# CALEC® ST II

## Multi-protocol heating and cooling energy calculator

Swiss Made

## Application

The CALEC® ST II energy calculator can be used to create high-quality meters for heating, air conditioning, refrigeration systems, and plants which use alternative thermal energy. The modular calculator provides a high degree of long-term stability. Flexible communication options simplify integration into energy management and building automation systems.


## Characteristics

- Communication interfaces:
  M-Bus, LON, Modbus, N2Open und BACnet MS/TP
- Metrological approval in accordance with
  2004/22/EC (MID) and PTB K7.2
  (cold, heat/cold combined)
- "Push In" clamping points

## Customer advantages

- Precise energy measurement for all thermal applications in buildings engineering
- Used in cooling and solar heating systems
- Modular configurable
- Efficient connection technology

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# Application

The CALEC® ST II is used for energy metering in split systems which are equipped with passive or active pulsed flow meters and 2-wire or 4-wire Pt100 or Pt500 temperature sensors. Integrated power supplies for flow transmitters simplify the connection of flow meters and make it easy to select the appropriate application for water and other heating or cooling media.

Choose from our wide range of volume-measuring elements. Our advisers will be pleased to help you select the right ones for your needs.

### Obligatory calibration and type-approval

In most countries energy metering systems used for commercial purposes are subject to compulsory verification. The devices comprising the metering system must all possess official pattern approval. CALEC® ST II has been approved according to both the european Measuring Instruments Directive 2004/22/EG and the German PTB K 7.2 directive for cooling meters.

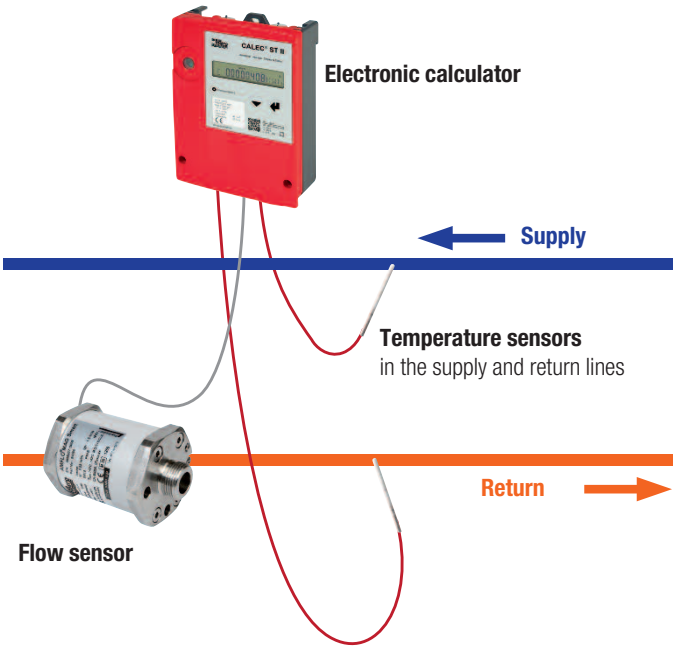
Officially verified heat and cooling meters must be reverified before the verification period has expired. The operator is responsible for compliance with this requirement. (Re-)Verification includes all parts (temperature and flow sensors, calculator) forming the complete heat meter. The plug-in calculator minimises the cost of recalibration as the wiring does not have to be disconnected, and device-specific data remain stored in the configuration memory in the base of the housing.

The “IMP EBS” option makes it even easier to set up devices which require calibration, as the pulse value and installation side can be set on-site.

You can use AMBUS® WIN II, which is available as a free download, for parameterisation, adjustment to new conditions, and to read data from the device.

### Basic function and measuring principle

A heat or cooling meter is composed of the following individually approved sub-assemblies:




Example: Cooling meter

The thermal output (P) of a pipe-conduit network is based on a measurement of the flow temperature, return-flow temperature and volume flow of the heat transfer medium.

**P = Volume rate of flow x (T heat side - T cold side) x k**

| | |
|---|---|
| T heat side: | For heating, flow temperature, for cooling, return temperature |
| T cold side: | For heating, return temperature, for cooling, flow temperature |
| k: | Heat coefficient (function considering temperature and pressure-related characteristics of the heat carrier) |

Energy can be determined by integration of output. The formula shows that, in order to meter energy, the specific heat and density of the heat transfer medium must be expressed in relation to the temperature of the counter mechanism. The following factors (among others) also have a decisive influence on metering accuracy:
- The static accuracy and stability of the temperature-measuring procedure
- The counter cycle of the temperature-measurement system, and the volume flow used to detect dynamic factors

CALEC® ST II is ideally equipped for use in demanding metering tasks, thanks to:
- The use for temperature-measuring purposes of a high-resolution AD converter (20 bit) designed with long-term stability in mind and equipped with self-calibration and filter functions
- Short counter-cycle (mains version: 1 s)
- The ability to use high-resolution mechanical or electronic flow indicators operating at pulse frequencies of up to 200 Hz (mains version)

NAMUR transmitters or electronic transmitters with external power supply can be powered directly from the CALEC® ST II.

