TEMA4G

Energy measuring solution for on board trains

Product description

Versions

Version	Date	Evolution
V 0.2	2021-03-31	Draft of TEMA4G description, EN 50463:2017 compliant product
V 1.0	2021-04-16	1st release
V 2	2021-08-06	Pictures updated (page 1 and chapter 2.10)
V 3	2021-11-18	Fig.6 connector description + No system change reported in the logbook (p.7)

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1 Product description

Energy meter and data communication device integrated in a metal box.

1.1 General technical description

The TEMA4G box is an energy measuring solution for energy measurement on board trains. The energy meter EM4TII+ and the communication device PEMG are installed and connected in a metal box.

The TEMA4G fulfills the requirements of the EN 50463 (1-4):2017 and the EU directive 1302/2014/EU in accordance with Commission Implementing Regulation (EU) 2018/868 and (EU) 2019/776.

The box consists of a metal housing and a transparent, plastic cover, which can be removed. The housing has a rectangular aperture for the cables from the voltage and current sensors, the power supply and the antenna.

The data communication between the energy meter and the data communication device is realized by an RS232 interface.

The PEMG is powered by the energy meter.

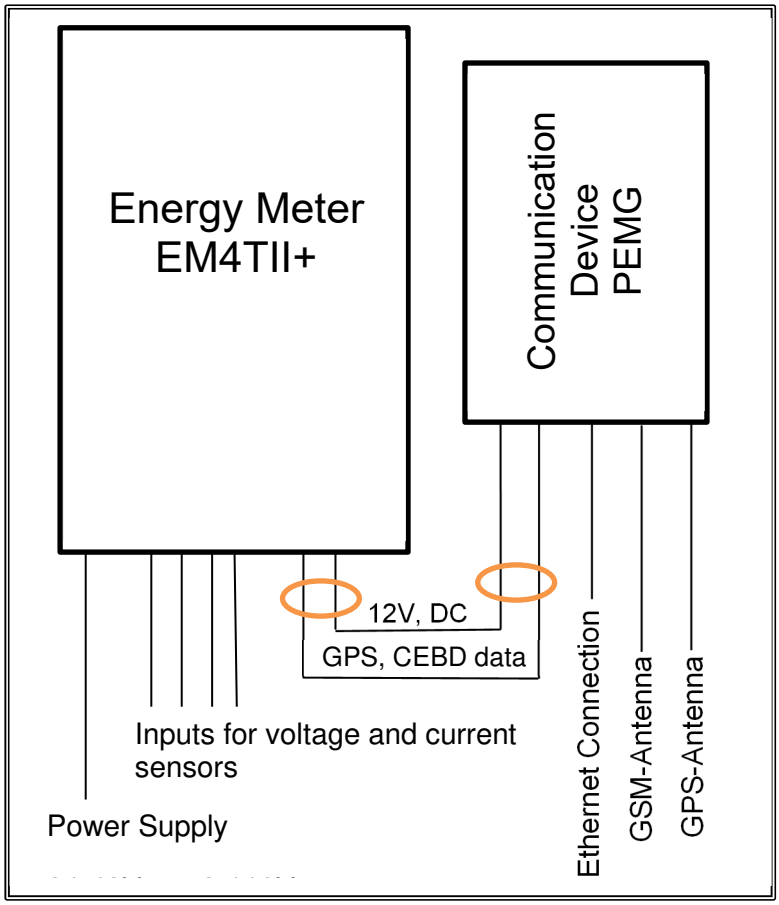


Figure 1: Scheme of TEMA4G box

1.2 General requirements

The TEMA4G fulfills all requirements for the ambient conditions defined in EN 50463-1:2017.

This includes the EMC requirements according with EN 50121-3-2 and the vibration and shock requirements according to EN 61373.

The TEMA4G is designed for an ambient temperature of -40°C to 85°C. It fulfills the fire protection requirements according to EN 45545-5.

1.3 Dimensions of the TEMA4G box

The dimension and the mounting points are as follows:

