EM4TII+ Manual

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Revisions

Version	Date	Evolution
Preliminary	2020-10-30	Creation- Preliminary version
V1.0	2020-11-05	First official version

1. Safety instructions and hazard warnings

Please read this chapter through carefully. It familiarises you with the important safety instructions and hazard warnings for handling the EM4TII+ device.

CAUTION

Do not under any circumstances open the device! Opening the device can cause electric shocks.
This device does not contain any parts which can be maintained by the user. Have all maintenance work carried out by servicing specialists only.

NOTE

The device is designed for a maximum secondary voltage converter voltage of 300 V.

Explanation of markings:

Protective earth

CE certification

Warning of a hazard
(adhere to the documentation!)

2. Product description

This operating manual describes all design variants of the EM4TII+. Be aware that meters may be designed differently with regard to configuration, interface, inputs/outputs etc. It is possible that some meter characteristics are described here which do not apply to your meter.

The EM4TII+ is a single-phase energy meter as per EN 50463-x:2017 and thus meets the requirements of the EU directive 1302/2014/EU in accordance to Commission Implementing Regulation (EU) 2018/868 and 2019/776.
The energy meter EM4TII+ contains the energy measurement function (EMF) as well as the vehicle-side Data Handling System (DHS) up to the output-side interface for the communication function (transfer of the CEBD to the communication function). The communication device must process and transfer the data to the ground site in XML format in accordance with EN 50463-4: 2017.

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 default period length of 5 minutes (other period lengths available on request). These datasets contain the date, time, traction type and events together with the primary energy (delta) values and can optionally contain the location coordinates too. The measured energy data consists of consumed and regenerated active and reactive (for AC) energy in separate registers and is stored in the load profile for at least 300 days (for 5-minute period length).

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 recorded in the load profile and in the logbook.

The EM4TII+ has a separate input for capturing serial data telegrams from a GPS receiver (NMEA 0183 format) from which the location coordinates can be generated and matched to the appropriate energy data. When receiving GPS data, the internal RTC device clock synchronises, if necessary, using the time information contained in the data telegrams.

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, activation and deactivation of the rail network voltage, synchronisation of the time and changing the parameters important for energy calculation.

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

The data is transferred via serial interfaces. All the measured and stored data can be read out via the RS interface (via modem or locally). The interface variants RS232, RS422 or RS485 are available. The applied data communication protocol is IEC 62056-21 and thus easily adapted by all common remote read out systems.

The supply voltage for the EM4TII+ can be selected between 24 V and 110 V as per EN 50155.
Two hardware variants are available, one for 24V or 48V, the other one for 72V, 96V or 110V

Optionally a communication unit (modem) can be supplied with 12V DC voltage from the EM4TII+.

The conditions of use (with regard to EMC, temperature, vibrations etc.) meet the special requirements for locomotives, including the EN 50155, EN 50121-3-2, EN 50124-1 and EN 61373.
Concerning shock and vibrations, the meter has been tested in respect to category 1, class B severity defined in EN 61373.
The compact and fireproof housing provides protection from the penetration of moisture and foreign bodies to level IP 65.

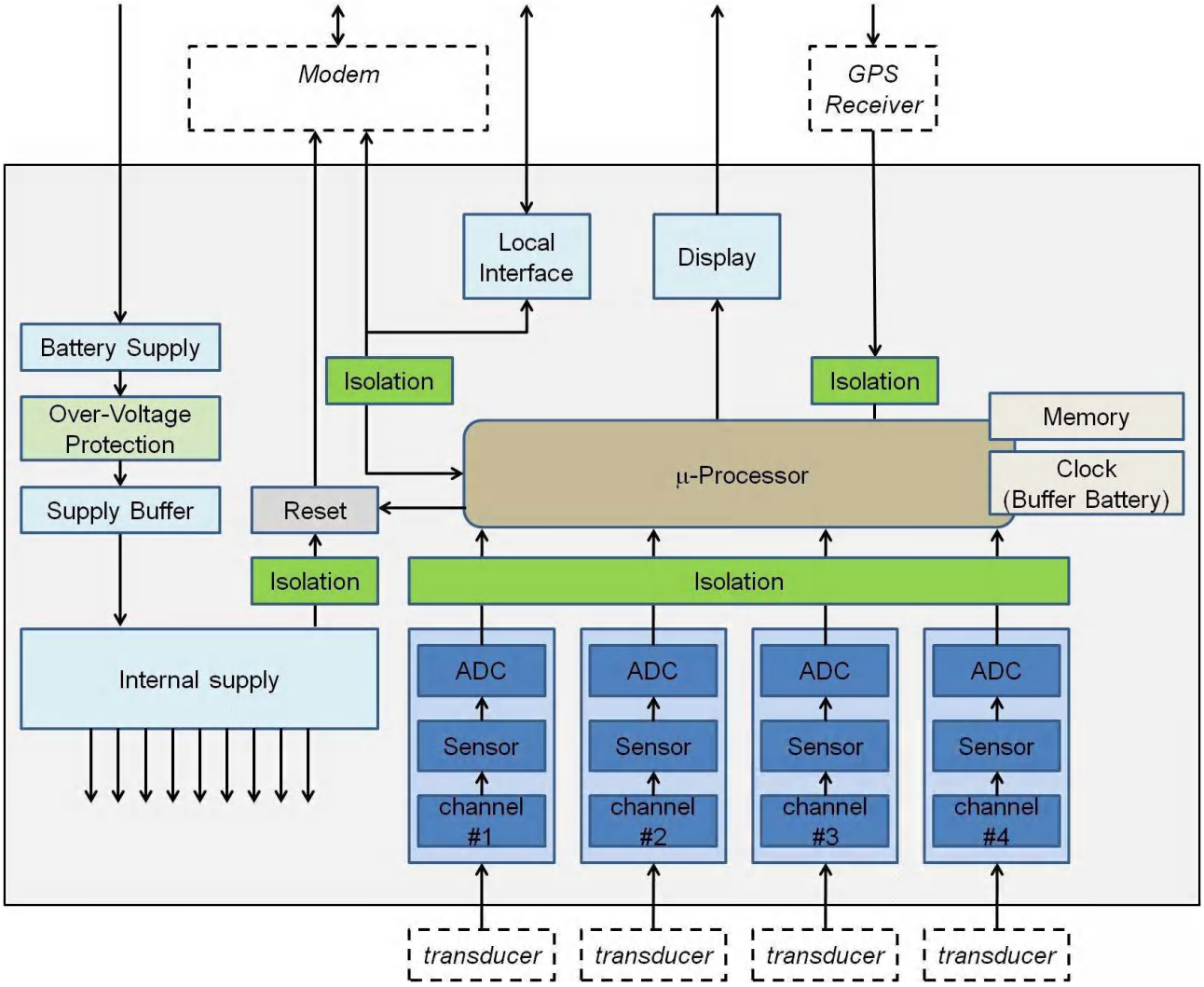
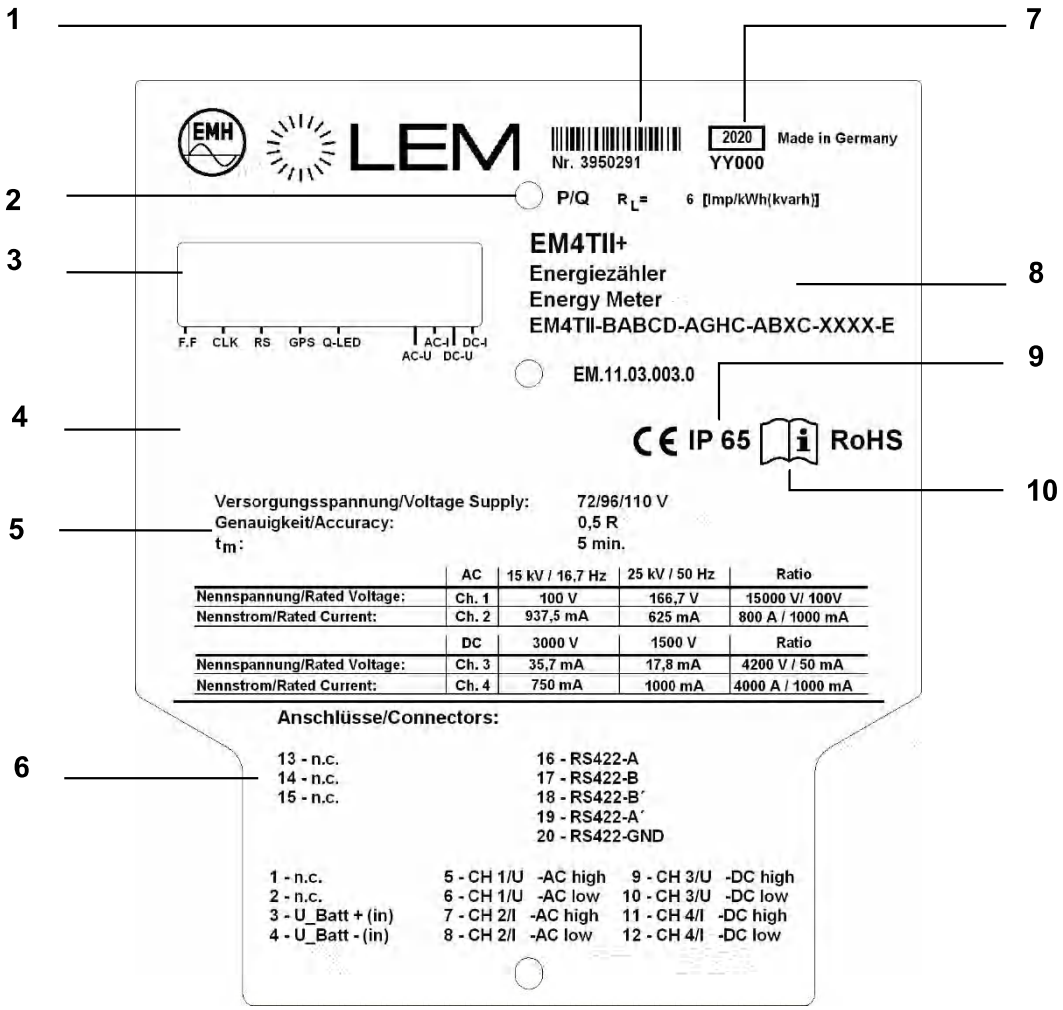