## Flow-rate measurement

The system is compatible with all standard flow meters which use a pulse output. The pulse value should be set as low as possible if continuous measurement or high-resolution energy metering is required.
When running on battery power, the CALEC® ST II can operate with contactors working at pulse frequencies of up to 6 Hz. The mains-powered CALEC® ST II can operate with contactors up to 20 Hz and electronic transmitters (NAMUR, etc.) with pulse frequencies of up to 200 Hz.

The flexible calculation of heat capacity and density facilitates accurate energy measurement, not only for water circuits, but also for a variety of other heating or refrigeration media.

The point of installation of the flow meter is crucially important, because the volume-to-mass conversion is based on the temperature detected at this point.
It is preferable to fit the flow transmitter to the section of the line where the temperature is closest to room temperature.

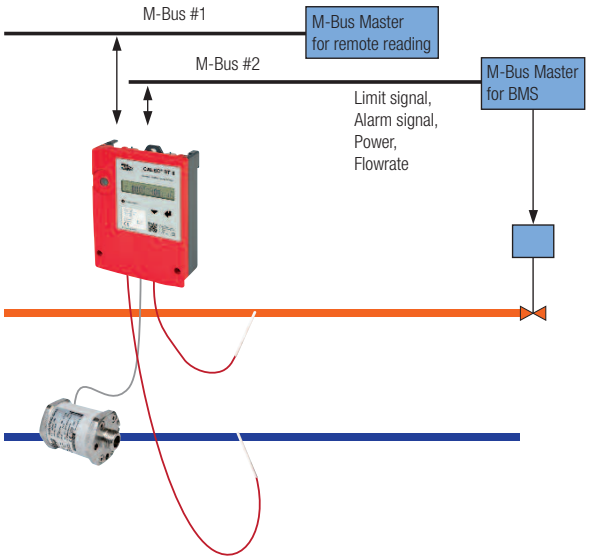
## Temperature measurement

The CALEC® ST II is fitted with two highly-accurate temperature-measurement inputs, which are each connected to type-approved, paired temperature sensors in two- or four-wire configuration. The planning of systems should conform to heat meter standard EN 1434, parts 2 and 6. EN 1434-4 stipulates that only sensors of the same design and length should be paired together.
The counter mechanism is available in either Pt 100 or Pt 500 configuration.

Thermal energy is measured from a temperature difference from dT above (respectively below) 0 K. The CALEC® ST II is the ideal solution for air-conditioning or cooling installation when used with appropriate temperature sensors and flow meters for cooling.

# Data communication

The CALEC® ST II is fitted with two separate interfaces for data transfer to higher-level systems.
These two interfaces can be configured as M-Bus, LON TP-F10, Modbus RTU, N2Open, BACnet MS/TP, or any combination of the above.




## M-Bus Interface

The M-Bus has established itself as the standard for meter reading as it has been standardised in EN 13757, and offers a variety of other features.
Advantages include:

- easy installation
- high cost-effectiveness
- multi-vendor capability.

Not only standard data such as meter readings and current values can be read out over the M-Bus interface, but also all additional data available from the device, for example billing and logger values. With CALEC® ST II prrimary addresses and baud rates can be set with the operating keys, eliminating the need for a PC when commissioning the system.

The M-Bus is a single master bus, i.e. a slave can usually only communicate with a master.
However, sometimes it can also be necessary to transmit data to two different M-Bus masters. The CALEC® ST II provides a simple solution as the device is equipped with two configured interfaces.

## LON interface

A LON network can combine BMS and meter readout in one system. LON (Local Operating Network) is a multi-master system with intelligent nodes which can use different transmission media. For CALEC® ST II a LON interface (FTT-10A) for transmissions over twisted pair cabling is available. An outstanding feature of the LON technology is its interoperability which guarantees that the Building automation remains operational beyond the service-life of its individual components. CALEC® ST II is the first energy calculator to be certified according to LonMark® 3.4. This means lower costs and reduced delivery date risks for system integration. LonMark® 3.4 certification means, among other things:

- Assurance of communication functionality and data availability
- Low integration costs since standard tools can be used and all features required by LonMark® are available (object library, XIF files, service LED, service key, etc.).

## Modbus RTU interface

The Modbus interface allows direct connection of CALEC® ST II to a Modbus controller. The Modbus protocol as de facto standard in control and building management systems is widely used since it is an open protocol (www.modbus.org). It is based on a master/slave architecture and allows for a simple system integration by means of a mapping table. Modbus RTU uses the physical layer of the RS485 interface.

## N2Open interface

CALEC® ST II can communicate directly with N2Open controllers (e. g. from the JCI company ) by means of the N2Open interface. N2Open also uses the physical layer of the RS485 interface.

## BACnet MS/TP interface

BACnet MS/TP is now a widely-used open standard in building automation. The CALEC® ST II with BACnet MS/TP interfaces facilitates integration into BACnet networks without the use of gateways.  The physics of the RS485 interfaces is used for transmission.

# Digital inputs and outputs

The CALEC® ST II can be fitted with two digital-signal interfaces, which can be configured – by means of a switch – as either inputs or outputs. These signals can be used to process counter impulses, or to warn when limit values have been exceeded, or to transmit alarm messages to the building-management system.