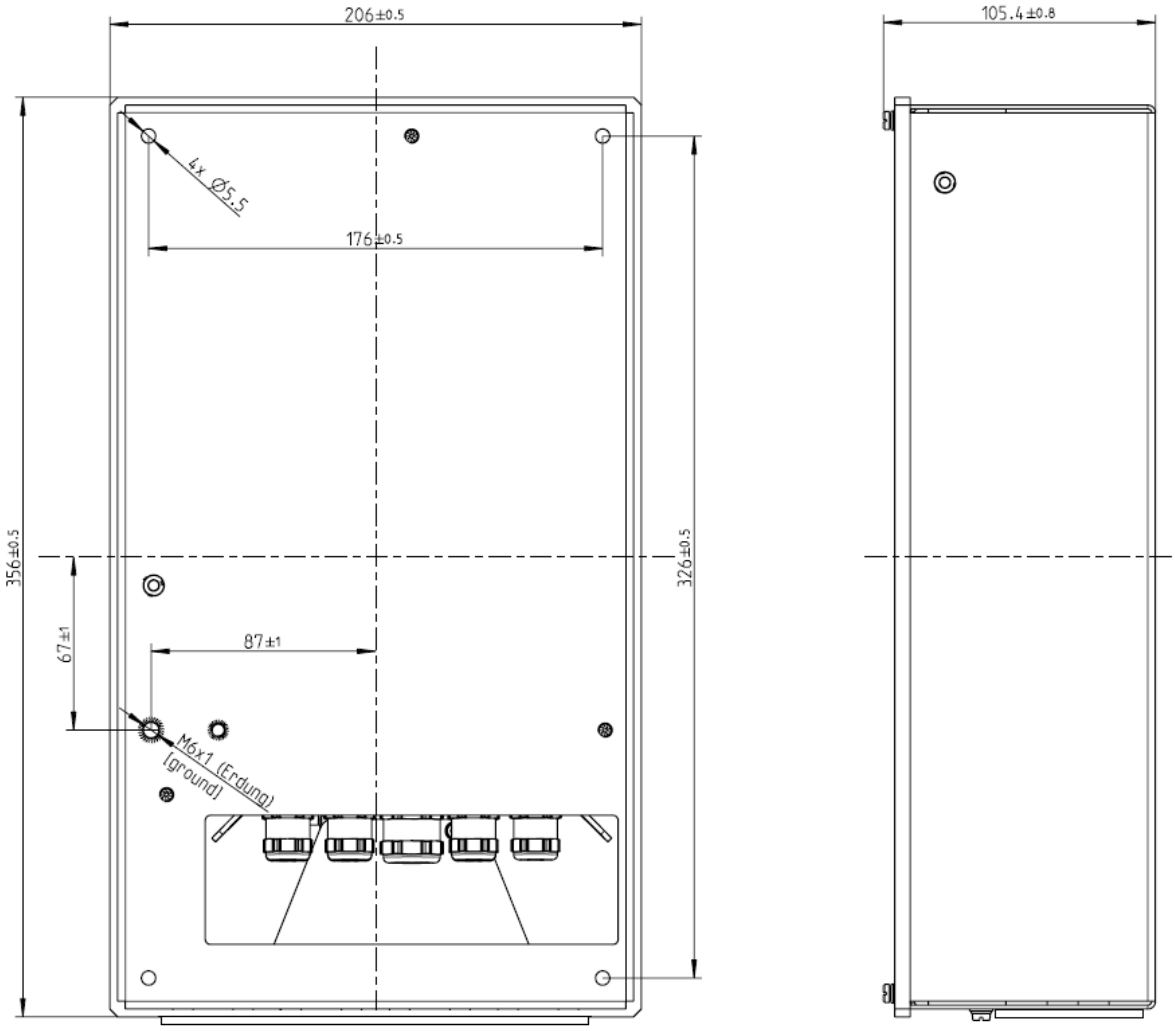


Figure 2: Dimensions TEMA4G

On the connection side a rectangular opening is provided. The aperture is protected with edge protections on all four sides.