Figure 2.1: Block diagram

View of the rating plate:



1	Serial number
2	Test LED for active and reactive power
3	LC display
4	Space for ownership marking
5	Specifications on operation of the meter
6	Connection plan and terminal assignment
7	Year + date-code (day of the year) of manufacture
8	Type designation and type code
9	Protection type
10	Adhere to the operating manual

Scope of delivery:

- 1x EM4TII+ base device
- Operating manual
- Additional locking bolts for cable gland (2 x Ø 6.4 x 25 mm and 2 x Ø 9.3 x 20 mm)

3. Installation and connection

3.1 Wall mounting

The EM4TII+ device is designed for three-point mounting as per DIN 43857-2. For a detailed view of the fastening holes see figure 3.1. The four sealing screws for the terminal cover are tightened evenly and alternately to **0.5 Nm** with a PZ2.

ATTENTION!
Damage of the unit due to excessive torque!
- Tighten the sealing screws with a maximum torque of 0.5 Nm.

Once the connections are correctly done and the cover applied, the two lower screws of this transparent cover can be sealed, so that it is not possible any more to easily open the meter.

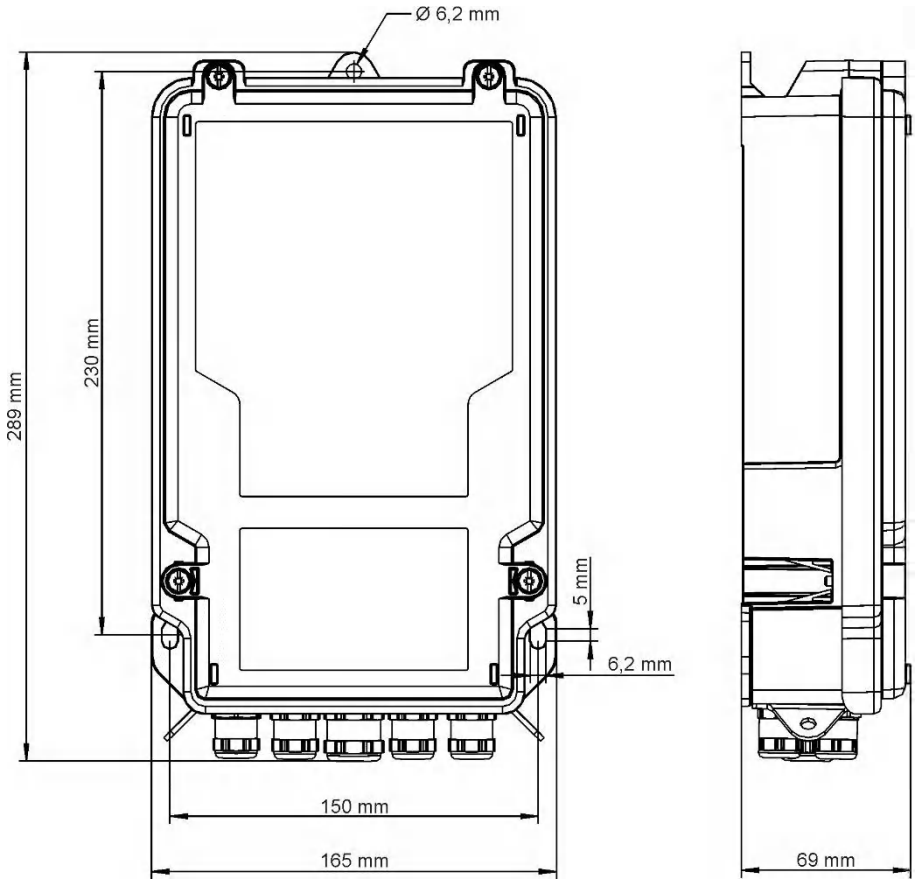


Figure 3.1: Scale drawing

An existing EM4T installation can be adjusted to an EM4TII+ model using an installation kit which is available as an accessory. For compliance with Standard EN 50463:2017 an exchange of the measurement-System (meter + communication) is necessary.

⚠ DANGER!

Contact of parts under voltage is extremely dangerous!

When installing or changing the meter, the conductors to which the meter is connected must be free of voltage.

- Remove the relevant back-up fuses and store them in such a way that other people cannot re-insert the back-up fuses without notice.
- If you use selective circuit breakers for disconnection from the mains, secure them against unintentional reconnection.
- When installing and connecting the meter, only use the screw terminals provided for this purpose.

ATTENTION!

Damage to the connection terminals due to excessive torque!

The appropriate torque depends on the type of the wire and the maximum current.

- Tighten the connection terminals with the appropriate torque according to IEC 60999-1.

3.2 Electrical connection

⚠ DANGER!

Contact of parts under voltage is extremely dangerous!

- Secure meters with a transformer connection in the voltage path with a back-up fuse of <6 A.

The supply lines to the device - which can total up to nine depending on the energy meter design - must be laid with cable glands and connected as per figure 3.2.

