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INTERNATIONAL STANDARD

Information technology – Home electronic system (HES) architecture – Part 3-5: Media and media dependent layers – Powerline for network based control of HES Class 1

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FOREWORD

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International Standard ISO/IEC 14543-3-5 was prepared by subcommittee 25: Interconnection of information technology equipment, of ISO/IEC joint technical committee 1: Information technology.

This International Standard is a product family standard. It shall be used in conjunction with ISO/IEC 14543-2-1, 14543-3-1, 14543-3-2, 14543-3-3, 14543-3-4, 14543-3-6 and 14543-3-7.

The list of all currently available parts of the ISO/IEC 14543 series, under the general title *Information technology – Home electronic system (HES) architecture,* can be found on the IEC web site.

This International Standard has been approved by vote of the member bodies, and the voting results may be obtained from the address given on the second title page.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

INTRODUCTION

The Reference model for Open System Interconnection (OSI), specified in ISO/IEC 7498, assigns the functions that are needed for communications between two entities that are connected by a medium to seven logical layers. This International Standard specifies interconnection of entities used for home and building control via the medium powerline. It specifies the medium dependent functions, that is the mains characteristics and the transmission technology in terms of the Physical Layer and the Data Link Layer, according to ISO/IEC 7498.

Currently, ISO/IEC 14543, *Information technology – Home Electronic System (HES) architecture*, consists of the following parts:

Part 2-1: *Introduction and device modularity*
Part 3-1: *Communication layers – Application layer for network based control of HES Class 1*
Part 3-2: *Communication layers – Transport, network and general parts of data link layer for network based control of HES Class 1*
Part 3-3: *User process for network based control of HES Class 1*
Part 3-4: *System management – Management procedures for network based control of HES Class 1*
Part 3-5: *Media and media dependent layers – Powerline for network based control of HES Class 1*
Part 3-6: *Media and media dependent layers – Twisted pair for network based control of HES Class 1*
Part 3-7: *Media and media dependent layers – Radio frequency for network based control of HES Class 1*
Part 4: *Home and building automation in a mixed-use building (technical report)*
Part 5-1: *Intelligent grouping and resource sharing for HES Class 2 and Class 3 – Core protocol (under consideration)*
Part 5-2: *Intelligent grouping and resource sharing for HES Class 2 and Class 3 – Device certification (under consideration)*

Additional parts may be added at a later date.

INFORMATION TECHNOLOGY – HOME ELECTRONIC SYSTEM (HES) ARCHITECTURE –

Part 3-5: Media and media dependent layers – Powerline for network based control of HES Class 1

1 Scope

This part of ISO/IEC 14543 defines the mandatory and optional requirements for the medium specific Physical and Data Link Layer of Powerline Class 1 in its two variations PL110 and PL132.

NOTE Data Link Layer interface and general definitions, which are medium independent, are given in ISO/IEC 14543-3-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 14543-2-1, *Information technology – Home Electronic System (HES) architecture – Part 2-1: Introduction and device modularity*

ISO/IEC 14543-3-1, *Information technology – Home Electronic System (HES) architecture – Part 3-1: Communication layers – Application layer for network based control of HES Class 1*

ISO/IEC 14543-3-2, *Information technology – Home Electronic System (HES) architecture – Part 3-2: Communication layers – Transport, network and general parts of data link layer for network based control of HES Class 1*

ISO/IEC 14543-3-3, *Information technology – Home Electronic System (HES) architecture – Part 3-3: User process for network based control of HES Class 1*

ISO/IEC 14543-3-4, *Information technology – Home Electronic System (HES) architecture – Part 3-4: System management – Management procedures for network based control of HES Class 1*

ISO/IEC 14543-3-6, *Information technology – Home Electronic System (HES) architecture – Part 3-6: Media and media dependent layers – Twisted pair for network based control of HES Class 1*

ISO/IEC 14543-3-7, *Information technology – Home Electronic System (HES) architecture – Part 3-6: Media and media dependent layers – Radio frequency for network based control of HES Class 1*

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

EN 50065-1, *Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances*

EN 50065-7, *Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz – Part 7: Equipment impedance*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this International Standard the definitions given in ISO/IEC 14543-2-1 (some of which are repeated below for convenience) and the following apply.