### Limit-value signals

Digital output signals can be used to emit limit-value monitoring signals. The following parameters can be monitored in this respect:

| Factor | Display |
|---|---|
| Temperature on “hot” side | t-hot |
| Temperature on “cold” side | t-cold |
| Temperature difference | t-diff |
| Output | POUEr |
| Flow | FLOU |
| Mass flow | MAS-FLOU |
| C-factor | C-Factor |
| Density | dEnSitY |

**1. Function of one-sided limit-value monitoring (Limit1)**

If an adjustable maximum limit is exceeded **or** if the reading fails to reach an adjustable minimum, the output signal switches over, hysteresis (0 - 10 %) and control direction are selectable as required. While the excess-reading remains in force, the meter (showing “Cnt” for “counter”) calculates the total duration of the error for inspection purposes.

**2. Function of two-sided limit-value monitoring (Limit2)**

If an adjustable maximum limit is exceeded **and** if there is failure to reach an adjustable minimum, the functions operate in a similar way to those of Limit1.

### Alarm message

The microprocessor monitors the temperature sensor and internal functions, and displays any resulting error messages. This information can also be used to generate an alarm signal via the digital outputs.

# Analogue outputs

CALEC® ST II can be equipped with two passive analogue outputs. An external power supply is required for operating purposes. The outputs are electrically isolated from each other and from the counter mechanism. The current per channel can be adjusted within a range of 0 - 20 mA or 4 - 20 mA. The following readings can be emitted as current signals:

| Reading | Display |
|---|---|
| Temperature on “hot” side | t-hot |
| Temperature on “cold” side | t-cold |
| Temperature difference | t-diff |
| Output | POUEr |
| Flow | FLOU |
| Mass flow | MAS-FLOU |
| C-factor | C-Factor |
| Density | dEnSitY |

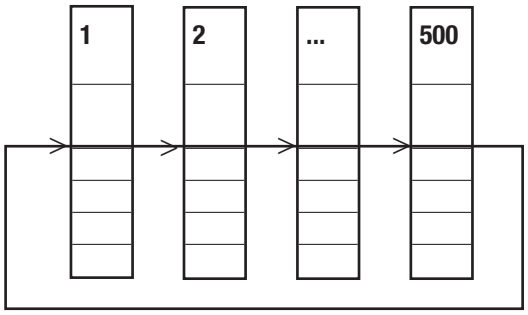
# Additional functions

### Billing date values

With the 12 freely programmable billing date values, the indexes can be memorized (e.g. monthly) for defined dates and consulted at any time.

### Data logging
The CALEC® ST II can record up to 500 data records in a ring buffer at fixed intervals.

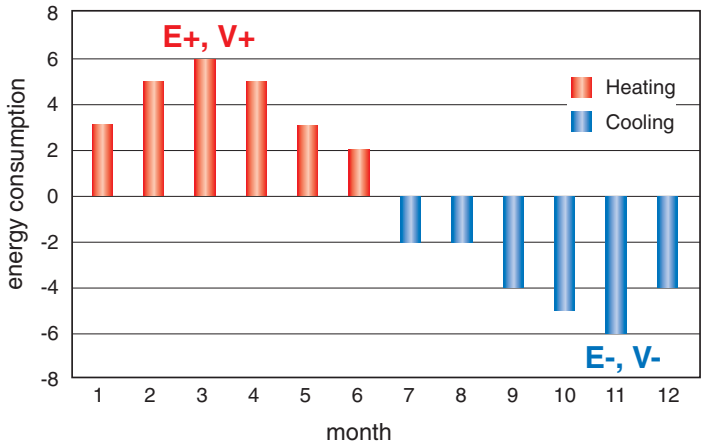
| Factor | Display |
|---|---|
| Date | - |
| Energy | Total |
| Volume | Total |
| Auxiliary meter 1 | Total |
| Auxiliary meter 2 | Total |
| Output | Peak value |
| Downtimes | Total |
| Alarm hours | Total |




### Simultaneous readout
In a plant with many meters, a considerable time difference between readings can occur if these are read out sequentially. CALEC® ST II avoids this problem with the ”Freeze“ command. A broadcast command instructs all meters simulateneously to store the required value after which they can be read out sequentially.

### Low-flow OFF function
The system is factory-adjusted to carry out an energy calculation as soon as a temperature difference of >0 (when measuring heat) or <0 (when measuring cold) is detected. If, for example, a circulation conduit carries, over a long period of time, large quantities of heat transfer medium with a very low temperature difference, this can lead to significant reading errors in temperature measurement. The so-called “lowflow OFF function” can be activated to avoid this, ensuring that energy is only detected when a pre-defined temperature difference is exceeded.

## Special functions




### Energy metering in heating/cooling systems
The “bi-directional energy metering” (BDE) option allows emitted energy to be metered even in twin-conduit networks that perform a combined heating and cooling function. The measurement readings for heating and cooling are recorded separately for their corresponding cost-calculation purposes.

### Recording of "heat return"
The "Tarif Return Limit" (TGR) option can be used to set a programmable limit for the return temperature of the heat quantity. If this limit is then exceeded, the flow is "returned" to the supply network and thus reduces efficiency.

