0x03 |
| Byte 2, 3 | Start address | 0x03EB |
| Byte 4, 5 | Number of registers | 0x0001 |
| Byte 6, 7 | CRC16 checksum | 0xF598 |

### Answer of the ISOMETER® to the master

| Byte | Name | Example |
|---|---|---|
| Byte 0 | ISOMETER® Modbus address | 0x03 |
| Byte 1 | Function code | 0x03 |
| Byte 2 | Number of data bytes | 0x02 |
| Byte 3, 4 | Data | 0x0047 |
| Byte 7, 8 | CRC16 checksum | 0x81B6 |

## 5.2.2 Writing the Modbus register (parameter setting)

Registers in the device can be modified with function code 0x10 (set multiple registers). Parameter registers start with address 3000. For the contents of the registers, see table in chapter 5.3.2.1.

### The master sends a command to the ISOMETER®

In this example, address 3 is used to set the content of register address 3003 to 2.

| Byte | Name | Example |
|---|---|---|
| Byte 0 | ISOMETER® Modbus address | 0x03 |
| Byte 1 | Function code | 0x10 |
| Byte 2, 3 | Start register | 0x0BBB |
| Byte 4, 5 | Number of registers | 0x0001 |
| Byte 6 | Number of data bytes | 0x02 |
| Byte 7, 8 | Data | 0x0002 |
| Byte 9, 10 | CRC16 checksum | 0x9F7A |

**Response of the ISOMETER® to the master**

| Byte | Name | Example |
|---|---|---|
| Byte 0 | ISOMETER® Modbus address | 0x03 |
| Byte 1 | Function code | 0x10 |
| Byte 2, 3 | Start register | 0x0BBB |
| Byte 4, 5 | Number of registers | 0x0001 |
| Byte 6, 7 | CRC16 checksum | 0x722A |

### 5.2.3 Exception code

If the ISOMETER® cannot respond to a request, it will send an exception code with which possible faults can be narrowed down.

| Exception code | Description |
|---|---|
| 0x01 | Impermissible function |
| 0x02 | Impermissible data access |
| 0x03 | Impermissible data value |
| 0x04 | Internal fault |
| 0x05 | Acknowledgement of receipt (answer will be time-delayed) |
| 0x06 | Request not accepted (repeat request if necessary) |

**Structure of the exception code**

| Byte | Name | Example |
|---|---|---|
| Byte 0 | ISOMETER® Modbus address | 0x03 |
| Byte 1 | Function code (0x03) + 0x80 | 0x83 |
| Byte 2 | Data (exception code) | 0x04 |
| Byte 3, 4 | CRC16 checksum | 0xE133 |

## 5.3 Modbus register assignment

### 5.3.1 Modbus measured value registers

Depending on the device condition, the information in the registers is the measured value without alarm, the measured value with alarm 1, the measured value with alarm 2, or the device error. For more information see , page 37.

| Register | Measured value | | | Device error |
|---|---|---|---|---|
| | Without alarm | Alarm 1 [prewarning] | Alarm 2 [alarm] | |
| 1000…1003 | $R_F$ Insulation fault (71) | $R_F$ Insulation fault (1) | $R_F$ Insulation fault (1) | Earth connection (102) |
| 1004…1007 | | | | |
| 1008…1011 | $U_n$ Voltage (76) | $U_n$ Overvoltage (78) [alarm] | | Connection to system (101) |
| 1012…1015 | $C_e$ Capacitance (82) | | | |
| 1016…1019 | $U_{L+e}$ Voltage (76) | $U_n$ Undervoltage (77) [alarm] | | |
| 1020…1023 | $U_{L-e}$ Voltage (76) | | | |
| 1024…1027 | Fault location in % (1022) | | | |
| 1028…1031 | | | | |
| 1032…1035 | Measured value update counter (1022) | | | Device error (115) |

( ) channel description code (see “Channel descriptions”, page 39)

#### 5.3.1.1 Measurement coding

Each measured value is available as a channel and consists of 8 bytes (4 registers). The first measured value register address is 1000. The structure of a channel is always the same. Content and number depend on the device. The structure of a channel is shown with the example of channel 1:

| 1000 | | 1001 | | 1002 | | 1003 | |
|---|---|---|---|---|---|---|---|
| HiByte | LoByte | HiByte | LoByte | HiByte | LoByte | HiByte | LoByte |
| Floating point value (Float) | | | | Alarm type and test type (AT&T) | Range and unit (R&U) | Channel description | |