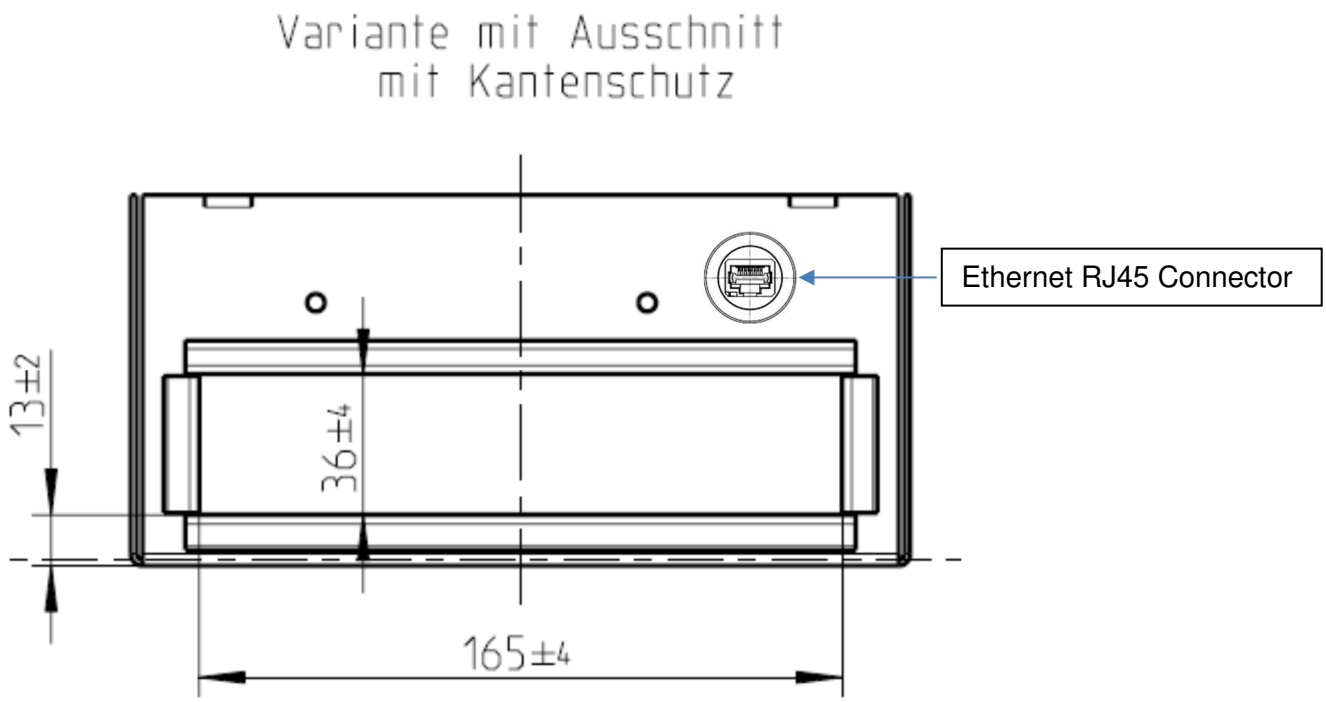


Figure 3: Rectangular opening with edge protection

2 Energy meter EM4TII+

2.1 General technical description

The EM4TII+ is a single-phase energy meter as per EN 50463-x:2017 and thus meets the requirements of the EU directives 1302/2014/EU in accordance with Commission Implementing Regulation (EU) 2018/868 and 2019/776.

The EM4TII+ processes signals from transformer-based and electronic transducer systems for current and voltage and generates a load profile from the energy values they calculate.

The load profiles are recorded in datasets with a period length of 5 minutes (other period lengths available on request). These datasets contain the date, time, and events (generating additional load profile) together with the primary energy (delta) values and the location coordinates, as defined in EN 50463-3:2017. The measured energy data consists of consumed and regenerated active and for AC reactive energy in separate registers and is stored in the load profile (for 5-minute period length) for at least 300 days.

The energy values are generated separately from the signals from 2 AC and 2 DC input channels (U and I in each case). In the process the highly precise measurement of energy values is achieved using the digitally sampled converter signals and thus makes for the highest degree of temperature and long-term stability.

The EM4TII+ is also optionally available for DC measurement in a design with 1 voltage input and up to 3 current inputs which records the energy consumption on vehicles with more than one current consumption points.

The EM4TII+ is suitable for use in multi-system vehicles. It can be used on 25 kV 50 Hz and 15 kV 16.7 Hz as well as 750 V DC, 1.5 kV DC and 3 kV DC. A system change is detected by the energy meter and saved in the load profile.

As well as the load profiles special events can be saved in a logbook, as per EN 50463-3:2017. This includes, for instance, the activation and deactivation of the supply voltage, synchronization of the time and changing the parameters important for energy calculation.

In addition, the identification data on the EM4TII+ for the vehicle (consumption point ID) or the train number, for instance, can be stored and if necessary, read out separately. The illuminated display on the EM4TII+ shows a rolling display of all the relevant energy and status information without it being necessary to activate a mechanical or optical key.

In the TEMA4G the RS232-data-interface of the EM4TII+ is connected to the RS232-interface of the PEMG.

The supply voltage for the EM4TII+ can be selected between 24 V – 48 V and 72 V -110 V as per EN 50155.

2.2 Traction supply systems

The energy meter is designed to be used on all traction supply systems detailed in EN 50163:

- AC 15 kV, 16,7 Hz
- AC 25 kV, 50 Hz
- AC 25kV, 60 Hz
- DC 3 kV
- DC 1,5 kV
- DC 750 V
- DC 600 V

In addition, the energy meter can also be used on the not EN 50163-compliant traction system of DC 1.2 kV. This voltage system will not be detected.

In case the energy meter is of multi-system-type, the change of the traction supply system is detected at AC-systems based on the frequency and at DC-systems based on the voltage level.

The consumed respectively the regenerated energy delta values for different kind of traction supply systems are stored in the same register. This is valid for AC as well as for DC. The correlation of the energy values to the different traction supply systems can be done by using the traction system type flags in the load-profiles (CEBD).

2.3 Energy calculation

The EM4TII+ is a primary energy meter. The primary energy is calculated from the analogue values of voltage and current input channels (corresponds to the secondary outputs of the voltage and current sensors) multiplied by the ratio of the voltage and currents sensors (k-factor).

The energy meter is a 4-quadrant-meter. It provides four energy registers, consumed and regenerated active energy and for AC consumed and regenerated reactive energy (OBIS-codes 1.8.0. 2.8.0, 3.8.0, 4.8.0). The energy register values are index values.

2.4 Time reference

The energy meter includes a battery buffered real time clock (RTC). In the TEMA4G setup the clock is synchronized with the time reference included in the location signal (GPS). If no GPS is connected to the EM4TII, alternatively the clock can be set with a programming command.

The clock uses solely UTC-time.

The battery has a lifetime of at least 10 years and should be replaced latest at the end of this time respectively when the energy meter must be re-verified.

2.5 Accuracy

The energy meter fulfills accuracy class 0,5R in accordance with EN 50463-2:2017 for all specified traction supply systems.

2.6 Compiled energy billing data

The energy meter produces the compiled energy billing data (CEBD) in accordance with EN 50463-3:2017.

The CEBD data assembled and stored in the energy meter includes the following data:

- Time data
- Time reference period
- Energy data (delta values)
- Location data
- Status word (indicates events)
- Consumption Point ID
- Quality flags
- Traction system type flag in accordance with EN 50463-3:2017

In accordance with EN 50463-3:2017, the time reference period (TRP) is set to 5 minutes. But it is also possible to set other values. In case of events the energy meter will record additional load profile with a time stamp of the event.