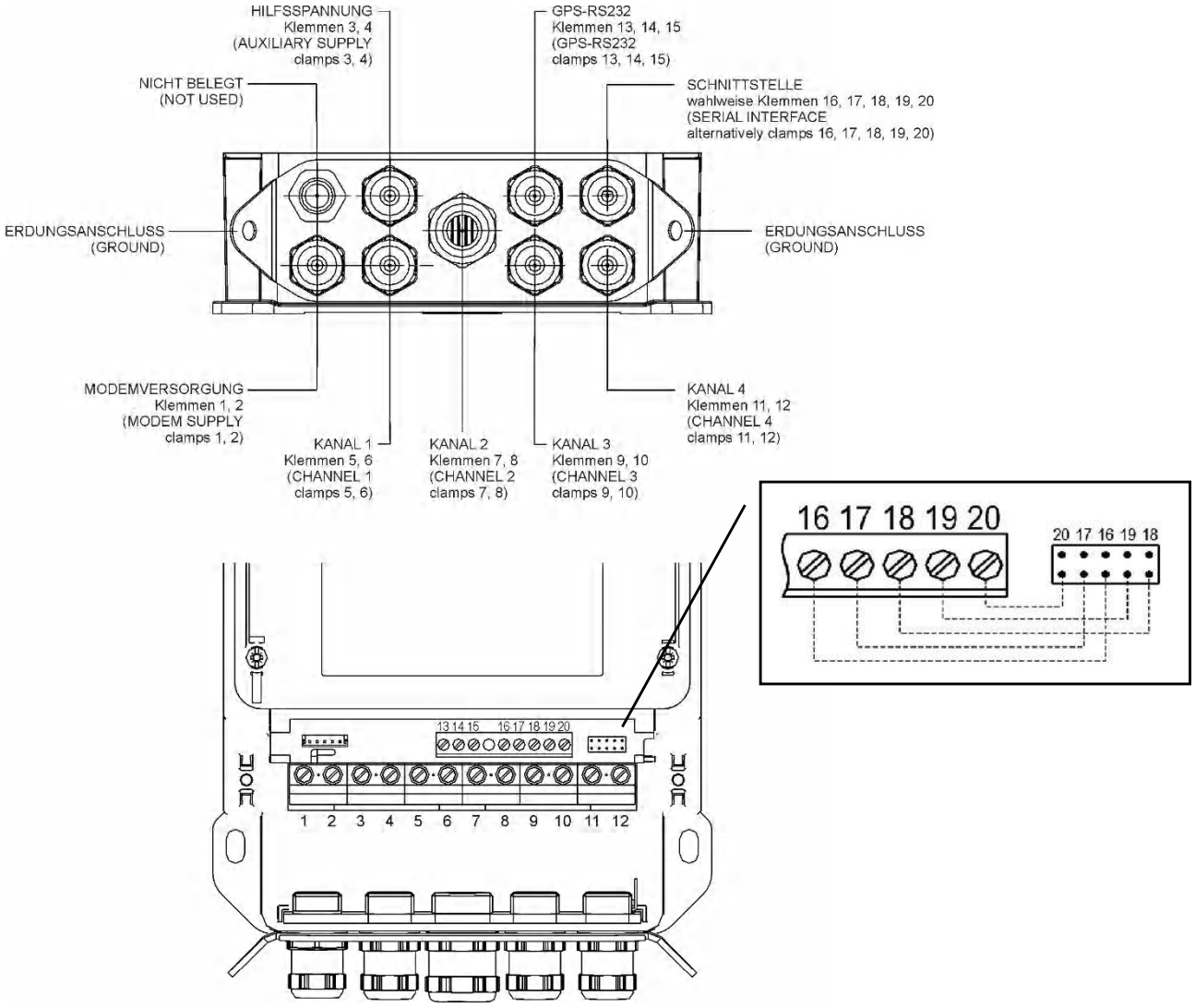


Figure 3.2: Terminal block

Note: When using the EM4TII+ with the communication device PEMG, connections for power supply, communication and GPS are combined in one cable

Version	Channel 1	Channel 2	Channel 3	Channel 4
AC	AC-voltage	AC-current		
ACDC	AC-voltage	AC-current	DC-voltage	DC-current
DC	DC-voltage	DC-current		
DCDC	DC-voltage	DC-current	DC-current	
DCDCDC	DC-voltage	DC-current	DC-current	DC-current

Table 3.1: EM4TII+ inputs configurations

DC-voltage is always measured via a voltage/current transducer.

The connection wires 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)

Parallel to the screw terminal for the RS interface there is a plug connector (grid dimension 2.54 mm) to which a computer/laptop can be connected locally. The plug connector and the screw terminals are connected to each other electrically. Thus, both interfaces are of the same RS type. When reading out locally you must make sure that there is currently no communication in process via the RS screw terminals. An active communication process is indicated in the display by an arrow over "RS". If an attempt to communicate is made whilst another communication process is in process, the current communication process breaks down.

Cable glands (properties):

- Measuring signal: 3 x M16 x 1.5 (Ø 6.5 – 9.5 mm); 1 x M20 x 1.5 (Ø 9.5 – 13.5 mm)
- Supply and communication: 4 x M16 x 1.5 (Ø 4.0 – 6.5 mm)

13 – GPS (in) - RS232-TxD	16 – RS232-n.c.	RS485-n.c.	RS422-A
14 – GPS (in) - RS232-RxD	17 – RS232-n.c.	RS485-n.c.	RS422-B
15 – GPS (in) - RS232-GND	18 – RS232-TxD	RS485-B +	RS422-B’
	19 – RS232-RxD	RS485-A -	RS422-A’
	20 – RS232-GND	RS485-GND	RS422-GND
1 – U_Modem + (out)	5 – CH1 high	9 – CH3 high	
2 – U_Modem - (out)	6 – CH1 low	10 – CH3 low	
3 – U_Batt + (in)	7 – CH2 high	11 – CH4 high	
4 – U_Batt - (in)	8 – CH2 low	12 – CH4 low	

Figure 3.3: Connection assignment (n.c: not connected)

Since the nomenclature of the terminals of the RS422 interface for the LEM Products EM4T and EM4TII+ are different, please use in case of replacement of the EM4T with EM4TII+ in an installation the table below to connect the RS422 interface.

Marking of the connector		Data flow direction (relative to EM4T/EM4TII+)
EM4T	EM4TII+	
Tx+	A	Send
Rx+	A‘	Receive
Tx-	B	Send
Rx-	B‘	Receive

4. Displays and parameterization, data interfaces

4.1 Display screen and operating display

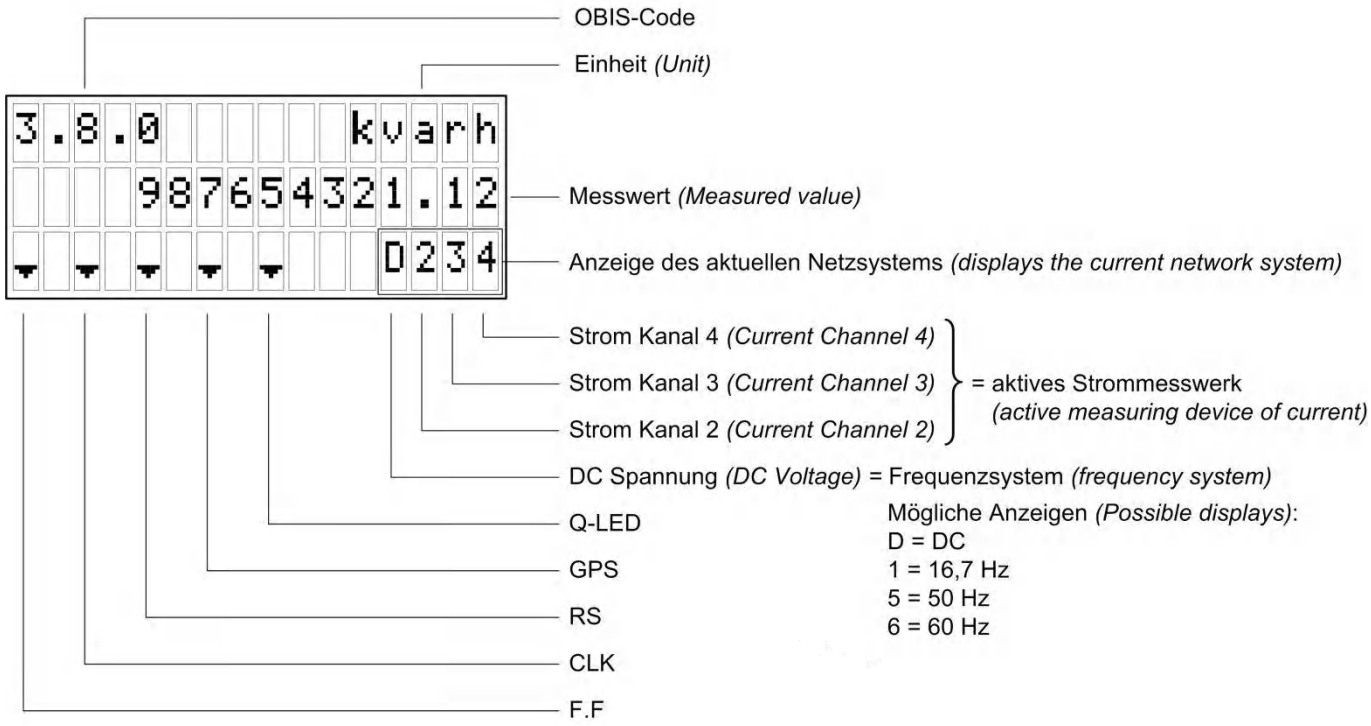


Figure 4.1: LC display

Display of detected mains system 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)