### 5.3.1.2 Float = Floating point value of the channels

Representation of the bit order for processing analogue measured values according to IEEE 754

| Word | 0x00 | | | | | | | | | | | | | | | | 0x01 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Byte | HiByte | | | | | | | | LoByte | | | | | | | | HiByte | | | | | | | | LoByte | | | | | | | |
| Bit | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | S | E | E | E | E | E | E | E | E | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M |

E exponent
M mantissa
S sign

### 5.3.1.3 AT&T = Alarm type and test type (internal/external)

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Meaning |
|---|---|---|---|---|---|---|---|---|---|
| | Test external | Test internal | Reserved | Reserved | Reserved | Alarm | Fault | | |
| Alarm type | X | X | X | X | X | 0 | 0 | 0 | No alarm |
| | X | X | X | X | X | 0 | 0 | 1 | Prewarning |
| | 0 | 0 | X | X | X | 0 | 1 | 0 | Device error |
| | X | X | X | X | X | 0 | 1 | 1 | Reserved |
| | X | X | X | X | X | 1 | 0 | 0 | Warning |
| | X | X | X | X | X | 1 | 0 | 1 | Alarm |
| | X | X | X | X | X | 1 | 1 | 0 | Reserved |
| | X | X | X | X | X | 1 | 1 | 1 | Reserved |
| Test | 0 | 0 | X | X | X | X | X | X | No test |
| | 0 | 1 | X | X | X | X | X | X | Internal test |
| | 1 | 0 | X | X | X | X | X | X | External test |

- Bits 0 to 2: coding for the alarm type
- Bits 3 to 5: reserved; value 0
- Bit 6 oder 7: set when an internal or external test is active

Other values are reserved. The complete byte is calculated from the sum of the alarm type and the test type.

### 5.3.1.4 R&U = Range and unit

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Meaning |
|---|---|---|---|---|---|---|---|---|---|
| Unit | - | - | - | 0 | 0 | 0 | 0 | 0 | Invalid (init) |
| | - | - | - | 0 | 0 | 0 | 0 | 1 | No unit |
| | - | - | - | 0 | 0 | 0 | 1 | 0 | Ω |
| | - | - | - | 0 | 0 | 0 | 1 | 1 | A |
| | - | - | - | 0 | 0 | 1 | 0 | 0 | V |
| | - | - | - | 0 | 0 | 1 | 0 | 1 | % |
| | - | - | - | 0 | 0 | 1 | 1 | 0 | Hz |
| | - | - | - | 0 | 0 | 1 | 1 | 1 | Baud |
| | - | - | - | 0 | 1 | 0 | 0 | 0 | F |
| | - | - | - | 0 | 1 | 0 | 0 | 1 | H |
| | - | - | - | 0 | 1 | 0 | 1 | 0 | °C |
| | - | - | - | 0 | 1 | 0 | 1 | 1 | °F |
| | - | - | - | 0 | 1 | 1 | 0 | 0 | Second |
| | - | - | - | 0 | 1 | 1 | 0 | 1 | Minute |
| | - | - | - | 0 | 1 | 1 | 1 | 0 | Hour |
| | - | - | - | 0 | 1 | 1 | 1 | 1 | Day |
| | - | - | - | 1 | 0 | 0 | 0 | 0 | Month |
| Range of validity | 0 | 0 | X | X | X | X | X | X | Actual value |
| | 0 | 1 | X | X | X | X | X | X | The actual value is lower |
| | 1 | 0 | X | X | X | X | X | X | The actual value is higher |
| | 1 | 1 | X | X | X | X | X | X | Invalid value |

- Bits 0 to 4: coding for the unit
- Bits 6 and 7: validity range of a value
- Bit 5: reserved

The complete byte is calculated from the sum of the unit and the range of validity.