The energy data consumed and regenerate active energy and, in case of AC, consumed and regenerate reactive energy, are stored as delta values.

The compiled energy billing data are stored in a memory, with a memory depth of at least 300 days for 5-minute period length.

2.7 Logbook

The energy meter EM4TII+ contains a logbook, which logs the following events:

- Power-down of supply voltage
- Power-up of supply voltage
- Modification of a settable configuration (CPID, ….)
- Deletion of CEBD memory
- Deletion of logbook
- Device clock has been set / synchronized
- Detection of device error

2.8 General data

2.8.1 Technical data

Weight:	4,3 kg
Maximum power consumption:	9 W, max. 3 W by the energy meter itself and max. 6 W by the communication device (typical 3 W)
Power supply:	see clause 2.11

2.8.2 Mechanical features

The dimensions and the fastening holes of the energy meter are shown in the following figure:

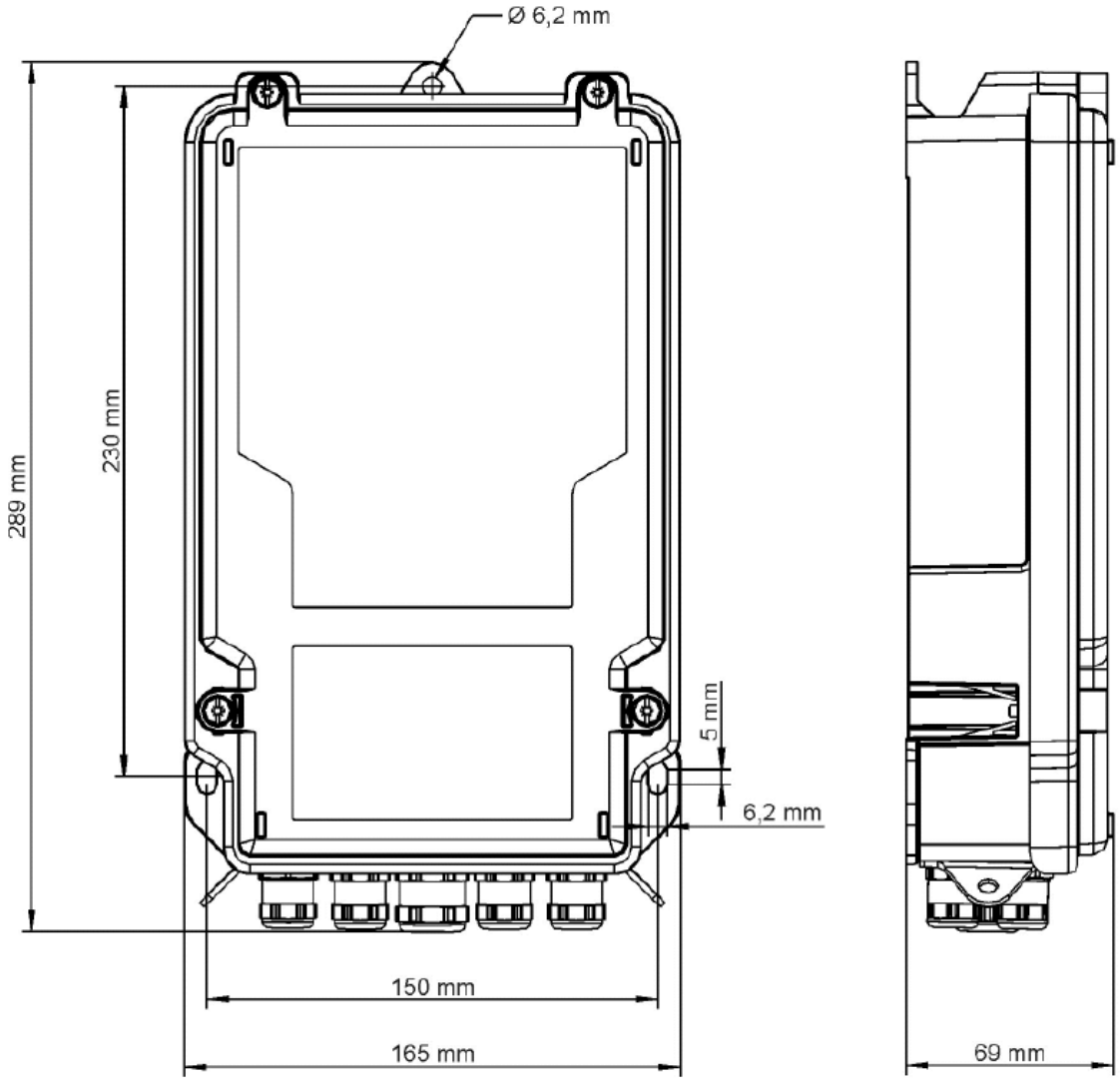


Figure 4: Mechanical dimensions EM4TII+

The energy meter fulfills protection class IP65 in accordance with EN 60529.

The transparent cover of the energy meter can be sealed, to protect the meter against unauthorized access.

2.9 Interfaces of the energy meter

2.9.1 Measuring inputs

The energy meter EM4TII+ provides two measuring inputs (one for the voltages and one for the current signal) for AC supply systems and two measuring inputs (one for the voltages and one for the current signal) for the DC supply systems, in case realized in the meter.