3.1.1
differential mode
PL signals are injected between phase and neutral

3.1.2
router
connects one sub-network to another sub-network

3.1.3
PL110
powerline signalling operating in a frequency band of 95 kHz to 125 kHz according to EN 50065-1

3.1.4
PL132
powerline signalling operating in a frequency band of 125 kHz to 140 kHz according to EN 50065-1

3.2 Abbreviations

ACK	acknowledgement
APDU	Application Layer Protocol Data Unit
CS	Check Sequence
CSMA	Carrier Sense Multiple Access protocol
CTRL	Control field
DAF	Destination Address Flag
DOA	Domain Address
FCS	Frame Check Sequence
FEC	Forward Error Correction
FSK	Frequency Shift Keying
HES Class 1	refers to simple control and command
HES Class 2	refers to Class 1 plus simple voice and stable picture transmission
HES Class 3	refers to Class 2 plus complex video transfers
LPDU	Link Layer Protocol Data Unit
MAU	Medium Attachment Unit
MSK	Minimum Shift Keying
NACK	Not acknowledge
NPCI	Network Protocol Control Information
NRZ	No Return to Zero
PL	Powerline
SPD	Surge Protection Devices
TPDU	Transport Layer Protocol Data Unit
SFSK	Spread Frequency Shift Keying

4 Conformance

A device conforming to this International Standard shall support the physical medium as specified in clause 5 or clause 7, and it shall provide transmission capability as specified in clause 6.

5 Requirements for HES Class 1, PL110

5.1 Physical Layer PL110

5.1.1 General

This clause describes the physical layer characteristics of the PL110 powerline signalling which operates in the frequency band (95 to 125) kHz band as described in EN 50065-1 and which has a nominal centre frequency of 110 kHz.

The main characteristics of PL110 physical layer are:

- a spread frequency shift keying signalling;
- asynchronous transmission of data packets;
- symbols globally synchronised to the mains frequency;
- half duplex bi-directional communication.

Electrical wiring in the building/home shall be in compliance with the current national regulations. Powerline communication is described in EN 50065-1.

The electric power distribution network normally determines the physical topology of the powerline network. The structure of this network may be single phase or three phase. The rated voltage between one phase and neutral shall be 110 V and 230 V, respectively. PL110 signals are injected between phase and neutral.

General requirements for the physical layer type PL110 are given in Table 1.

Table 1 – General requirements for physical layer PL110

Characteristics	Description
Medium	Electrical power distribution network
Topology	Installation dependant (e.g., linear, star, tree)
Bit rate	1 200 bit/s
Mains frequency	50 Hz and 60 Hz, respectively
Number of Domain Addresses	255
Number of Individual Addresses	32 767
Modulation type	Spread frequency shift keying (SFSK)
Frequency for logical 0	105,6 kHz ± 0,1%
Frequency for logical 1	115,2 kHz ± 0,1%
Bit duration	833,3 µs
Maximum output level	122 dB µV [a]
Input sensitivity	≤60 dB µV [b]
Device class	Class 122[c]
Compliance to standards	EN 50065-1

[a] Measurement according to EN 50065-1.

[b] With artificial network according to CISPR 16-1-1 [(50 µH + 5 Ω) / 50 Ω].

[c] Equipment manufactured in accordance with class 116 according to EN 50065-1 will now meet the requirements of Class 122 and may be marked Class 116 provided that its output complies with the previous standard.

The logical structure of the physical layer PL110 entity is shown in Figure 1. Each PL110-device includes one physical layer PL110 entity.

The PL110 entity shall consist of three blocks:

- connector;
- medium attachment unit (MAU);
- error correction.