#### 5.3.1.5 Channel descriptions

| Value | Description of measured value / message | Comments |
|---|---|---|
| 0 | | |
| 1 (0x01) | Insulation fault | |
| 71 (0x47) | Insulation fault | Insulation resistance $R_F$ in Ω |
| 76 (0x4C) | Voltage | Measured value in V |
| 77 (0x4D) | Undervoltage | |
| 78 (0x4E) | Overvoltage | |
| 82 (0x52) | Capacitance | Measured value in F |
| 86 (0x56) | Insulation fault | Impedance $Z_i$ |
| 101 (0x65) | System connection | |
| 102 (0x66) | Earth connection | |
| 115 (0x73) | Device error | ISOMETER® fault |
| 129 (0x81) | Device error | |
| 145 (0x91) | Own address | |

### 5.3.2 Modbus parameter register

#### 5.3.2.1 Parameter coding

| Register | Property | Description | Format | Unit | Value range |
|---|---|---|---|---|---|
| 999 | RO | Number of Modbus measured-value channels with active alarm | UINT 16 | | 0…9 |
| 3000 | RW | Reserved | | | |
| 3001 | RW | Prewarning value for resistance measurement “R1” | UINT 16 | kΩ | R2 … 5000 |
| 3002 | RW | Reserved | | | |
| 3003 | RW | Alarm value for resistance measurement “R2” | UINT 16 | kΩ | 10 … R1 |
| 3004 | RW | Reserved | | | |
| 3005 | | $U_{BatH}$ specified battery value, upper limit | UINT 16 | V | $U_{BatL}$ … 500 |
| 3006 | RW | Reserved | | | |
| 3007 | RW | $U_{BatL}$ specified battery value, lower limit | UINT 16 | V | 3 … $U_{BatH}$ |
| 3008 | RW | Reserved | | | |
| 3009 | RW | $U_{CrossH}$ cross fault upper limit | UINT 16 | V | $U_{CrossL}$ … 500 |

| Register | Property | Description | Format | Unit | Value range |
|---|---|---|---|---|---|
| 3010 | RW | Reserved | UINT 16 | | |
| 3011 | RW | $U_{CrossL}$ cross fault lower limit | UINT 16 | V | 3 … $U_{CrossH}$ |
| 3012 | RW | Memory function for alarm messages (fault memory) "M" | UINT 16 | | 0 = off<br>1 = on |
| 3013 | RW | Operating mode of relay K1 "r1" | UINT 16 | | 0 = n/o<br>1 = n/c |
| 3014 | RW | Operating mode of relay K2 "r2" | UINT 16 | | 0 = n/o<br>1 = n/c |
| 3015 | RW | Bus address "Adr" | UINT 16 | | 0 / 3…90 |
| 3016 | RW | Baud rate "Adr 1" | UINT 16 | | 0 = BMS<br>1 = 1.2 k<br>2 = 2.4 k<br>3 = 4.8 k<br>4 = 9.6 k<br>5 = 19.2 k<br>6 = 38.4 k<br>7 = 57.6 k<br>8 = 115.2 k |
| 3017 | RW | Parity "Adr 2" | UINT 16 | | 0 = 8N1<br>1 = 8O1<br>2 = 8E1<br>3 = 8N2 |
| 3018 | RW | Start-up delay "t" during device start | UINT 16 | s | 0 …10 |
| 3019 | RW | Response delay "ton1" for relay "K1" | UINT 16 | s | 0 … 99 |
| 3020 | RW | Delay on release "toff" for relays "K1" and "K2" | UINT 16 | s | 0 … 99 |
| 3021 | RW | Repetition time "test" for automatic device test | UINT 16 | | 0 = off<br>1 = 1 h<br>2 = 24 h |
| 3022 | RW | Reserved | | | |
| 3023 | RW | Reserved | | | |
| 3024 | RW | Test of the system connection during device test "nEt" | UINT 16 | | 0 = off<br>1 = on |
| 3025 | RW | Device test during device start "S.Ct" | UINT 16 | | 0 = off<br>1 = on |
| 3026 | RW | Request stop mode (0 = deactivate devices) | UINT 16 | | 0 = Stop<br>1 = --- |
| 3027 | RW | Alarm assignment of relay K1 "r1" | UINT 16 | | Bit 10 … Bit 1 |