The measuring inputs are equipped with measuring shunts, whose value depends on the rated input signal. The different shunt versions cover the following rated current and voltage ranges:

Shunt version	Rated value range	Input (I: Current, V: Voltage)
A	70 -300 V	AC-V
H	17.857 – 50 mA	AC-V, DC-V
B	50 – 100 mA 62.5 – 100 mA	AC-V, DC-V, AC-I, DC-I
E	100 – 200 mA	AC-I, DC-I
F	200 – 500 mA	AC-I, DC-I
G	500 – 1000 mA	AC-I, DC-I
C	1 – 2 A	AC-I, DC-I
D	5A	AC-I

Table 1: Shunt versions of the current and voltage inputs

Note: An energy meter, designed for AC 1A, is equipped with a different shunt than the AC 5A version. Therefore, two devices with different hardware are needed.

The following combinations of measuring inputs are available:

Version	Channel 1	Channel 2	Channel 3	Channel 4
AC only	AC-V	AC-I	Not used	Not used
DC only	DC-V	DC-I	Not used	Not used
ACDC	AC-V	AC-I	DC-V	DC-I
DCDC	DC-V	DC-I	DC-I	Not used
DCDCDC	DC-V	DC-I	DC-I	DC-I
AC+AC	AC-V	AC-I	AC-V*	AC-I
DC+DC	DC-V	DC-I	DC-V	DC-I

Table 2: Possible combinations if current and voltage inputs

*AC+AC Chanel 3: Mandatory voltage/current transducer

DC-V always measured by voltage/current transducer

2.9.2 Communication interface

The energy meter has a RS232-interface to which the communication device is connected.

The implemented data communication protocol is compliant with the IEC 62056-21.

The communication device uses the communication interface to read the CEBD from the energy meter and to set the Consumption Point ID.

2.9.3 Data input for GPS receiver connection

The EM4TII is equipped with a dedicated serial interface (RS232 type) to be connected to a GPS receiver system.

On this interface, an RMC (Recommended Minimum Sentence C) data set according to NMEA 0183 sent with 4800 Baud is expected by the EM4TII. In the TEMA4G the data set will be provided by the PEMG.

The location information contained in these GPS data sets are used in the formation of the CEBD.

The time information included in the GPS signal is used for automatic synchronization of the built-in real time clock.

2.9.4 Terminal connections

For the connection of the sensors, the power supply and the RS-interface the energy meter provides PCB-mounted screw terminals.

The connection cables to be used:

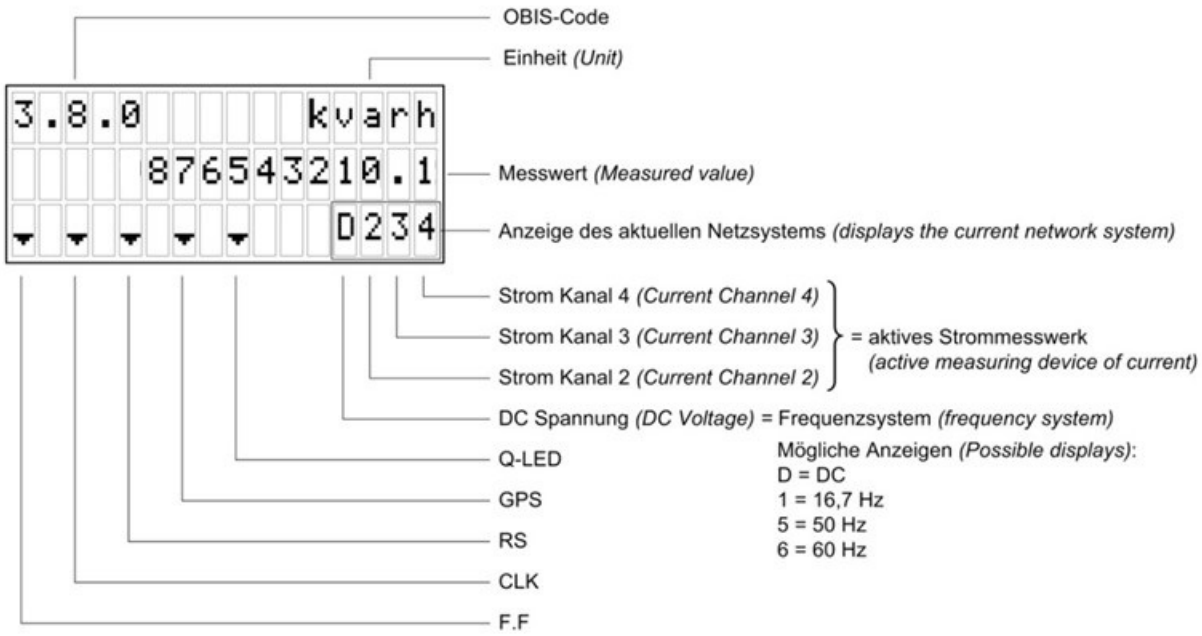
Screw terminals:

- Interfaces: 0.14 mm² to 1.5 mm² (use wire end ferrule)
- Measuring and supply terminals: 0.2 mm² to 4 mm² (use wire end ferrules)

The connection assignments of the numbered terminals are described in the manual of the EM4TII+ or on the name plate.