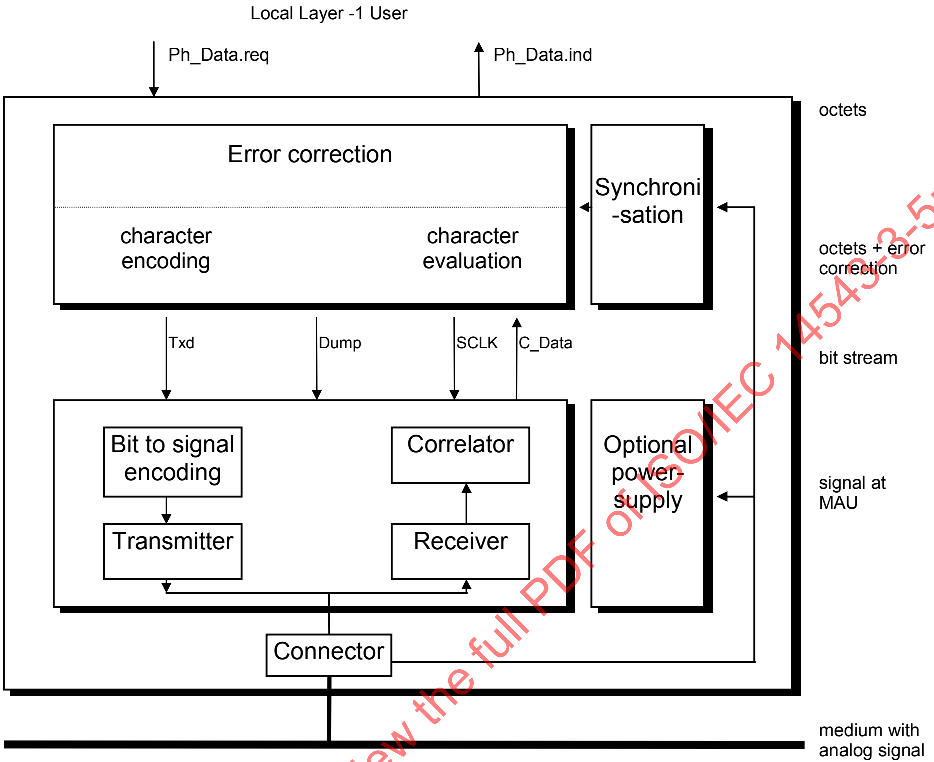


Figure 1 – Structure of the MAU (example)

5.1.2 Transmission medium

5.1.2.1 Requirements for protection against electric shocks and connectors

The PL110 devices are connected to the mains installation network. The requirements for protection against electric shocks for human beings (and animals) and connectors shall be considered within the assembled device. They are not subject to the physical layer description.

These requirements are specified in the installation and equipment standards (safety standards).

5.1.2.2 Powerline cables

The requirements for powerline cables are defined by the use as installation wires according to national regulations. Normally, the type of cable, the connected loads and the topology of the network is not known. In contrast to the theoretical values of typical cable characteristics, for example as specified in IEC 60227-4 and IEC 60502-1, the impedance at one network access point is determined more by the connected load than by the cabling.

Typical cables for fixed electrical installation are “thermoplastic-insulated and sheathed cable”, “PC insulated flat cable, overall covering vulcanised rubber” or “sheathed metal-clad wiring cable with PVC insulated cores sheet-zinc cover with additional PVC jacket”.

NOTE The use of shielded power cables and of cables with cross-sections greater than 35 mm^2 can influence PL110 signalling significantly!

5.1.3 Medium attachment unit (MAU)

The Medium Attachment Unit converts the frequency-coded signals into values representing logical ones and zeroes and vice versa. In parallel, a power supply circuit may be connected to the medium. Signal converter and power supply shall be independent from each other. The power supply shall meet the requirements specified in Table 2.

Table 2 – Power supply of the MAU

Power supply	Nominal values
Receiving mode	5 V at 30 mA / 24 V at 1 mA
Transmitting mode	5 V at 30 mA / 24 V at 10 mA – 50 mA (dependent on impedance)

Compliance is checked by measurement.

The power supply of the MAU may be internal or external.

5.1.3.1 Signal encoding

A signal of 105,6 kHz for a period of 833,3 µs shall correspond to a logical 0, a signal of 115,2 kHz for a period of 833,3 µs to a logical 1. See Figure 2.