| Register | Property | Description | Format | Unit | Value range |
|---|---|---|---|---|---|
| 3028 | RW | Alarm assignment of relay K2 “r2” | UINT 16 | | Bit 10 … Bit 1 |
| 3029 | RW | Measuring pulse period duration | UINT 16 | s | 0 = auto 0.8<br>1 = auto 2.0<br>2 = 0.8<br>3 = 2.0<br>4 = 4.0<br>5 = 8.0 |
| 3030 | RW | Response delay “ton2” for relay “K2” | UINT 16 | s | 0 … 99 |
| 8003 | WO | Factory settings for all parameters | UINT 16 | | 0x6661 “fa” |
| 8004 | WO | Factory setting only for parameters resettable by FAC | UINT 16 | | 0x4653 “FS” |
| 8005 | WO | Start device test | UINT 16 | | 0x5445 “TE” |
| 8006 | WO | Clear fault memory | UINT 16 | | 0x434C “CL” |
| 9800 … 9809 | RO | Device name (ASCII) | UNIT 16 | | |
| 9820 | RO | Software identification number | UINT 16 | | |
| 9821 | RO | Software version number | UINT 16 | | |
| 9822 | RO | Software version: Year | UINT 16 | | |
| 9823 | RO | Software version: Month | UINT 16 | | |
| 9824 | RO | Software version: Day | UINT 16 | | |
| 9825 | RO | Modbus driver version | UINT 16 | | |

RO Read only
RW Read/Write
WO Write only

### 5.3.2.2 Alarm assignment of the relays

Several messages and alarms can be assigned to each relay. For the assignment to each relay, a 16-bit register is used with the bits described below. The following table applies to relay K1 and relay K2, in which “x” stands for the relay number. A set bit activates the specified function.

| Bit | Display indication | Meaning |
|---|---|---|
| 0 | Reserved | When reading: 0<br>When writing: any value |
| 1 | x Err | Device error E.xx |
| 2 | rx +R1 < Ω | Prewarning R1 - Fault $R_F$ at L+ |
| 3 | rx –R1 < Ω | Prewarning R1 - Fault $R_F$ at L– |

| Bit | Display indication | Meaning |
|---|---|---|
| 4 | rx +R2 < Ω | Alarm R2 - Fault $R_F$ at L+ |
| 5 | rx –R2 < Ω | Alarm R2 - Fault $R_F$ at L– |
| 6 | rx U < V | Alarm message $U_n$ - undervoltage |
| 7 | rx U > V | Alarm message $U_n$ - overvoltage |
| 8 | rx U V | Message - battery voltage $U_n$ is ok |
| 9 | rx test | Manually started self test |
| 10 | rx S.AL | Device start with alarm |
| 11 | Reserved | When reading: 0<br>When writing: any value |
| 12…15 | Reserved | When reading: 0<br>When writing: any value |

#### 5.3.2.3 Device name

The data format of the device name consists of ten Words with two ASCII characters each.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0x00 | 0x01 | 0x02 | 0x03 | 0x04 | 0x05 | 0x06 | 0x07 | 0x08 | 0x09 |

## 5.4 IsoData data string

In IsoData mode the ISOMETER® sends the entire data string roughly once per second. Communication with the ISOMETER® in this mode is not possible and no additional sender may be connected via the RS-485 bus cable.

IsoData is activated in the menu "out", menu item "Adr", when Adr is set to 0. In this case, the "Adr" symbol flashes on the measured value display.