2.10 Display

The energy meter has a 3-line display with 16 digits per line with the following content:



The cursor field in the display indicates the following:

Cursor arrow	Function
Q LED	OFF: Reference variable for the LED is active energy ON: Reference variable for the LED is reactive energy
GPS	OFF: no GPS telegram received FLASHING: GPS telegram received ON: Valid GPS telegram received -> clock engaged
RS	OFF: No communication on the RS232 interface ON: Communication on the RS232 interface
CLK	OFF: Power reserve for the device clock not depleted ON: Power reserve for the device clock depleted
F.F	OFF: There is no fatal device fault ON: There is a fatal device fault

Table 3: LC display

Display of detected traction supply systems on the display screen (possible values):

- 12 → 16.7 Hz measurement of current on channel 2 (only possible with AC or ACDC version)
- 52 → 50 Hz measurement of current on channel 2 (only possible with AC or ACDC version)
- 62 → 60 Hz measurement of current on channel 2 (only possible with AC or ACDC version)
- D4 → DC measurement of current on channel 4 (only possible with ACDC version)
- D2 → DC measurement of current on channel 2 (only possible with DC, DCDC or DCDCDC version)
- D 3 → DC measurement of current on channel 3 (only possible with DCDC or DCDCDC version)
- D 4 → DC measurement of current on channel 4 (only possible with DCDCDC version)

2.11 Supply voltage

The supply voltage for the EM4TII+ can be selected between two variants: version one covers the rated supply voltage range 24 – 48V. Version two covers the rated supply voltage range 72 – 110V. The tolerance of the supply voltage shall be in accordance with EN 50155.

The energy meter provides a stabilized 12V supply voltage output for the communication device PEMG.

The maximum power consumption is 9 W, where max. 3 W is consumed by the energy meter itself and max. 6 W by the connected communication device.

2.12 Approvals

With an Intermediate Statement of Verification in accordance with EU-directive 2008/57/EC, clause 18 (4), issued from a Notified Body, the conformity to the TSI “Locomotives and passenger rolling stock” (EU-directive 1302/2014/EU) and amendments (EU) 2018/868 and (EU) 2019/776 has been approved.

To ensure, that the accuracy keeps the limits of EN 50463-2:2017 over lifetime, a re-verification is required. The re-verification shall be done latest after 10 years. It is recommended to change the device battery of the EM4TII+ at the same time.

3 Communication device PEMG

3.1 General description

The communication device PEMG has been designed to work together with the energy meter EM4TII+.

It is connected to GPS antenna and provides location data information in NMEA 0183 format to the dedicated GPS RS 232 interface of the EM4TII+.

The PEMG collects the CEBD from the energy meter and transmits the data periodically to the on-ground data collection server (DCS). The used method is the so called “Push” method, at which the data package is send cyclic to an IP address. Access via “Pull” method is also possible.

The protocol used to transfer the data is defined by the standard EN50463-4:2017.

The transfer cycles per day can be set. By default, and under the condition that a network is available, the PEMG will transfer the CEBD each 10 minutes. Data packages, which have not been transferred completely, will be automatically sent later.

The PEMG has an integrated energy source (Super-Cap). It allows the device to send the last CEBD data after an intentional power down.

For higher flexibility, the communication device provides three configurable IP addresses. The first IP address is reserved for the DCS. The two other IP addresses can be used for other purposes. The owner of the TEMA4G is responsible for the correct setting of the IP addresses and must assure that the first IP address will not be corrupted.

The LEDs of the PEMG indicates the following:

LED	Function
Green	OFF: PEMG powered off BLINKING: GPS receiver is searching for satellites ON: GPS signal is OK and PEMG is powered on
Red	OFF: No errors detected FLASHING: Error state, the code of which is indicated by the number of flashes

Table 4: PEMG LED indication

3.2 Communication

The PEMG provides 2 communication channels:

- GSM
- Ethernet (service/maintenance interface, as required in EN 50463-1)

The transfer protocol used on these channels is HTTPs.

The data is transferred in XML-format in accordance with EN 50463-4:2017.

3.3 Networks

The PEMG supports 2G (GPRS) and 4G (LTE) networks. In Germany the E-UTRA frequency bands 3, 7, 20 and 38 are used. Western Europe recently uses the E-UTRA bands 3, 7, 8 and 20. The frequency ranges are 800 MHz, 900 MHz, 1800 MHz and 2,6 GHz.

3.4 SIM-cards

The communication device needs a SIM card for the data transmission. The SIM-card shall be provided by the customer. The SIM card shall be cleared, shall have a uniform PIN and the PIN code shall be unlocked. The SIM card format shall be Micro SIM.

Before delivery, the manufacturer tests the functionality of the communication device with inserted SIM card. This gives the end user a fully functional communication device.

LEM is not responsible for the SIM-card. The availability of SIM cards and a possible delivery delay due to missing SIM cards for the TEMA4G are not in responsibility of LEM.