Cursor field:

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 4.1: Cursor arrows definition

The individual pieces of energy and operation information are displayed cyclically (approximately 10 seconds) as shown in table 4.2:

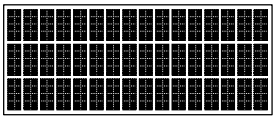
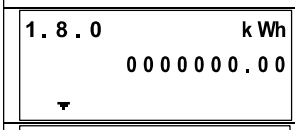
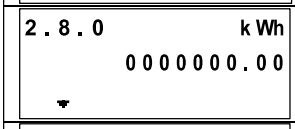
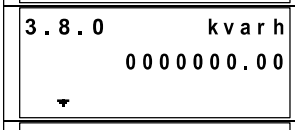
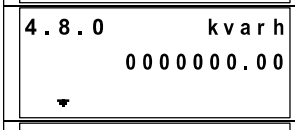
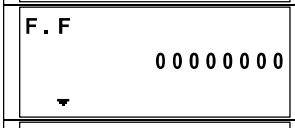
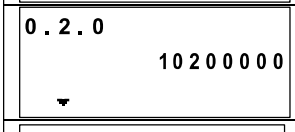
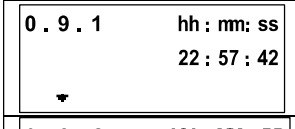
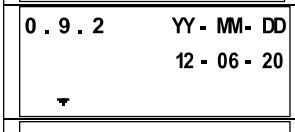
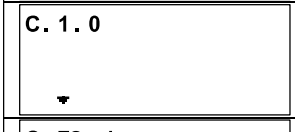
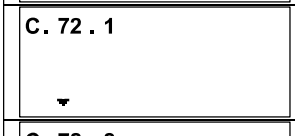
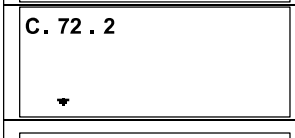
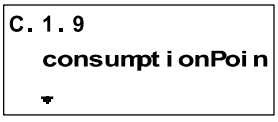
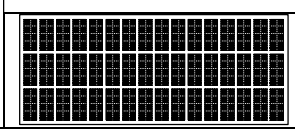
	Display	Meaning	Duration of the display
Rolling list		Display test	Appears after commissioning for approximately 1 s
		Energy register for positive active energy	Appears for 10 s for each
		Energy register for negative active energy	
		Energy register for positive reactive energy	
		Energy register for negative reactive energy	
		Fault display	
		Identity number	
		Firmware identification	
		Time	
		Date	
		Manufacture number	
		Locomotive number	
		Train number	
		Consumption point ID (if string is longer than 16 characters, it is displayed in 2 parts for 5 sec each)	
		Display test	Appears for 1 s

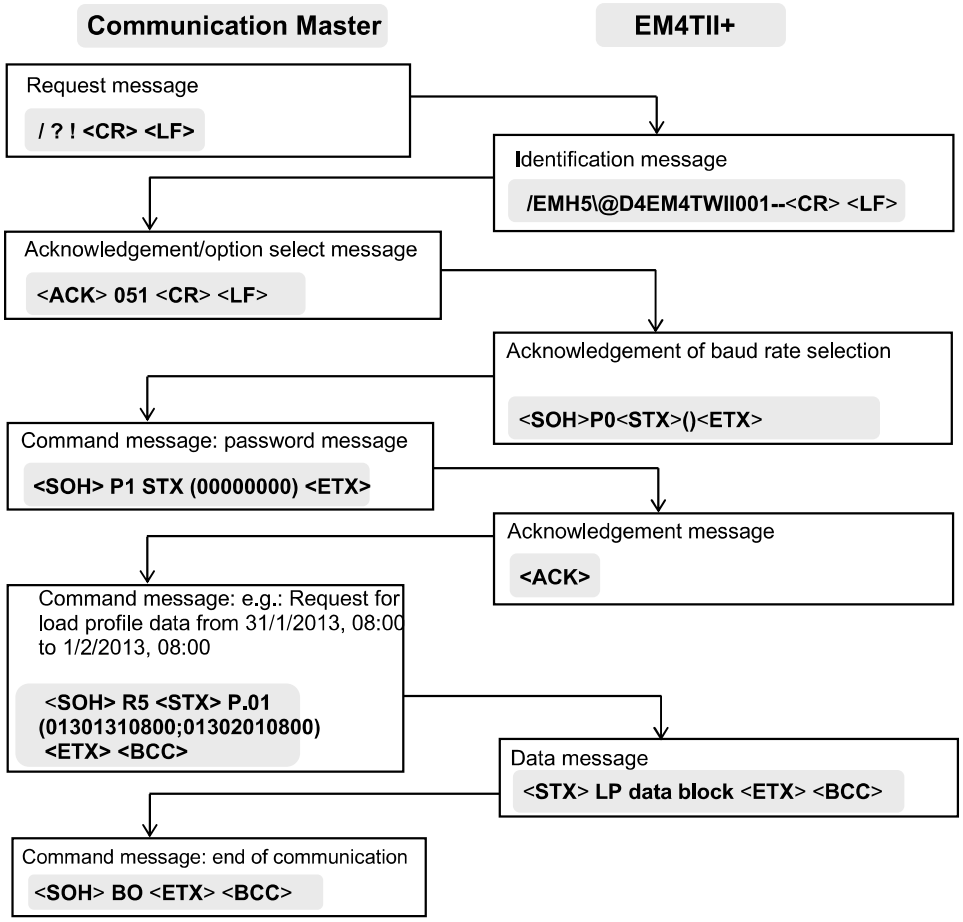
Table 4.2: Rolling list

4.2 Parameters and reading out meter data

Communication with the EM4TII+ follows the standard IEC 62056-21 (formerly IEC 61107).
Knowledge of this standard is assumed for the development of any kind of terminal software dedicated to read the meter data.
All data objects are identified here by the OBIS Code System (formerly EDIS code system).
OBIS codes are given here in part as a full 6-digit code. On the possibly shortened reference OBIS codes are referred to in this document, if any.

4.2.1 Protocol diagram

Here is a representation of a possible communication between the train computer or communication unit and the EM4TII+ to select the load profile:



4.2.2 Command and data formats

In chapter 4.2.1 an example of a data exchange was given. In the present chapter, all notions related to messages needed for communication will be explained.

In chapter 4.2.9, a sample communication cycle with explanations is given to show the use of the messages.

Please note:
The EM4TII+ interface parameters are:

Baud rate: 9600 bps
Data bits: 7
Stop bit: 1
Parity: even

Message explanation generally:

/	?	→ Command character
1	*5*	Please find the related explanation after the message descriptions.