### Heat carriers with frost protection additives
The below-freezing temperatures involved in running a refrigeration plant require the use of additional frost protection. This poses an insurmountable problem for many conventional heat meters, as has been investigated in detail in such publications as PTB Report PTB-ThEx-24 of June 2002.

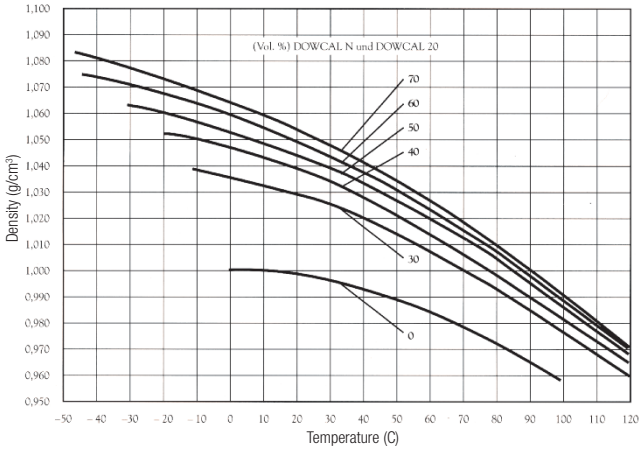
The “Glycol-based heat transfer medium” option available with CALEC® ST II ensures that metering is accurate even in these situations, as energy and volume can be calculated with a sliding scale of values for density and heating capacity for each temperature, independently of that temperature. CALEC® ST II gives accurately polynomial readings for the physical characteristics of 11 widely-used heat transfer liquids with respect to concentration and temperature (see following table).

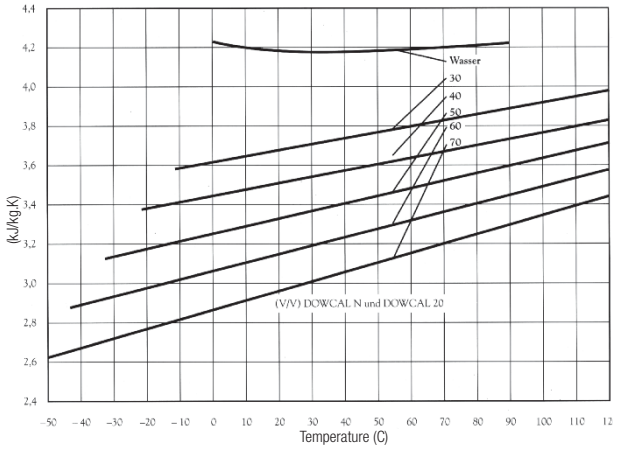
Only the heat transfer medium and concentration are established at start-up (see table):

| Medium [4] | Display | Concentration | Temperature range | Manufacturer | Type | Application/observations |
|---|---|---|---|---|---|---|
| Antifrogen N | AntifroN | 20 - 60 % | - 120 °C [1] | Clariant | E [2] | Confirms to DIN 4757-1; toxicity class 4<br>For cooling, solar, heating and heat pump systems<br>Low viscosity, requires lower |
| Antifrogen L | AntifroL | 20 - 60 % | - 120 °C [1] | Clariant | P [3] | Not harmful to health<br>For pharma-sector, food use |
| Tyfocor | Tyfocor | 20 - 60 % | - 120 °C [1] | Tyfocor | E | See type E |
| Tyfocor-L | TyfocorL | 20 - 60 % | - 120 °C [1] | Chemie | P | See type P |
| DowCal 10 | DOUCAL10 | 30 - 70 % | - 120 °C [1] | Dow | E | See type E |
| DowCal 20 | DOUCAL20 | 30 - 70 % | - 120 °C [1] | Dow | P | See type P |
| Glythermin P44 | GLYTHP44 | 40 - 80 % | - 100 °C [1] | BASF | P | FDA-approved in USA, corrosion protection less effective<br>For pharma-sector and food-production plants |
| Temper -10 | TEMPER10 | 100 % fix | -10...150 °C | Temper | S | Ready-to-use saline solution |
| Temper -20 | TEMPER20 | 100 % fix | -20...150 °C | Temper | S | Not harmful to health, (also for pharma and food sectors)<br>Biodegradable, water-protection class 1 |
| Temper -30 | TEMPER30 | 100 % fix | -30...150 °C | Temper | S | Low viscosity |
| Temper -40 | TEMPER40 | 100 % fix | -40...150 °C | Temper | S | High heat-transfer capacity |
| Additional products are available on request | | | | | | |

1) Minimum temperature depends on concentration -40 to 0°C
2) Based on ethylene glycol
3) Based on propylene glycol
4) All names are registered trademarks of their respective manufacturers.