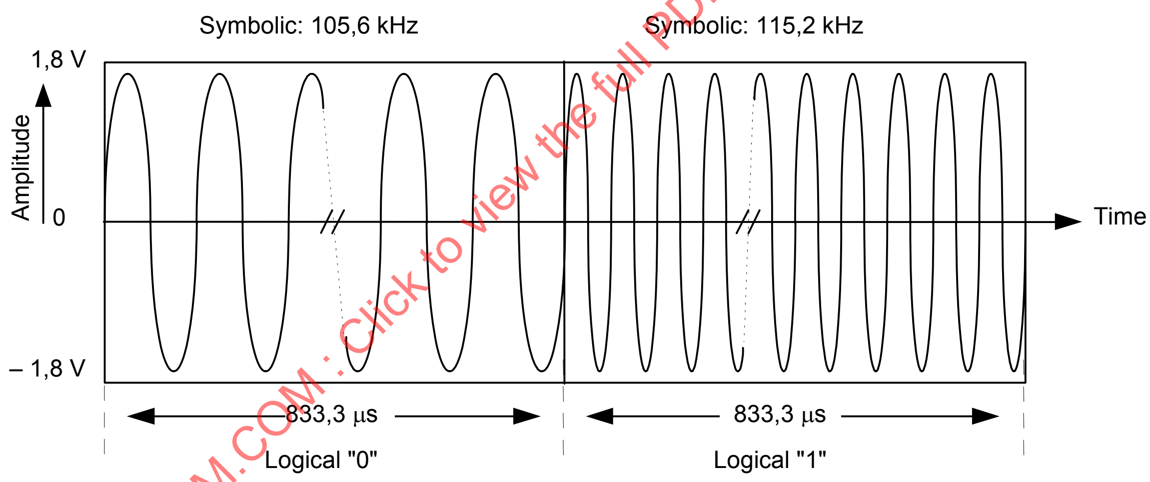


Figure 2 – Signal encoding

These NRZ signals are superimposed on the AC voltage of the mains at 50 Hz and 60 Hz, respectively. The maximum amplitude of the signal shall be limited to 122 dBµV, measured according to EN 50065-1 by using an artificial mains network as specified in CISPR 16-1-1. The sensitivity of the receiver shall exceed 60 dBµV.

For minimal disturbance, the change between adjacent symbols shall be phase continuous, as shown in Figure 2.

Compliance is checked by measurement.

5.1.3.2 Overlapping of logical 0 or 1

Overlapping of logical 0 or 1 symbols, for example, the simultaneous transmission of equal information at the same time from several MAUs (e.g., common ACK), results in fade-in / fade-out effects. Due to slight frequency deviations between several MAUs, the signal fades periodically with the difference of the MAU frequencies. In PL110 powerline communication this case can be avoided by setting a unique group response flag to each assigned group address.

5.1.3.3 Overlapping of logical 0 and 1

Overlapping of logical 0 and 1 symbols, for example, the simultaneous transmission of different information at the same time from several MAUs, results in a collision. While there is no indication of collision for any MAU, the probability of this state is minimised by a special bus access mechanism.