Request message — Command sequence

/	?	Device address	!	CR	LF
1	*9*	*20*	*2*	*3*	

Identification message — Answer f. EM4TII+

/	X	X	X	Z	Ident	CR	LF
1	*11*			*12*	*13*	*3*	

Acknowledgement/option select message — Command sequence

ACK	0	Z	Y	CR	LF
4	**)*	*12*	*10*	*3*	

*) always “0”

Data message (except in programming mode) — Answer f. EM4TII+

STX	Data	!	CR	LF	ETX	BCC
5	*14*	*2*	*3*		*6*	*8*

Data message (in programming mode) — Answer f. EM4TII+

STX	Data	ETX	BCC
5	*18*	*6*	*8*

Data message (in programming mode with optional partial blocks) — Answer f. EM4TII+

STX	Data	EOT	BCC
5	*18*	*7*	*8*

Programming command message

Command sequence

SOH	C	D	STX	Data set	ETX	BCC
15	*16*	*17*	*5*	*18*	*6*	*8*

Error message

Answer f. EM4TII+

STX	E	R	R	(	Error	)	ETX	BCC
5							*6*	*8*

Explanations of the parameters in the tables above:

1 Start character „/“

2 End character „!“

3 Final characters
CR: Carriage return
LF: Line feed

4 Acknowledge character (ACK)

5 Start character for the generation of the block test character (BCC, STX = start of text).

6 This character is not necessary if no data set follows.

6 End character of a block (ETX)

7 End character in a partial block (EOT)

8 Block check character (BCC).
The block begins after the first recognized SOH or STX signal and extends through the ETX character that ends the message. The calculated block check character follows immediately after the ETX character.

9 Request to send command „?“

10 „0“ – Read data
„1“ – Programming mode

11 Manufacturer identification „EMH“.

12 Baud rate identification (to change the baud rate)
The request message, the identification message and the acknowledge / option select message are sent with the opening baud rate (9600 bits by default). The baud rate of the further communication depends on the baud rate set in the protocol.
Communication baud rate:
„0“ 300 Bd
„1“ 600 Bd
„2“ 1200 Bd
„3“ 2400 Bd
„4“ 4800 Bd
„5” 9600 Bd

13 Manufacturer specific identification. Characters with the exception of “/” and “!”. Both last characters „/@“ point on the valid commands R5, R6 and W5.

14 Data block with the measured values. The measured values can be identified based on the table of EDIS codes.

15 Header character (SOH)

16 Programming command message identification
„P“ - Password command
„W“ - Write command
„R“ - Read command
„B“ - Cancel the execution of a command (break)

17 Command type identification (indicates the variant of the command)
Values:
a) for the password command „P“
„1“ – value is password 1 (W5 password according to IEC 62056-21)
b) for the write command „W“
„1“ – writes ASCII-coded values
„5“ – writes Format-coded (OBIS code)
c) for the read command „R“
„5“ – reads format coded (OBIS code)
„6“ – reads format coded (OBIS code) with partial blocks

18 Data set
Gives OBIS code and data of the message.

19 Error message
It consists of max. 32 characters except for "(", ")", "*", "/" and "!".

20 Serial number
Optional field, given as Manufacturer specific, maximum 8 characters, not used in standard version.

Note:
The serial number use/detection will require a special EM4TII+ configuration during manufacturing process.
The EM4TII+ standard version ignores this parameter, meaning that whatever the address given in the message, the energy meter will respond.

4.2.3 Communication cycle

To explain the use of the message notions explained in the previous chapter, a communication cycle is given as an example:

Request message:

```
/?<xxxxxxxxxx>!<CR><LF>
```

with <xxxxxxxxxx> = device address (optionally).
If no address is specified, any connected meter will answer

Acknowledgement/option select message:

```
<ACK>0ZY<CR><LF>
```

with Z = Communication baud rate
(0=300Bd, 1=600Bd, 2=1200Bd, 3=2400Bd, 4=4800Bd, 5=9600Bd),
Y = 0: switch to read mode
Y = 1: switch to programming mode

Password message (command message):

```
<SOH>P<n><STX>(<pppppppp>)<ETX><BCC>
```

with <n> = 1: Password 1
<pppppppp>= Password

Programming mode:

Read

```
<SOH>R5<STX><obis>([p1][;p2])[(e1)] [(e2)] [(e3)] [(e4)]
<ETX><BCC> [(e5)]<ETX><BCC>
```

with <obis> = OBIS code number of the parameters/profiles to read.
<p1> = time stamp beginning
<p2> = time stamp end
<e1..4> = OBIS codes of the energy registers to be included in the load profiles (no information -> select all)
<e5> = password, if necessary

Partial block reading

```
<SOH>R6<STX><edis>([p1;p2][;p3])[(e1)] [(e2)] [(e3)]
[(e4)]<ETX><BCC>
```

with <edis> = OBIS code of the profile to read
<p1> = time stamp beginning
<p2> = time stamp end
<p3> = number of records per block
<e1..4> = OBIS code of the energy registers to be read (no information -> select all)

Write

```
<SOH>W5<STX><obis>([p1])[(e1)]<ETX><BCC>
```

with <edis> = OBIS code of the parameter to be written
<p1> = parameter value
<e1> = password, if necessary

4.2.4 Access authorizations

The EM4TII+ user has two access levels via the data interface:

- The first level is the password level with read authorisation
- The second level is the service level with read and write authorisation

The password level enables the user to read data and parameters from the EM4TII+ using the login password. This password level does not allow you to write parameters.
The authorized service user can also use a second password to access the service level (W5 password according to IEC 62056-21). This enables him to write certain parameters (refer to Table 4.4 - Obis codes).

Access authorisations	Read (Data and parameters)	Write (Parameters)
Password level	All (except PWD*)	Not allowed
Service level		Adjustable parameters

(*PWD→Definition of passwords)

Table 4.3: Access authorisations

4.2.5 OBIS codes

All data and parameters can be read out with any of both passwords, except the passwords themselves.

For all write commands to the EM4TII+ the OBIS code must be given as 6-digit OBIS code (see table below).

For all write commands the usage of a separate password (W5 password according to IEC 62056-21) in addition to the obligatory login password is mandatory.

OBIS code	Description	Write	Read	Format	Remark
0-0:C.1.0*255	Manufacturing number	No	Yes	up to 8 digits	
0-0:C.72.1*255	Locomotive number	W5-password	Yes	8-digits ASCII string	
0-0:C.72.2*255	Train number	W5-password	Yes	8-digits ASCII string	
1-0:C.1.9*255	Consumption Point-ID	W5-password	Yes	32-digits ASCII string	Note 3)
1-0:0.0.0*255	Identification register 0	W5-password	Yes	8-digits ASCII string	
1-0:0.0.1*255	Identification register 1	W5-password	Yes	8-digits ASCII string	
0:1.8.0	Active energy positive	No	Yes	Floating point (kWh)	accumulated value
0:2.8.0	Active energy negative	No	Yes	Floating point (kWh)	accumulated value
0:3.8.0	Reactive energy positive	No	Yes	Float. point (kvarh)	accumulated value
0:4.8.0	Reactive energy negative	No	Yes	Float. point (kvarh)	accumulated value
12:#.8.0	# energy of ch. 12	No	Yes	Floating point (kWh/kvarh)	1: active positive 2: active negative 3: reactive positive 4: reactive negative
34:#.8.0	# energy of ch. 34	No	Yes	Floating point (kWh/kvarh)	
1-0:1.7.0*255	Total active power P	No	Yes	Floating point (kW)	all channels, Note 5)
1-##:1.7.0*255	actual active power P	No	Yes	Floating point (kW)	12: CH 1=U, CH 2=I 34: CH 3=U, CH 4=I 13: CH 1=U, CH 3=I 14: CH 1=U, CH 4=I
1-0:3.7.0*255	Total reactive power Q (AC)	No	Yes	Floating point (kvar)	all channels, Note 5)
1-##:3.7.0*255	actual reactive power Q (AC)	No	Yes	Floating point (kvar)	12: CH 1=U, CH 2=I 34: CH 3=U, CH 4=I
1-#:32.7.0*255	actual voltage of ch. #	No	Yes	Floating point (V)	CH 1 or 3
1-#:31.7.0*255	actual current of ch. #	No	Yes	Floating point (A)	CH 2, 3 or 4
1-#:14.7.0*255	actual frequency	No	Yes	Floating point (Hz)	CH 1 or 3
0-223:113.108.101*0	LED (P/Q) control	W5-password	Yes	1 bit	0 = P, 1 = Q
0.3.0	LED pulses per kWh	No	Yes	Floating point	
0-223:110.112.118*#	Primary transformer ratio	No	Yes	Floating point expressed as V or A	#: channel, Note 4) 0 → CH 1, … 3 → CH 4
0-223:110.115.118*#	Secondary transformer ratio	No	Yes	Floating point expressed as V or A	#: channel, Note 4) 0 → CH 1, … 3 → CH 4
0-223:110.101.109*#	Secondary rated values	No	Yes	Floating point expressed as V or A	#: channel, Note 4) 0 → CH 1, … 3 → CH 4
0.9.1	Time	No	Yes		
0.9.2	Date	No	Yes		
C.8.0	Operating seconds	No	Yes		
1-0:0.9.129*255	setting date and time	W5-password	Yes		Note 2)
0.8.4	Registration period time of load profile	No	Yes		in minutes
0-223:103.112.115*0	GPS RMC last message	No	Yes		
0-223:98.100.97*0	Baud rate	W5-password	Yes	2 digits	Note 1)
0-223:112.119.100*03	Login password	W5-password	No	8-digits ASCII string	
0-223:112.119.100*35	W5-password	W5-password	No	8-digits ASCII string	
0.2.0	Firmware version	No	Yes		
0-223:98.100.97*255	Firmware date	No	Yes		
C.90.#	Checksums (# = 0: parameterization variables; # = 1: configuration variables; # = 2: firmware binary code)	No	Yes	8 hex digits	
F.F	Error code	No	Yes	8 hex digits	Refer §4.2.8
P.01	Load profile	No	yes		
P.98	Logbook	No	yes		