The principle of information exchange is shown in the following scheme:

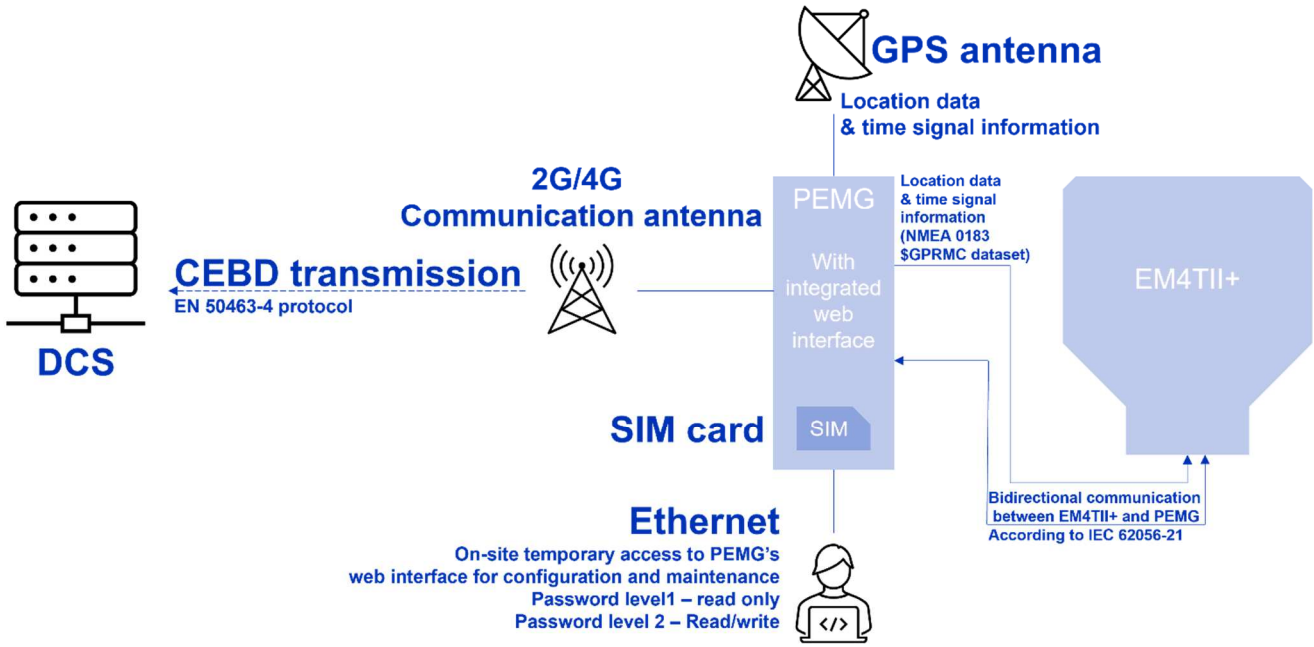


Figure 5: Communication scheme

3.5 Location data

The communication device contains a GPS-receiver, which shall be connected to a suitable GPS-antenna.

The detected coordinates coming from the GPS-receiver are send to the EM4TII+ in an RMC (Recommended Minimum Sentence C) data set according to NMEA 0183 sent with 4800 Bit/s is expected by the EM4TII.

As an option, it is possible to connect a GPS source directly to the GPS RS 232-interface of the EM4TII+. The format of the provided GPS-location-data shall be in accordance with NMEA 0183 dedicated GPS RS232-interface. The energy meter creates the complete CEBD in accordance with EN 50463-3, including the location. The PEMG-device is reading the CEBD data and transmits it to the DCS. Using this option, it is not necessary to connect a GPS antenna to the PEMG-device.

3.6 Configuration

The configuration of the modem is done through an embedded web server which can be accessed through the Ethernet interface of the PEMG. This Ethernet interface is an 8 Pin RJ45 female plug, compliant with 100 Mbit/s according to ISO/CEI 11801.

➡ For web server configuration and communication with PEMG please refer to the PEMG commissioning manual.

3.7 Data interfaces

3.7.1 Data interface between EM4TII+ and PEMG

The data interface is compatible to the EM4TII+ RS232-data interface. The connections are integrated in the single power supply / communication cable.

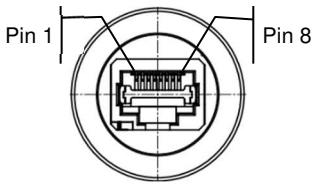
Type of interface: RS 232, 9600 Bd, 7E1

3.7.2 Ethernet interface on PEMG

The data are transmitted in XML format. The structure of the stored and transmitted CEBD data is in accordance with the EN50463-4:2017 standard.

Type of interface: 8 Pin RJ45 female plug, compliant with 100 Mbit/s according to ISO/CEI 11801.