| String | Description |
|---|---|
| !; | Start symbol |
| v; | Insulation fault location " " / "+" / "–" |
| 123456; | Insulation resistance $R_F$ [kΩ] |
| 1234; | System leakage capacitance $C_e$ [nF] |
| 123456; | Reserved |
| +1234 ,5; | System voltage (DC) $U_n$ [V] |
| +1234 ,5; | Residual DC voltage $U_{L+e}$ [V] |
| +1234 ,5; | Residual DC voltage $U_{L-e}$ [V] |
| +123; | Insulation fault location –100 … +100 [%] |
| 1234; | Alarm message [hexadecimal] (without leading "0x")<br>The alarms are included in this value with the OR function.<br>Assignment of the alarms:<br>0x0002 device error<br>0x0004 Prewarning insulation resistance $R_F$ at L+<br>0x0008 Prewarning insulation resistance $R_F$ at L–<br>0x000C Prewarning insulation resistance $R_F$ symmetrical<br>0x0010 Alarm insulation resistance $R_F$ at L+<br>0x0020 Alarm insulation resistance $R_F$ at L–<br>0x0030 Alarm insulation resistance $R_F$ symmetrical<br>0x0040 Alarm message undervoltage $U_n$<br>0x0080 Alarm message overvoltage $U_n$<br>0x0100 Message battery voltage $U_n$ ok<br>0x0200 Message system test<br>0x0400 Device start with alarm |
| 12; | Update counter, consecutively counts from 0 to 99.<br>It increases with the update of the insulation resistance value. |
| <CR><LF> | String end |

# 6 Technical data

## 6.1 Technical data isoBAT425

( )* = Factory settings

### Insulation coordination acc. to IEC 60664-1/-3

| | |
|---|---|
| **Definitions** | |
| Measuring circuit (IC1) | L+, L- |
| Supply circuit (IC2) | A1, A2 |
| Output circuit (IC3) | 11, 14, 24 |
| Control circuit (IC4) | E, KE, T/R, A, B |
| Rated voltage | 400 V |
| Overvoltage category | III |
| **Rated impulse voltage** | |
| IC1/(IC2-4) | 6 kV |
| IC2/(IC3-4) | 4 kV |
| IC3/IC4 | 4 kV |
| **Rated insulation voltage** | |
| IC1/(IC2-4) | 400 V |
| IC2/(IC3-4) | 250 V |
| IC3/IC4 | 250 V |
| Pollution degree | 3 |
| **Safe isolation (reinforced insulation) between** | |
| IC1/(IC2-4) | Overvoltage category III, 600 V |
| IC2/(IC3–4) | Overvoltage category III, 300 V |
| IC3/IC4 | Overvoltage category III, 300 V |
| **Protective impedance device between** | |
| IC1/IC4 | Overvoltage category III, 600 V |
| **Voltage tests (routine test) acc. to IEC 61010-1** | |
| IC2/(IC3-4) | AC 2.2 kV |
| IC3/IC4 | AC 2.2 kV |

### Supply voltage

| | |
|---|---|
| Supply voltage $U_s$ | AC 100…240 V / DC 24…240 V |
| Tolerance of $U_s$ | –30…+15 % |
| Frequency range $U_s$ | 47…63 Hz |
| Power consumption | ≤ 3 W, ≤ 9 VA |

### Monitored IT system

| | |
|---|---|
| Nominal system voltage $U_n$ | DC 0…400 V |
| Tolerance of $U_n$ | +25 % |

### Measuring circuit

| | |
|---|---|
| Measuring voltage $U_m$ | ±12 V |
| Measuring current $I_m$ $R_F$, $Z_F = 0\ \Omega$ | ≤ 110 µA |
| Internal resistance $R_i$, $Z_i$ | ≥ 115 kΩ |
| Permissible system leakage capacitance $C_e$ | ≤ 1 µF |

### Response values

| | |
|---|---|
| Response value $R_{an1}$ | 11…5000 kΩ (1500 kΩ)* |
| Response value $R_{an2}$ | 10…4900 kΩ (1000 kΩ)* |
| Relative uncertainty $R_{an}$ | ±15 %, at least ±2 kΩ |
| Hysteresis $R_{an}$ | 25 %, at least ±1 kΩ |
| Voltage detection $U_{BatH}$ | 4…500 V (400 V) |
| Voltage detection $U_{BatL}$ | 3…499 V (378 V) |
| Voltage detection $U_{CrossH}$ | 4…500 V (345 V) |
| Voltage detection $U_{CrossL}$ | 3…499 V (6 V) |
| Overvoltage detection | 510 V |
| Relative uncertainty $U$ | ±5 %, at least ±0.5 V |
| Hysteresis $U$ | 5 %, at least 2 V |