Table 4.4: OBIS codes

Note 1): Setting of the baud rate of the data interface
The setting of the baud rate of the data interface with the above OBIS code must be performed with one of the following parameters:

00	= 300 Baud
01	= 600 Baud
02	= 1200 Baud
03	= 2400 Baud
04	= 4800 Baud
05	= 9600 Baud

Note 2): Set the device clock

The setting of the device clock with the above OBIS code must be performed with the following parameter:

YYMMDDHHMMSS wwnz

YY	= year (00 .. 99)
MM	= month (01 ..12)
DD	= day (01 .. 31)
hh	= hour (00 .. 23)
mm	= minute (00 .. 59)
ss	= second (00 59)
ww	= 00 (value is ignored when writing): week in the year
n	= 0 (value is ignored when writing): day in the week
z	= season flag (0 = winter time, 1 = summer time, 2 = UTC time)

The EM4TII+ will code all timestamps (in the load profile and the log etc.) with UTC time.

Setting of the clock causes the capture period to end prematurely. The capture period which follows is ended synchronously and is shortened as necessary if the adjustment is not made synchronously with the capture period split.
If the time deviation between the old and the new device time is less than ±2 s, the clock is only synchronised. The capture period is not completed in this case.

Please note that for the standard version of the EM4TII+ the device clock is synchronised automatically based on the time information included in the GPS data telegrams.

Note 3): Consumption Point-ID

This dedicated register for the consumption point ID is an ASCII text string with 32 characters maximum, as the definition of CPID has evolved: please refer to EN 50463-1:2017, § 4.2.5.2

Note 4): Reading of transformer ratios
The configured transformer ratios of the EM4TII+ for the four input channels yield from the primary and secondary rated values identified by OBIS codes 0-223:110.112.118*# and 0-223:110.115.118*# (#=0 → channel 1, … , #=3 → channel 4).

Note 5): Power values in the case of regenerated energy
In the case of negative power values (i.e. feeding regenerated energy to the supply system), the power values given by the EM4TII+ are marked with a negative sign.
Nevertheless, the OBIS code system originally distinguishes between separate registers for positive and negative power values, the usage of only one value allows it easily to monitor the power directly even in the case of alternating signs of the power value.

4.2.6 Structure of load profile compilation

A status word is stored with each load profile record. Each bit in this status word contains information about a certain error or event. Each time an event occurs that changes the status word, a new header with the updated status word is generated and stored. The structure of header and the decoding of the status word is explained below:

Example: Structure of the load profile header as an example load profile data set:

P.01(121015061841)(########)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)(3.29.0)(kvarh)(4.29.0)(kvarh)

P.01➔	OBIS-Code for load profile,
(121015061841)➔	timestamp of load profile entry (format YYMMDDhhmmss)
(########)➔	status word in hexadecimal coding (see below)
(5)➔	recording interval in undisturbed case
(9)➔	number of variables stored in the load profile

Then the OBIS codes of the stored values follow (possibly with their physical units) and finally carriage return (0D) and line feed (0A).

The meaning of the bits of the status word is listed below.

If necessary, the status is composed by a plurality of individual bits, if multiple events are recorded.

This coding of the status word is also used in log (P.98) and is defined as follows:

Bit	hexadecimal coding	Meaning	Usage in load profile	Usage in log (P.98) *1 depending on configuration
b31	80000000	AC over voltage		X *1
b30	40000000	DC over voltage		X *1
b29	20000000	AC under voltage		X *1
b28	10000000	DC under voltage		X *1
b27	08000000	AC voltage below startup level		X *1
b26	04000000	DC voltage below startup level		X *1
b25	02000000	AC voltage above U_{min2}		X *1
b24	01000000	DC voltage above U_{min2}		X *1
b23 … b18	-	always 0 (reserved for future use)		
b17	00020000	Change of the supply system (Traction Type - C.5.3)	X	
b16	00010000	Change of the Consumption Point ID (C.1.9)	X	
b15	00008000	Status word has been recorded before the last clock synchronization	X	X
b14	00004000	Load profile memory was completely deleted	X	X
b13	00002000	Logbook was completely deleted		X
b12 … b9	-	always 0 (reserved for future use)		
b8	00000100	(At least) one configuration variable was changed by setting		X
b7	00000080	Failure of the supply voltage of the EM4TII+	X	X
b6	00000040	recovery of the supply voltage of the EM4TII+ (always captured in the load profile synchronously to capture periods)	X	X
b5	00000020	device clock was set	X	X
b4	-	always 0 (reserved for future use)		
b3	00000008	season change occurred (summer time to winter time or vice versa)	X	
b2	00000004	Measurement period are incomplete (due to asynchronous start of period)	X	
b1	00000002	power reserve of the device clock is depleted	X	
b0	00000001	fatal device error (legal metrological error)	X	X

Table 4.5: Status word bit coding

The header is followed by sets of nine (for standard version) measuring values until the next event generates a new header.
In the standard version the following values are recorded in the load profile:

- C.1.9 Consumption Point ID (according to EN 50463-1:2017), a max. 32 ASCII characters comprehensive text string

- C.5.1 Status of this load profile entry ("Quality flag" according to EN 50463-3), three bytes in the following code:

1) Status of the time indication (based on the EBIX system):
3DXXXX invalid time information (in case of failure) or time adjustment within the measurement period to more than two seconds
7FXXXX valid time
Note: Time indication status of 38XXXX isn't supported according to EN50463:2017 anymore. Instead 3DXXXX will be recorded

2) Status of the energy indication (based on the EBIX system):
XX2EXX replacement value, measured energy value does not exist
XX3DXX invalid energy indication (in case of failure)
XX7FXX valid (measured) energy value

3) Status of location information (based on the EBIX system):
XXXX2E no location information available (incorrect or no GPS receiver)
XXXX3D location uncertain, last reception of GPS information more than 15 seconds before the entry of the load profile
XXXX7F valid location information

- C.5.3 Traction system ("traction type flag" according to EN 50463-3:2017), which is a combination of frequency and voltage detection.
  A system is detected only when voltage and frequency match the expected combination. E.g. detection of one parameter only or conflicting detections are flagged as "undefined system".
  Traction type detection with bit code according to previous version (EM4TII) is available on special request (register name: C.5.2).
  Traction type detection is based on measurement on channel 1 and in case of ACDC-configuration on channel 1 and 3

	C.5.3 value	Meaning
	00	Undefined, no System recognized
	01	AC System 2: 25kV, 50Hz recognized
	02	AC System 1: 15kV, 16.7Hz recognized
	03	DC System 3: voltage 3000V recognized
	04	DC System 2: voltage 1500V recognized
	05	DC System 1: voltage 600V ... 750V

- 0.9.17 Location (latitude ± DD.XXXXX) at the end of the registration period with
  ±DD = degrees (positive: north, negative: south)
  XXXXX = decimal degrees

- 0.9.18 Location (longitude ± DDD.XXXXX) at the end of the registration period with
  ±DDD = degrees (positive: east, negative: west)
  XXXXX = decimal degrees

  Note: Location output format has been changed according to the requirements of the standard EN 50463:2017. The input format of coordinates according to NMEA0183 is still accepted with the old format "DDMM.XXXX"

- 1.29.0 energy feed (delta value) of positive active energy

- 2.29.0 energy feed (delta value) of negative active energy

- 3.29.0 energy feed (delta value) of positive reactive energy

- 4.29.0 energy feed (delta value) of negative reactive energy

4.2.7 Recognition of the traction power system

The EM4TII+ recognizes the currently applied traction power system.