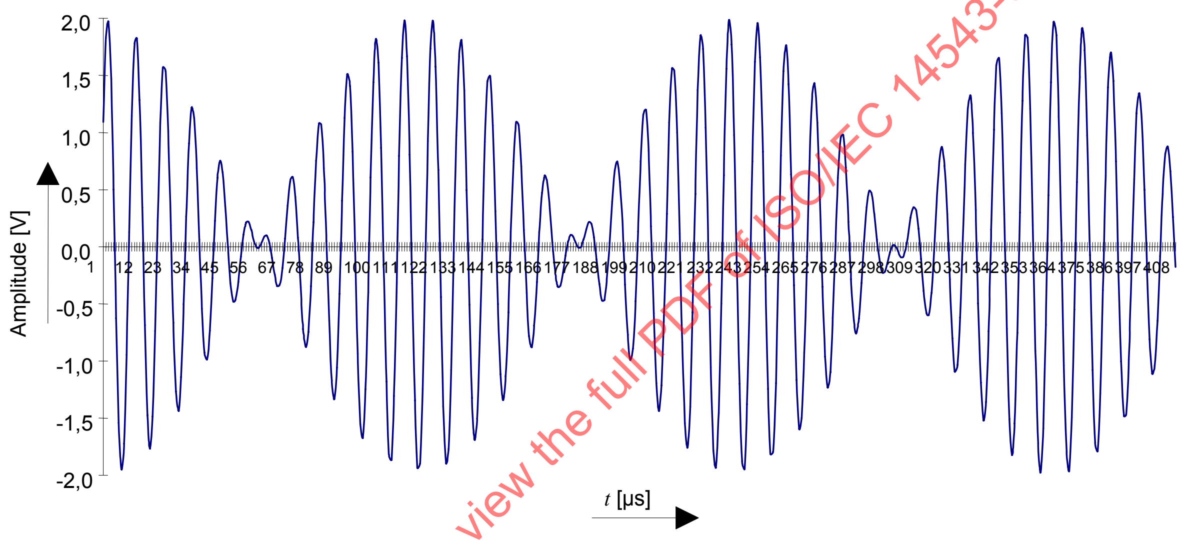


Figure 3 – Idealised overlapping of 105,6 kHz and 115,2 kHz

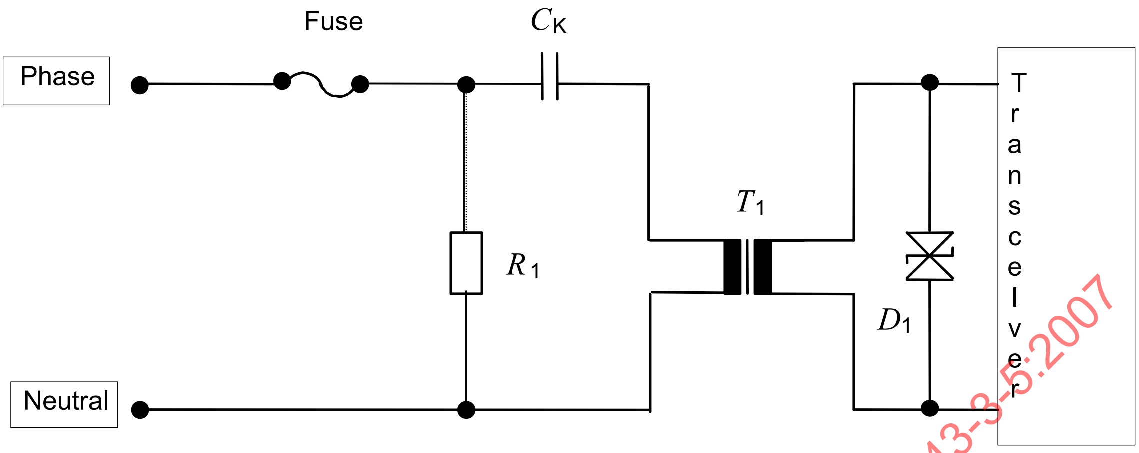
5.1.3.4 Impedance of the MAU

To limit the influence of connected MAUs on the characteristic of the powerline bus the impedance in receiving mode shall be high. For signal injection with minimum losses, the impedance in transmitting mode shall be low. When tested according to EN 50065-7, the limits for PL110 shall be:

Table 3 – Requirements for the impedance of the MAU

Impedance on	Requirements
Receiving mode	$\lvert Z_{in} \rvert \geq 80\ \Omega$ at 100 kHz to 125 kHz
Transmitting mode	$\lvert Z_{out} \rvert \leq 20\ \Omega$ at 100 kHz to 125 kHz

5.1.3.5 PL bus coupling



Legend:

C_K: coupling capacitor, X2-type
T_1: coupling transformer
D_1: transient voltage protection diode
R_1: resistor for discharging C_K (optional)

Figure 4 – Example of a PL inductive coupling circuit

Electrical coupling of signals to the powerline is done by special circuits. In general, capacitive or inductive coupling may be used. Inductive coupling may be or may not be combined with electrical insulation.

5.1.4 Installation topology

The structure of an electrical installation is either linear, star, ring, tree, or any combination thereof. Referring to the electrical distribution board as the centre, the topology normally has a star structure. Each branch of the electrical distribution network may have its own different structure.

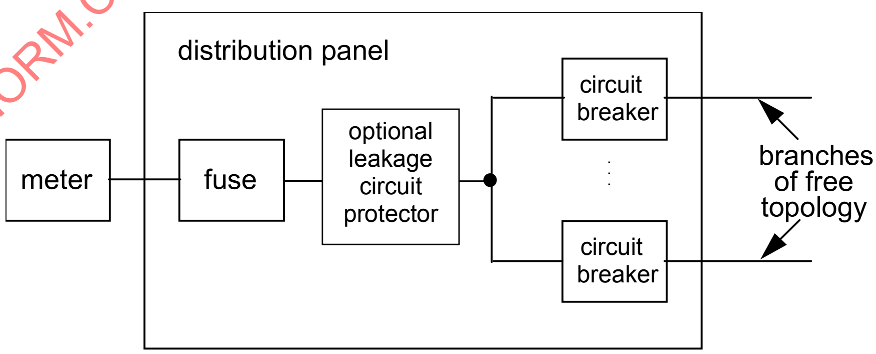


Figure 5 – Example of a typical PL topology

5.1.5 Installation requirements

The installation of the powerline network is subject to national and international regulations and standards. Additional instructions about the communication aspects of the network may be given in the manufacturer's instruction sheet.