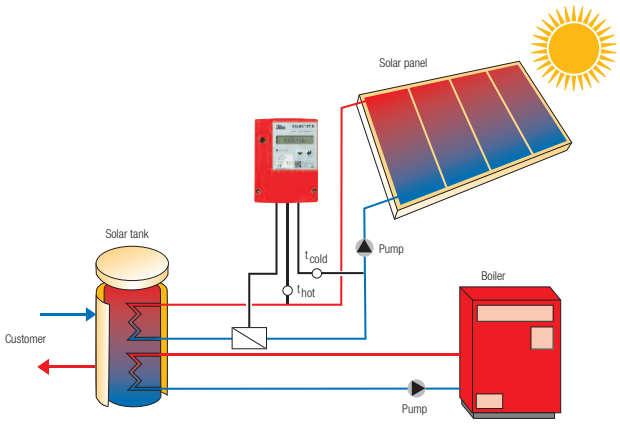
The following graphs give an example of how the dependency of temperature on specific heat and density can have an important bearing on the final calculation.




DOWCAL is a registered trademark of the Dow Chemical Company

## Solar-powered thermal systems




Solar thermal systems likewise pose demanding tasks for energy metering with respect to temperature range and heat transfer medium.

The **"Glycol-based heat transfer medium" (GLY)** option available with CALEC® ST II also offers an excellent solution in these cases (further details in the section on refrigeration systems).

**CALEC® ST II Flow**
The CALEC® ST II Flow configuration is designed for flow-rate measurement purposes. Temperature measurement (“hot” and “cold” side) is disabled in this configuration, i.e. no temperatures are detected or displayed. CALEC® ST II Flow uses the accumulated pulse signals from the flow detector to calculate the current flow-rate reading. These measurement readings can be sent to the display, the analogue outputs and/or the M-Bus, Modbus, LON, BACnet or N2Open interface for reading or further processing.

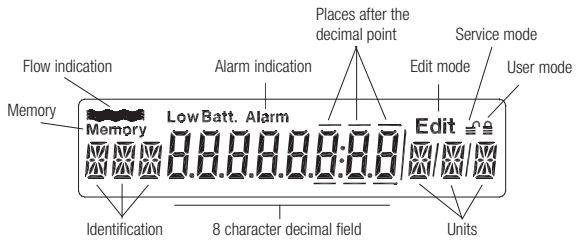
# CALEC® ST II configurations

We will gladly advise you about the available variants.

# Controls and displays

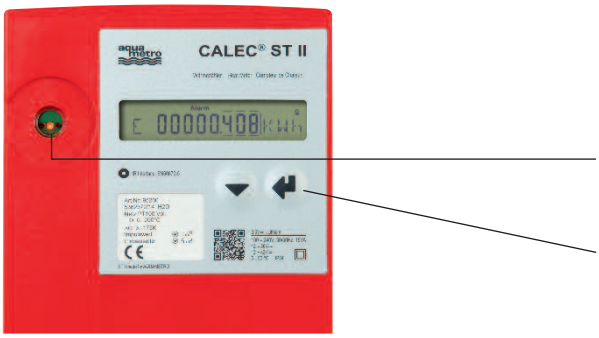
Thanks to their logically-structured functioning, all setting adjustments on the CALEC® ST II can be carried out locally and without the use of additional equipment.

### Multi-function display

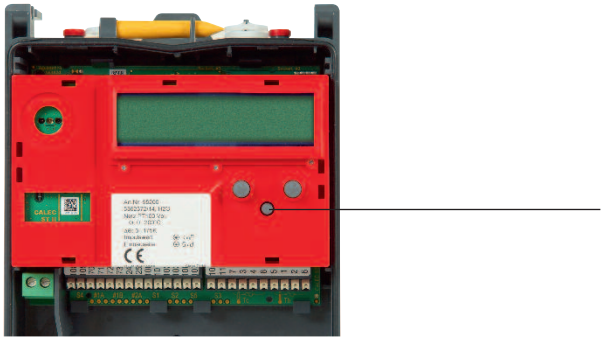



The multi-function display shows the eight-digit meter reading, along with symbols and short texts for user operation purposes.

Alarm conditions are indicated by a display text and a flashing red LED in the centre of the optical interface.