A traction power system is in this sense always understood as a combination of the supply frequency (DC or AC-frequency) and the supply voltage.

Rated voltage values (according to EN 50163:2004) of 600V/750V (DC), 1500V (DC), 3000V (DC), 15.000V (16.7 Hz AC), and 25.000V (50Hz AC) can be distinguished.

Tolerances between Umin1 and Umax2 according to EN 50163 are considered as valid for the permanent operation, except for 750V networks where U_{max1} limit is kept in order not to have an overlap with U_{min1} from the 1500V network.

Note:
According to the tolerances defined in EN 50163 for permanent operation, a distinction between the nominal voltages 600V and 750V (DC) is not possible in this context.

In addition to the detection of voltage system, the EM4TII+ recognizes the currently applied supply frequency. For AC frequencies a valid deviation from the nominal frequencies defined in EN 50163 in a range of ± 9% is assumed.

A system is detected only when voltage and frequency match the expected combination. E.g. detection of frequency without voltage or AC voltage without matching frequency is flagged as “undefined system”

To avoid unnecessary detection of short-term irregular supply situations in this context, the applied traction system is recognized basically with a bounce time of 10s. This applies both in recognizing the power system after idle state (i.e. after the operation without recognized traction power system) and after a change in the system for multi-system vehicles. After such a system change, the previously recognized system is assumed immediately to be no longer active after recognition of the new system. In this respect, it is ensured that in normal operation only one system is recognized as valid.

Note:
"Lab situations”, such as the simultaneous operation with AC and DC, may cause detection of two systems simultaneously, according to the former traction type definition C.5.2.
According to the new traction type definition (EN 50463-3:2017) conflicting detections are flagged as “undefined system”.
Damage to the EM4TII+ is impossible in such a case, if the maximum input values of voltage and current for the specific device design are not exceeded.

The first occurrence of one of the following events causes a previously recognized traction system to be assumed as no longer active:

- change to a different system (see above)
- a loss of a valid frequency detection, if previously an AC system has been detected
- a decrease of the traction supply voltage below U_{min1} (to EN 50163) for more than 120 seconds if previously a valid supply system has been detected
  (Note: The duration of 120 seconds corresponds to the regulations of EN 50163)
- a decrease in the supply voltage below 30% of the previously detected supply voltage

On the display of the EM4TII+ a flag signalizes the current supply frequency (DC, 16.7 Hz, 50 Hz or 60 Hz) in the case of a detected traction system.

Furthermore, in the billing load profile and in the logbook of EM4TII+ any change of the traction system is stored with the seconds-accurate timestamp.
This includes any change (in multi-system vehicles), and the achievement and leaving of any traction system according to EN 50163.

4.2.8 Error register (F.F)

In the error register the error code is stored due to a device error.
Each of these causes lead to setting of the status "fatal device error" in the status word of the load profile and the logbook.

Bit	hexadecimal encoding	Meaning
b31	-	always 0 (reserved for future use)
...	...	
b14		
b13	00002000	Failure to initialize the register structure
b12	00001000	Failure to initialize the display output lists
b11	00000800	Failure to initialize the ROM memory
b10	00000400	Error in the memory area of the OBIS code
b9	00000200	Error in the configuration area
b8	00000100	Error in calibration area
b7	-	always 0 (reserved for future use)
b6		
b5	00000020	Error in data transfer from the flash memory
b4	00000010	Error in data transfer in the flash memory
b3	00000008	Error in the checksum in the calibration parameters
b2	00000004	Error in the checksum in the firmware code
b1	00000002	Error in the checksum in the configuration variables
b0	00000001	Error in the checksum in the parameterization variables

Table 4.6: Error register

4.2.9 Examples of read-outs from the EM4TII+

The following examples of read-outs illustrate how data and parameters are accessed from the EM4TII+. Note that details in the communication might be realised differently in a specific device.

Blue Data to the meter,
Green Data back from the meter.

1) Read-out from read-out table 1:

```
/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>050<CR><LF>
<STX>1-0:1.8.0*255(000000000.0*kWh)<CR><LF>
1-0:2.8.0*255(000000000.0*kWh)<CR><LF>
1-0:3.8.0*255(000000000.0*kvarh)<CR><LF>
1-0:4.8.0*255(000000000.0*kvarh)<CR><LF>
0-0:F.F.0*255(00000000)<CR><LF>
1-0:0.0.1*255()<CR><LF>
1-0:0.2.0*255(10600000)<CR><LF>
1-0:0.9.1*255(140253)<CR><LF>
1-0:0.9.2*255(121221)<CR><LF>
0-0:C.1.0*255(03878504)<CR><LF>
0-0:C.72.1*255()<CR><LF>
0-0:C.72.2*255()<CR><LF>
1-0:0.8.4*255(5*min)<CR><LF>
1-0:0.3.0*255(6.00*Imp/kWh)<CR><LF>
1-0:0.2.1*1(121120??)<CR><LF>
1-0:0.2.1*50(121120??)<CR><LF>
0-0:C.90.2*255(9F139CC2)<CR><LF>
1-0:C.1.9*255(Point-ID)<CR><LF>
!<CR><LF>
<ETX>+
<SOH>B0<ETX>q
```

2) Reading of date and time with commands 0.9.2 and 0.9.1 (for ex. on 03.01.2013 at 10:14:15 h):

```
/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>051<CR><LF>
<SOH>P0<STX>()<ETX>`
<SOH>P1<STX>(00000000)<ETX>a
<ACK>
<SOH>R5<STX>0.9.2()<ETX>\
<STX>0.9.2(130103)<ETX>9
<SOH>R5<STX>0.9.1()<ETX>_
<STX>0.9.1(101415)<ETX>:
<SOH>B0<ETX>q
```

3) Writing of date and time:

```
/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>051<CR><LF>
<SOH>P0<STX>()<ETX>`
<SOH>P1<STX>(00000000)<ETX>a
<ACK>
<SOH>W5<STX>1-0:0.9.129*255(1301031605000002)(00000000)<ETX>^
<ACK>
<SOH>B0<ETX>q
```

4) Reading of the load profile beginning at 03.01.2013 at 11:00 h:

/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>051<CR><LF>
<SOH>P0<STX>()<ETX>`
<SOH>P1<STX>(00000000)<ETX>a
<ACK>
<SOH>R5<STX>P.01(1301031100;)<ETX>#
<STX>P.01(130103110500)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)
(kWh)(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F2E)(00)(+00.00000)(+000.00000)(00000.0)(00000.0)(00000.0)(00000.0)<CR><LF>
P.01(130103110553)(00000080)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F2E)(00)(+00.00000)(+000.00000)(00000.0)(00000.0)(00000.0)(00000.0)<CR><LF>
P.01(130103111000)(00000040)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F2E)(00)(+00.00000)(+000.00000)(00000.0)(00000.0)(00000.0)(00000.0)<CR><LF>
P.01(130103111500)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F2E)(40)(+00.00000)(+000.00000) (00000.0)(00000.0)(00000.0)(00000.0)<CR><LF>
P.01(130103112000)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F2E)(40)(+00.00000)(+000.00000)(00005.6)(00000.0)(00001.5)(00000.0)<CR><LF>
P.01(130103112500)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F7F)(40)(+53.99050)(+009.99670)(00028.1)(00000.0)(00007.5)(00000.0)<CR><LF>
P.01(130103113000)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F7F)(40)(+53.96860)(+010.01483)(00080.4)(00000.0)(00021.5)(00000.0)<CR><LF>
P.01(130103113500)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F7F)(40)(+53.93360)(+010.02900)(00080.5)(00000.0)(00021.5)(00000.0)<CR><LF>
P.01(130103114000)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F7F)(40)(+53.87300)(+010.03870)(00080.4)(00000.0)(00021.5)(00000.0)<CR><LF>
P.01(130103114500)(00000000)(5)(9)(C.1.9)()(C.5.1)()(C.5.3)()(0.9.17)()(0.9.18)()(1.29.0)(kWh)(2.29.0)(kWh)
(3.29.0)(kvarh)(4.29.0)(kvarh)<CR><LF>
(0004916097866601)(7F7F7F)(40)(+53.82730)(+010.02458)(00080.5)(00000.0)(00021.5)(00000.0)<CR><LF>
<ETX><BCC>
<SOH>B0<ETX>q