5.1.6 Surge protection

The electrical installation may or may not be provided with external surge protection. Where external SPD is provided it shall comply with type 1 (for primary protection) or type 2 (for secondary protection).

NOTE Type 1 and type 2 protection will be specified in forthcoming IEC 61643-11 (see bibliography).

5.1.7 Services at the data link layer / physical layer interface

Two services Ph_Data.req (p_class, p_data) and Ph_Data.ind (p_class, p_data) shall be implemented at the data link / physical layer interface.

Ph_Data.req shall be called by the data link layer. Each Ph_Data.req() service primitive shall transfer a single octet to the physical layer. The class parameter shall contain timing information.

p_class:	start_of_sys.prio_frame:	This parameter value shall be used to transmit training sequence, preamble I, preamble II and character after at least 58 bit times idle line since the last bit of the preceding data link message cycle.
	start_of_prio_frame:	This parameter value shall be used to transmit training sequence, preamble I, preamble II and character after at least 74 + (n-16) $\mid 0 \leq n \leq 7$ bit times idle line since the last bit of the preceding data link message cycle.
	start_of_repeated_frame:	This parameter value shall be used to transmit training sequence, preamble I, preamble II and character after exactly 40 bit times since the last bit of the preceding L_Data request.
	inner_frame_char:	This parameter value shall be used to transmit a character without any time gap after the last bit of the preceding character.
	ack_char:	This parameter value shall be used to transmit training sequence, preamble I, preamble II and character after exactly 4 bit times after the last bit of the preceding L_Data request.
	nack_char:	This parameter value shall be used to transmit training sequence, preamble I, preamble II and character after exactly 22 bit times after the last bit of the preceding L_Data request.
p_data:	octet:	This parameter value shall contain the octet to be expanded by forward error correction to a character to be transmitted. Due to the fact that no collision-detection is carried out during transmission the return value of a Ph_Data.con shall always be "OK".

Ph_Data.ind shall be called by the physical layer. Each Ph_Data.ind() service primitive shall transfer a single octet to the data link layer.

Ph_Data.ind (p_class, p_data)

p_class:	start_of_frame:	This parameter value shall be used to indicate that after detection of preamble I and preamble II a character was received.
	inner_frame_char:	This parameter value shall be used to indicate that a character was received immediately after the preceding bit.
	ack_char:	This parameter value shall be used to indicate that after detection of preamble I and preamble II a character was received.
	bit_error:	This parameter value shall be used to indicate that an uncorrectable bit error was detected in the received character and that reception was terminated.
p_data:	octet:	This parameter value shall be used to indicate that the data octet error was corrected and extracted from the received character.

5.1.8 Features of PL110 physical layer

5.1.8.1 General

This subclause describes the frame format, error correction and synchronization of PL110 medium. Compliance to the requirements of this subclause are subject to transient and logical measurement equipment.

5.1.8.2 PL110 character overview

Each PL110 frame shall start with a training sequence and a preamble. Training sequence and preamble shall not be coded. Each Data Link layer octet shall be coded to a 12 bit character (8 bits data + 4 bits error correction).

Transmission direction ←

7	6	5	4	3	2	1	0	E 3	E 2	E 1	E 0
Octet								Error Correction			

Figure 6 – Character

During transmission and reception no time gaps are allowed between the bits of a character.

5.1.8.3 Frame structure

The datagram shall consist of training sequence, preamble I and preamble II, LPDU, and Check Sequence (CS) and the Domain Address. Frame Check Sequence shall be calculated with respect to Twisted Pair type 1 LPDU (see ISO/IEC 14543-3-6), which itself shall be identical to the Twisted Pair type 1 LPDU. The CS for physical layer Twisted Pair Type 1 and PL110 shall therefore be identical.