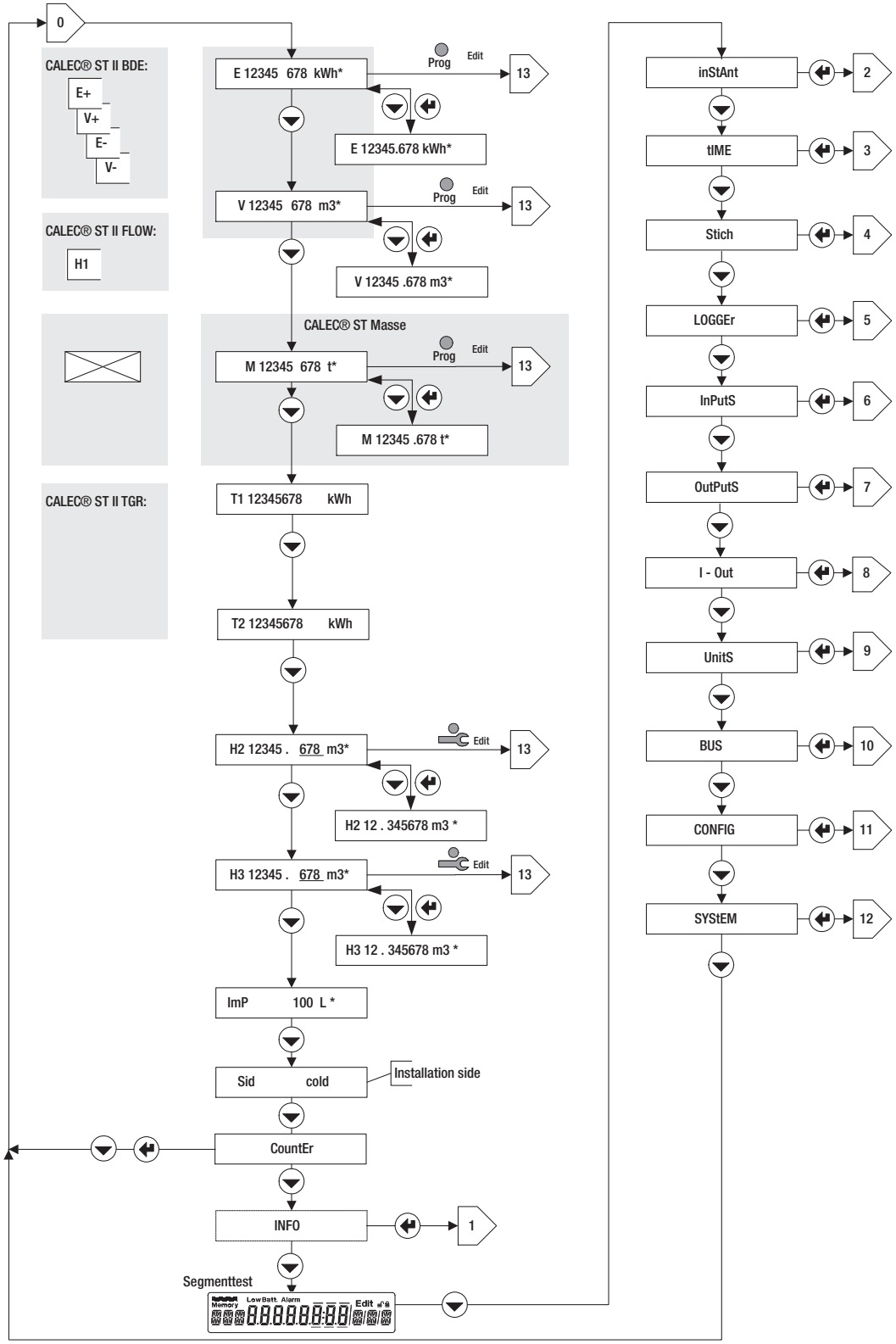

When the device is in operation and the housing is closed the displayed values can be selected using two keys:




Under the cover, and thus protected by the lead seal, is the Service button, which allows additional service information to be displayed and adjustments to be carried out.

For professional use, the PC software AMBUS® Win II is available to download from our website. It provides effective support with startup and data analysis.

The following graph shows the information available at various points on the main operating flowchart, along with the short text designations of various sub-functions:




| Display: | Description: |
|---|---|
| Info: | Error message display |
| InstAnt: | Current readings for temperature, output, flow rate, C-factor, density |
| Time: | Date and time |
| Stich: | Critical-date values |
| LoGGer: | Data-log memory settings |
| InPuts: | Settings and status of signal inputs |
| OutPuts: | Settings and status of signal outputs |
| I - Out: | Settings and status of the mA signal outputs |
| UnitS: | Measurement-unit settings |
| BUS: | M-Bus settings |
| CONFIG: | Further settings (e.g. for glycol-based heat transfer medium) |
| SYStem: | System data (e.g. firmware version) |

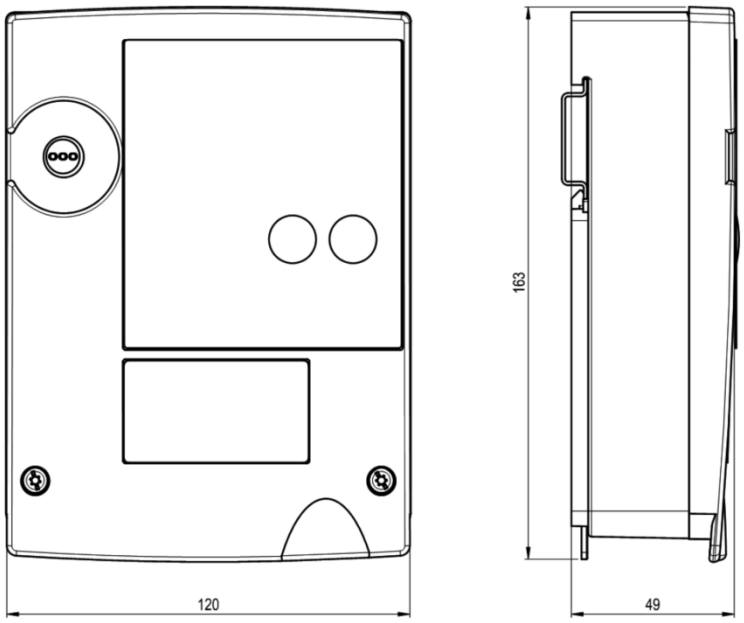
# Plug-in calculator module

The energy calculator is housed in a plug-in module. The bottom of the housing (which contains the field wiring) does not have to be removed when recalibrating the unit. Furthermore, device-specific data are retained in the configuration memory (EEPROM) in the bottom of the housing (except parameters that are subject to calibration, like impulse value and installation side).