Note the different quality flag values reported by OBIS code C.5.1: the first entries are marked with “no location available“ (7F7F2E), the others with “valid location information” (7F7F7F)

Note: System change
The device is suitable for multi-system locomotives as it is designed for measuring DC and / or AC voltages.
A system change is always detected and triggers the re-start of the capture period for the load profile.

5) Reading of a single register (1.8.0 as example):
/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>051<CR><LF>
<SOH>P0<STX>()<ETX>`
<SOH>P1<STX>(00000000)<ETX>a
<ACK>
<SOH>R5<STX>0:1.8.0()<ETX>^
<STX>0:1.8.0(0955760.30*kWh)<ETX>P
<SOH>B0<ETX>q

6) Reading of the time with 0.9.1 command:
/?!<CR><LF>
/EMH5\@D4EM4TIIW001--<CR><LF>
<ACK>051<CR><LF>
<SOH>P0<STX>()<ETX>`
<SOH>P1<STX>(00000000)<ETX>a
<ACK>
<SOH>R5<STX>0.9.1()<ETX>_
<STX>0.9.1(104106)<ETX>8
<SOH>B0<ETX>q

4.3 Data input for GPS receiver connection

The EM4TII+ is equipped optionally with a dedicated serial input (RS232 type) to be connected to a GPS receiver system. The output signal of this interface (TX) is not used and can be left unconnected.

On this interface, an RMC (Recommended Minimum Sentence C) data set according to NMEA 0183 sent with 4800 Baud is expected by the EM4TII+ every second or 2 seconds (max).

The location information contained in these GPS data sets are used in the formation of the load profile. The input format of coordinates according to NMEA0183 is still accepted with the old format “DDMM.XXXX”

The EM4TII+ evaluates from the GPS receiver the dataset “$GPRMC” entities only.
Other datasets are ignored. Nevertheless, other datasets should be limited to avoid a buffer overflow. A data connection with 4800 Baud can transfer 480 characters per second. If possible, avoid sending more than 240 characters per second.

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

5. Maintenance

The meter is maintenance-free. With damages (e.g. caused by transportation or storage) no repairs may be carried out. Once the meter has been opened, all warranty claims cease. This also applies if a defect can be traced back to external influences (e.g. fire, extreme temperature- and weather conditions, incorrect or careless use or treatment).

The battery (Li-$SOCl_2$ technology, 3.6V, non-rechargeable) must be replaced when the cursor “CLK” appears in the display. The user must not perform this replacement. A replacement of the battery is recommended during every re-verification process or after 10 years operation.

The data retention time of the flash memory (non-volatile) is at least 10 years.

Please note that the re-verification period of the EM4TII+ may be subject to national or international legal requirements. Recommended re-verification period is at least 8 years.

6. Measurement

6.1 Measuring principle

The load profiles are recorded in datasets at parameterized intervals.

The measuring circuit comprises a Sigma Delta ADC for each measuring channel which enables simultaneous capturing of measured values at a sample rate of 4800 Hz. The Sigma Delta method effectively suppresses high-frequency interference on the channels.
The microprocessor reads in the sampled values and calculates the active power and active energy over adjustable intervals (standard value = 5 min). The datasets are backed up in Flash memories.

The supply voltage can be selected between 24 and 110V as per EN 50155. Optionally a communication unit (modem) can be supplied with voltage of 12 V via the EM4TII+.

6.2 Formula: generation of measured values

Measured values are generated at one second intervals from 4800 sample values:

Effective voltage value

$$U_{eff,1s} = \sqrt{\frac{\sum_{n=1}^{N} u_n^2}{N}} = \sqrt{\frac{\sum_{n=1}^{4800} u_n^2}{4800}}$$

Effective current value

$$I_{eff,1s} = \sqrt{\frac{\sum_{n=1}^{4800} i_n^2}{4800}}$$

Active power

$$P = \frac{1}{4800} \sum_{n=1}^{4800} u_n \cdot i_n$$

Reactive power

$$Q = \frac{1}{4800} \sum_{n=1}^{4800} u90_n \cdot i_n$$

u_n : Sample value for voltage at time point n
$u90_n$: Sample value for voltage at time point n shifted by 90°
i_n : Sample value for current at time point n
N : Interval of the measuring period from N sample values (4800Hz sample rate)

7. Technical data

7.1 General specifications

Measuring input channels	4 galvanic isolated inputs for connection of U- and I-sensors (either for AC, DC or ACDC), or for connection of one U-sensor (DC) and up to three I-sensors (DCDCDC)
Ranges for rated input values Rated voltage (secondary) Rated current (secondary)	 AC: 70 – 300 V or 17,9 – 100 mA DC: 17,9 – 100 mA AC: 50 – 2000 mA or 5A DC: 50 – 2000 mA
Accuracy	Class 0,5 R (acc. to EN 50463-2) for ranges specified in the line above. In case of rated input values out these limits or for a multi-system energy meter the class accuracy may be higher (0,75R or 1,0R).
Frequency	DC, 16,7 Hz, 50Hz and 60 Hz
Sampling interval	4800 Hz
ADC resolution	16 Bit
Load profile	Recording of consumed and regenerated active and reactive energy, units kWh or kvarh Recording period length min. 1 minute Recording of location and status information according to EN 50463-3 Memory depth at least 300 days for 5-minute period length (60 days for 1 minute period length)
Clock accuracy	< 20 ppm
Interfaces	1 x RS-interface (bidirectional, RS232, RS422 or RS485) with 2 connections in parallel (screw terminals and pin header), e.g. for modem connection; data protocol according to EN 50463-3 and IEC 62056-21. 1 x RS232 (unidirectional) for registration of GPS-data telegrams according to NMEA 0183
Display	LCD, self-luminous, letter height approx. 4 mm
Degree of protection	IP 65
Supply voltage	24 – 48 or 72 – 110 V (according to EN 50155), Power consumption (without modem) 3 W, Inrush current 500 mA max (without modem supply)
Supply voltage for modem (optional)	12 V continuous load 3W, peak value 6W Daily modem reset by EM4TII+
Temperature ranges	Operating temperature: -40 °C – +75 °C (limited legibility of the display screen is to be expected between –40 °C and –30 °C) Storage temperature: -40 °C – +85 °C
Altitude range Application area	EN 50125-1:2014: Class A1 (max. 1400m)
Connections	Terminal blocks inside the device
Dimensions	165 x 289 x 70 mm (W x H x D)
Weight	approx. 1,5 kg

7.2 Applied standards and regulations

EN 50463:2017	Railway application – Energy measurement on board trains
EN 50115:2017	Railway applications – Electronic equipment used on rolling stock
EN 50121-3-2: 2016	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock – Apparatus
EN 61373:2010	Railway applications - Rolling stock equipment - Shock and vibration tests
EN 50124-1: 2017	Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment
IEC 62056-21:2002	Electricity metering - Data exchange for meter reading, tariff and load control - Part 21: Direct local data exchange
EN 50163:2004/A1:2007	Railway applications - Supply voltages of traction systems