TEMA4G pinout	Function	Colour
1	ETN TXP	green
2	ETN TXN	green-white
3	ETN RXP	orange
6	ETN RXN	orange-white



3.8 Antennas

3.8.1 GPS antenna

The communication device provides a connector for the connection of an external GPS antenna. The connector has the following technical data:

- Connector type: SMA, female
- Impedance: 50 Ohm
- Operating voltage: 3,3 or 5 V (configurable)
- Maximum current: 50 mA

3.8.2 GSM antenna

The device provides a connector for the connection of an external GSM antenna. The connector has the following technical data:

- Connector type: FME, male
- Impedance: 50 Ohm
- Maximum power: 2 Watt

3.9 Mechanical features

The dimensions and the fastening holes of the communication device are shown in Figure 6:

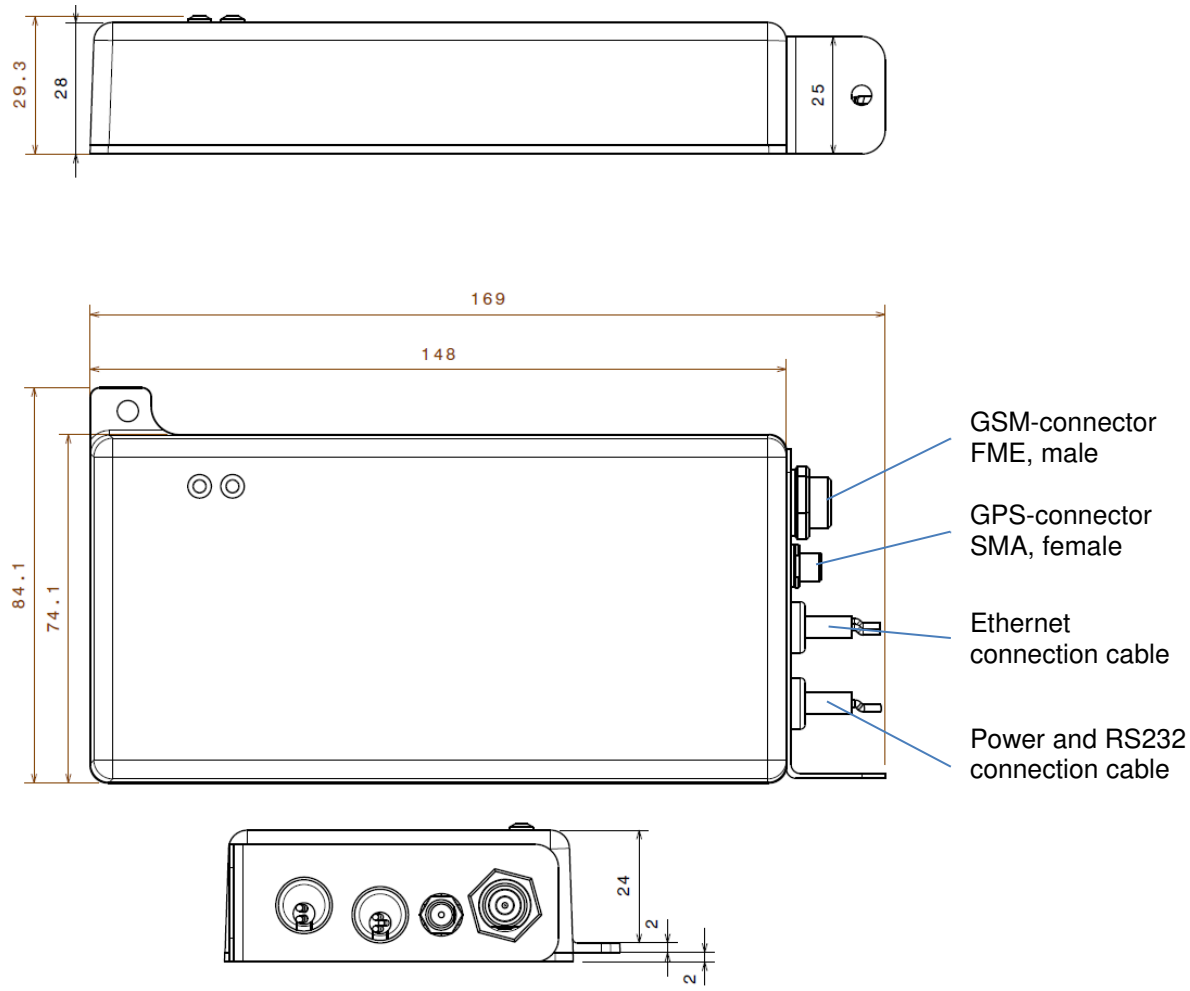


Figure 6: Dimensions of the PEMG

The PEMG fulfills protection class IP65 in accordance to EN 60529.

3.10 Approvals

With an Intermediate Statement of Verification in accordance with EU-directive 2008/57/EC, clause 18 (4), issued from a Notified Body, the conformity to the TSI “Locomotives and passenger rolling stock” (EU-directive 1302/2014/EU) and amendments (EU) 2018/868 and (EU) 2019/776 has been approved.

4 References

This document refers to the following standards and regulations:

EN 45545-5:2013/A1:2015	Railway applications - Fire protection on railway vehicles - Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles;
EN 50121-3-2:2016	Railway applications - Electromagnetic compatibility - Rolling stock – Apparatus; Part 3-2:
EN 50155:2017	Railway applications - Rolling stock - Electronic equipment;
EN 50163:2004/A1:2007	Railway applications - Supply voltages of traction systems;
EN 50463:2017 (1-4)	Railway applications - Energy measurement on board trains
EN 60529:2014	Degrees of protection provided by enclosures (IP Code)
EN 61373:2010	Railway applications - Rolling stock equipment - Shock and vibration tests
EN 62056-21:2002	Electricity metering - Data exchange for meter reading, tariff and load control - Part 21: Direct local data exchange