# Housing, dimensions

**Housing**
Lower section with connection terminals, computer module and cover.

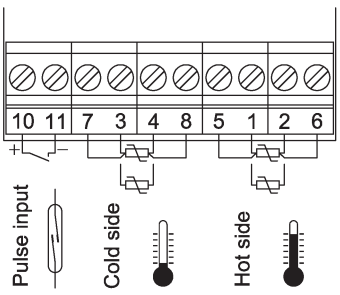
**Installation**
DIN-standard rail or three-point attachment directly to the wall.



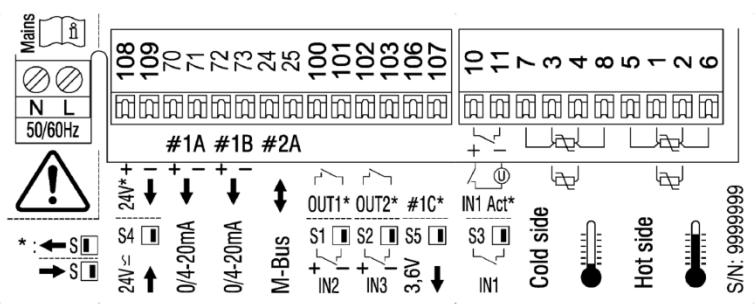

# Electrical connections

The wiring layout used depends on device configuration and applicable options. The factory-configured state of the unit is shown on the diagram attached to the inside of the housing cover.

**Battery-powered version (Example)**




**Network version (with M-Bus and low-voltage power supply) (Example)**




# Approval permits

European approval in accordance with the Measuring Instruments Directive (MID) 2004/22/EC, CH-MI004-14020
Approval 22.75/14.xx as a cooling meter in accordance with PTB K7.2.

# Technical data and standards

The following tables contain information on the technical data of the available functions. Please refer to the price list for possible combinations.

| **Standards** | |
|---|---|
| CE directives | 2004/22/EC Measuring Instruments Directive (MID) |
| | 2004/108/EC Electromagnetic compatibility (EMC) |
| | 2006/95/EC Low voltage (LVD) |
| | 2003/108 Waste Electrical and Electronic Equipment (WEEE) Directive |
| Standards | EN 1434, EN 61000-6-1, EN 61000-6-2, EN 61010, DIN 43863-5 |

| **Housing and operating conditions** | |
|---|---|
| Dimensions | W x H x D = 120 x 163 x 49 mm |
| Ambient temperature | +5...55 °C, EN 1434 class C |
| Storage temperature | 0...60 °C |
| Humidity | Max. 95% rel. humidity (non-condensing) |
| Operating altitude | Up to 2,000 m above sea level |
| Protection rating | IP 54 |
| Terminals | 1.5 $mm^2$ spring terminals, Power connection 2.5 $mm^2$ screw terminals |

| **Basic data for calculator** | |
|---|---|
| Temperature measuring range | 0...+200 °C (heat carrier: water)<br>-40...+180 °C (special heat carrier) |
| Temperature difference | 0...190 K, Approval 3...190 K, on demand 2...190 K |
| Temperature sensor | Pt100 or Pt500 in accordance with IEC 751 paired in accordance with EN 1434, 2-wire or 4-wire connection. Max. sensor cable length 2-wire connection 10 m, 4-wire connection 15 m. |
| Temperature measurement resolution | 20-bit resolution, typical ±0.005 K (Ta = 5...55 °C) |
| Installation side | Hot or cold side |
| Pulse value of the flow sensor | 0.001...9999.999 litres |
| Pulse values and units for auxiliary inputs and contact outputs | Volume: 0.001...9999.999 ml, l, $m^3$ , GAL<br>Energy: 0.001...9999.999 Wh, kWh, MWh, MJ, KBTU |
| Error limits | Better than those required for calculators in accordance with EN 1434-1. Suitable for combined class 2 heat meters in accordance with EN 1434-1 when used with suitable volume metering units. |
| Optical interface | IEC 870-5, M-Bus protocol |

| **Display** | |
|---|---|
| Display units: volume | $m^3$, US Gal |
| Display units: energy | kWh, MWh, MJ, GJ, KBTU, MBTU |
| Data backup in the event of a power failure | In EERPOM >10 years |
| Data logger | 500 values from all readings with a time stamp, stored in ring memory<br>Logger interval: 1 min, 1 hour, 1 day, 1 week, 1 month |

| **Additional functions** | |
|---|---|
| Adjustable low flow cut-off (SMU) | Function for stopping the energy calculation when the temperature difference is too low<br>ΔT SMU adjustable ΔT = 0 - 2.99 K |
| Limit-value monitoring | One-sided or two-sided, hysteresis 0 - 10%, action of the output signal is selectable |