## Time response

| | |
|---|---|
| Response time $t_{ae}$ at $R_F = 0.5 \times R_{an}$ for the measuring pulse period durations | |
| $T_{MP} = 0.8$ s | ≤ 3.5 s |
| $T_{MP} = 2$ s | ≤ 8 s |
| $T_{MP} = 4$ s | ≤ 16 s |
| $T_{MP} = 8$ s | ≤ 32 s |
| Start-up delay $t$ | 0…10 s (0 s)* |
| Response delay $t_{on}$ | 0…99 s (0 s)* |
| Delay on release $t_{off}$ | 0…99 s (0 s)* |

## Displays, memory

| | |
|---|---|
| Display | LC display, multi-functional, not illuminated |
| Display range measured value insulation resistance ($R_F$) | 1 kΩ …10 MΩ |
| Operating uncertainty | ±15 %, at least ±2 kΩ |
| Display range measured value system voltage ($U_n$) | DC 0…500 V |
| Operating uncertainty | ±5 %, at least ±0.5 V |
| Display range measured value system leakage capacitance at $R_F > 10$ kΩ | 0…9.99 µF |
| Operating uncertainty | ±10 %, at least ± 0.02 µF |
| Password | off / 0…999 (off / 0)* |
| Fault memory alarm messages | on/(off)* |

## Interface

| | |
|---|---|
| Interface / protocol | RS-485 / BMS, Modbus RTU, isoData |
| Baud rate | BMS (9.6 kbit/s), Modbus RTU (selectable), isoData (115.2 kbit/s) |
| Cable length(9.6 kbit/s) | ≤ 1200 m |
| Cable: twisted pairs, shield connected to PE on one side | min. J-Y(St)Y 2 x 0.6 |
| Terminating resistor | 120 Ω (0.25 W), internal, can be connected |
| Device address, BMS bus, Modbus RTU | 3…90 (3)* |

## Switching elements

| | |
|---|---|
| Switching elements | 2 x 1 n/o contacts, common terminal 11 |
| Operating principle | n/c or n/o (n/o)* |
| Electrical endurance | 10.000 cycles |
| Electrical endurance at DC 30 V / ≤ 0.1 A (L/R = 7 ms) | $10^6$ cycles |

| Contact data acc. to IEC 60947-5-1 | |
|---|---|
| Utilisation category | AC-12 / AC-14 / DC-12 / DC-12 / DC-12 |
| Rated operational voltage | 230 V / 230 V / 24 V / 110 V / 220 V |
| Rated operational current | 5 A / 2 A / 1 A / 0.2 A / 0.1 A |
| Minimum contact rating | 1 mA at AC/DC ≥ 10 V |

## Environment/EMC

| | |
|---|---|
| EMC | IEC 61326-2-4 |

| Ambient temperatures | |
|---|---|
| Operation | –25…+55 ºC |
| Transport | –40…+85 ºC |
| Storage | –40…+70 ºC |

| Classification of climatic conditions acc. to IEC 60721 | |
|---|---|
| Stationary use (IEC 60721-3-3) | 3K22 |
| Transport (IEC 60721-3-2) | 2K11 |
| Long-term storage (IEC 60721-3-1) | 1K22 |

| Classification of mechanical conditions acc. to IEC 60721 | |
|---|---|
| Stationary use (IEC 60721-3-3) | 3M11 |
| Transport (IEC 60721-3-2) | 2M4 |
| Long-term storage (IEC 60721-3-1) | 1M12 |

## Other

| | |
|---|---|
| Operating mode | continuous operation |
| Mounting | cooling slots must be ventilated vertically |
| Degree of protection, built-in components (DIN EN 60529) | IP30 |
| Degree of protection, terminals (DIN EN 60529) | IP20 |

| | |
|---|---|
| Enclosure material | polycarbonate |
| DIN rail mounting acc. to | IEC 60715 |
| Screw fixing | 2 x M4 with mounting clip |
| Weight | ≤ 150 g |

## 6.2 Technical data ZE420

### Insulation coordination acc. to IEC 60664-1/-3

| **Definitions** | |
|---|---|
| Measuring circuit (IC1) | L+, L– |
| Control circuit (IC2) | E |
| Rated voltage | 400 V |
| Overvoltage category | III |

| **Rated impulse voltage** | |
|---|---|
| IC1/IC2 | 6 kV |

| **Rated insulation voltage** | |
|---|---|
| IC1/IC2 | 400 V |
| Pollution degree | 3 |

| **Protective impedance device between** | |
|---|---|
| IC1/IC2 | Overvoltage category III, 600 V |