| **Battery-powered version** | |
|---|---|
| Power supply | 3.6 V lithium battery, service life >6 years at ambient temperature of <45 °C |
| Calculation cycle | 20 s |

| **Mains version** | |
|---|---|
| Power supply | 100 - 240 V AC, 50/60 Hz, max. 15 VA (in accordance with EN 1434)<br>12 - 42 V DC or 12 - 36 V AC, max. 1 VA, (in accordance with EN 1434) |
| Calculation cycle | 1 s |
| Backup battery | 3.6 V lithium battery |

| **Low-voltage power supply for flow transmitter** | | |
|---|---|---|
| | Terminals 108/109 | Terminals 106/107 |
| Supply voltage | 24 V DC, max.150 mA, el. isolation max. 48V V DC | 3.6 VDC, max. 2 mA |
| Flow transmitter | e.g. AMFLO® MAG Smart or active sensors | e.g. AMFLO® SONIC UFA 113 |

| **Pulse inputs and outputs** | | | | |
|---|---|---|---|---|
| Main input #1 (10/11) | Connecting a pulse generator according to NAMUR, with potential-free contact (reed relay) or SSR (solid state relay), or for active sensors with the following values. | | | |
| | Input passive | | Input active | |
| | Open-circuit voltage | 8 V | Voltage range | 3...48 VDC |
| | Short-circuit current | 8 mA | Current signal | > 2 mA |
| | Switching level | <1.5 mA, >2.1 mA | Reverse polarity protection | -48 V |
| | Min. OFF (t off) | 20 Hz 20 ms | Electrical isolation | 48 V |
| | Min. ON (t on) | 20 Hz 3 ms | Min. OFF (t off) | 20 Hz 20 ms |
| | Min. OFF (t off) | 200 Hz 2 ms | Min. ON (t on) | 20 Hz 3 ms |
| | Min. ON (t on) | 200 Hz 300 µs | Min. OFF (t off) | 200 Hz 2 ms |
| | Input capacity | 20 nF | Min. ON (t on) | 200 Hz 300µs |
| Switchable input and output<br>Output #1/ input #2 (100/101) | Input | | Output | |
| | Open-circuit voltage | 8 V Max. | Contact rating | 48 VDC, 100 mA |
| | Switching level | <1.5 mA, >2.1 mA | Electrical isolation | 48 V |
| | Min. OFF (t off) | 20 Hz 20 ms | Contact resistance (on) | <30 ohms |
| | Min. ON (t on) | 20 Hz 3 ms | Contact resistance (off) | >10 MOhm |
| | Min. OFF (t off) | 200 Hz 2 ms | Pulse frequency | max. 4 Hz |
| | Min. ON (t on) | 200 Hz 300 µs | Pulse width | 100 ms |
| | Input capacity | 20 nF | | |
| Switchable input and output<br>Output #2/ input #3 (102/103) | Input | | Output | |
| | Open-circuit voltage | 8 V | Contact rating | 48 VDC, 100 mA |
| | Short-circuit current | 800 µA | Electrical isolation | 48 V |
| | Switching level | <1.4, >3.2 kOhm | Contact resistance (on) | <30 ohms |
| | Pulse length t off : | 20 ms | Contact resistance (off) | >10 MOhm |
| | Pulse length t on: | 3 ms | Pulse frequency | max. 4 Hz |
| | Max. frequency | 20 Hz | Pulse width | 100 ms |
| | Input capacity | 20 nF | | |

| **Interface options for battery and mains versions** | |
|---|---|
| **M-Bus** | **Factory settings** |
| M-Bus Interface | in accordance with EN 13757-2/-3 |
| Addresses | Primary address: 0<br>Secondary address: Serial number |
| Baud rate | 2400 Baud |

| **Options for mains version** | |
|---|---|
| **Modbus RTU** | **Factory settings** |
| Physical layer and address | RS 485, / address: 1 |
| Baud rate | 19200 |
| Address range (slave) | 1...247 |
| Parity | Even |
| Function code | 03: Read holding register |
| **LON Interface** | **Factory settings** |
| Type | LON TP-FT 10 free topology (2-wire twisted pair), certified in accordance with LonMark® 3.4 |
| Baud rate | 78 kBaud |
| Maximum bus length | 500 m / 2,700 m with/without termination resistors, 64 nodes per segment |
| **BACnet MS/TP** | **Factory settings** |
| Physical layer and AMT ID | RS 485 / ID: 431 |
| BACnet device profile and instance | B - ASC / the last 5 digits of the serial number |
| BACnet MAC address | The last 2 digits of the serial number |
| Baud rate and mode | Automatic / master |
| **N2Open** | **Factory settings** |
| Physical layer and address | RS 485 / address: 1 |
| Baud rate | 9600 |
| **2 analogue outputs** | |
| Output signal | 4...20 mA or 0...20 mA |
| Supply voltage | 6...24 VDC |
| Electrical isolation | Max. 48 VDC |
| Maximum resistance | ≤ 837 ohms at 24 VDC, 0 ohms at 6 V |
| Maximum transformer error | 0.15% of measured value + 0.15% of end value |



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