### Monitored IT system

| | |
|---|---|
| Nominal system voltage $U_n$ | DC 0…400 V |
| Tolerance of $U_n$ | +25 % |

### Environment/EMC

| | |
|---|---|
| EMC | IEC 61326-2-4 |

| **Ambient temperatures** | |
|---|---|
| Operation | –25…+55 °C |
| Transport | –40…+85 °C |
| Storage | –40…+70 °C |

| Classification of climatic conditions acc. to IEC 60721 | |
|---|---|
| Stationary use (IEC 60721-3-3) | 3K22 |
| Transport (IEC 60721-3-2) | 2K11 |
| Long-term storage (IEC 60721-3-1) | 1K22 |

| Classification of mechanical conditions acc. to IEC 60721 | |
|---|---|
| Stationary use (IEC 60721-3-3) | 3M11 |
| Transport (IEC 60721-3-2) | 2M4 |
| Long-term storage (IEC 60721-3-1) | 1M12 |

### Other

| | |
|---|---|
| Operating mode | continuous operation |
| Mounting | cooling slots must be ventilated vertically |
| Degree of protection, built-in components (DIN EN 60529) | IP30 |
| Degree of protection, terminals (DIN EN 60529) | IP20 |
| Enclosure material | polycarbonate |
| DIN rail mounting acc. to | IEC 60715 |
| Screw fixing | 2 x M4 with mounting clip |
| Weight | ≤ 150 g |

## 6.3 Connection

| Push-wire terminals | |
|---|---|
| Nominal current | ≤ 10 A |
| Conductor sizes | AWG 24…14 |
| Stripping length | 10 mm |
| Rigid | 0.2…2.5 mm² |
| Flexible without ferrules | 0.75…2.5 mm² |
| Flexible with ferrules with/without plastic sleeve | 0.25…2.5 mm² |
| Multi-conductor flexible with TWIN ferrules with plastic sleeve | 0.5…1.5 mm² |
| Opening force | 50 N |
| Test opening | Ø 2.1 mm |

## 6.4 Standards and certifications

The ISOMETER® was developed in compliance with the standards specified in the Declaration of Conformity.

not for ZE420

### EU Declaration of Conformity

Hereby, Bender GmbH & Co. KG declares that the device covered by the Radio Directive complies with Directive 2014/53/EU. The full text of the EU Declaration of Conformity is available at the following Internet address:

https://www.bender.de/fileadmin/content/Products/CE/CEKO_isoXX425.pdf

### UKCA Declaration of Conformity

Hereby, Bender GmbH & Co. KG declares that this device is in compliance with Radio Equipment Regulations 2017 (S.I. 2017/1206). The full text of the UK declaration of conformity is available at the following internet address:

https://www.bender.de/fileadmin/content/Products/UKCA/UKCA_isoXX425.pdf

## 6.5 Ordering data

### ISOMETER®

| Model | Nominal system voltage $U_n$ | Article number | |
|---|---|---|---|
| | | Push-wire terminals | Screw-type terminals |
| isoBAT425-D4-4 mit ZE420 | DC 0…400 V | B71036327 | |
| isoBAT425-D4-4 | DC 0…400 V | B71036324 | |
| ZE420 | DC 0…400 V | B71036326 | |

### Accessories

| Description | Article number |
|---|---|
| Mounting clip for screw mounting | B98060008 |
| XM420 mounting frame | B990994 |

## 6.6 Change log

| Date | Document version | Valid from software version | State/Changes |
|---|---|---|---|
| 09.2023 | 05 | D0560 V1.xx | Editorial revision<br>• Transfer to SMC incl. new CI and new chapter structure<br>• Better separation of descriptive and instructional texts (function/ operation)<br>Standards: Link to website added.<br>Term: “stop mode” instead of “stop function”<br>Section “Manual self test” and “Stop mode”: Information on interface adapted to German version. |

**Bender GmbH & Co. KG**

Londorfer Straße 65
35305 Grünberg
Germany

Tel.: +49 6401 807-0
info@bender.de
www.bender.de