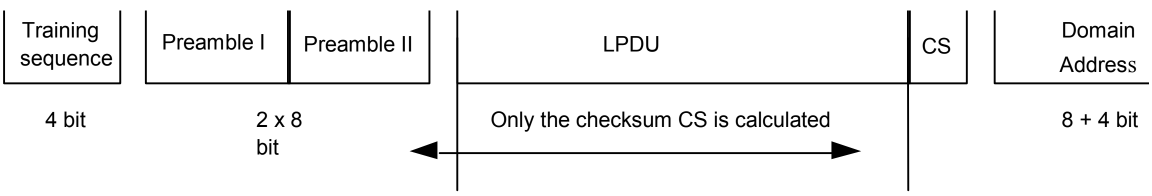


Figure 7 – Structure of a datagram

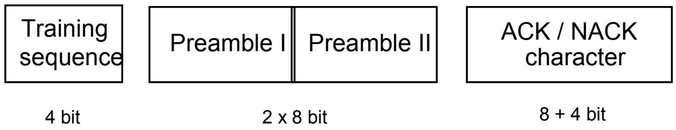


Figure 8 – Structure of an acknowledgement frame

5.1.8.4 Training sequence

After switching into the status start_of_pdu the physical layer shall transmit a training sequence of 4 bit duration. The bit sequence is fixed to [0 1 0 1].

5.1.8.5 Preamble transmission start

The next 16 bit shall consist of preamble I and preamble II. This preamble shall allow the receiver to start. The sequence of each preamble is fixed to B0h.

5.1.8.6 Faulty transmission detection

The error correction of the PL110 physical layer shall be done by powerline (12,8) block-coding. Generation shall be calculated with the following matrix:

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} E \\ T \end{bmatrix}$$

Figure 9 – Generation matrix of PL110

Coding shall result in an overhead of 4 bit referring to one octet. The hamming distance of this coding shall be a minimum of 3 characters per bit. With this (12,8) block-coding, it shall be possible to correct every single bit error in a 12 bit character and identify some multiple errors.

The code shall be calculated by determining redundancy r as the function of the transformation matrix T and the octet x:

$$r = T \cdot x$$

To decode an estimated r' of the redundancy that depends on the incoming data, d shall be performed. The estimated redundancy shall be subtracted by the received redundancy d_u. The result shall be a syndrome with the value of s indicating the column of the error. Correction shall be done by inverting this bit. For an error-free transmission the difference of r' and d_u shall be 0.

$$d = \begin{bmatrix} d_0 & d_u \end{bmatrix}^T$$

$$r' = T \cdot d_0$$

$$s = d_u - r'$$

where
T is the transformation matrix,
r is the redundancy,
x is the octet,
d is the data,
d_u is the received redundancy,
s is the value of the syndrome.

Table 4 – Table of syndromes related to errors

Value of the syndrome	3	5	6	7	9	10	11	12	8	4	2	1	13	14	15	0
Error location	1	2	3	4	5	6	7	8	9	10	11	12	error			Error-free

For all calculations, GF2 arithmetic shall be used:

a	b	$a+b$	$a \times b$	$a-b$	$\frac{a}{b}$
1	1	0	1	0	1
0	1	1	0	1	0
1	0	1	0	1	–
0	0	0	0	0	–

Figure 10 – Operations of Galois Field GF2

EXAMPLE 1

$$x := \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}^T$$ octet to be transmitted

$$r = T \cdot x = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix} \cdot x = \begin{bmatrix} 0 \\ 1 \\ 1 \\ 1 \end{bmatrix}$$ redundancy

$$c = \begin{bmatrix} x, r \end{bmatrix}^T = \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \,|\, 0 & 1 & 1 & 1 \end{bmatrix}$$ character to be transmitted

↓ Transmission error

$$d = \left[d_o, d_u\right]^T = \left[1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0 \mid 0 \quad 1 \quad 1 \quad 1\right] \qquad \text{received character}$$

$$r' = T \cdot d_o = \ldots = \left[0 \quad 0 \quad 0 \quad 1\right]^T \qquad \text{estimated redundancy}$$

$$s = d_u - r' = \left[0 \quad 1 \quad 1 \quad 0\right]^T = 6_{10}$$

Referring to Figure 12 a syndrome value of 6 shall correspond to an error in column 3. Inverting bit number 3 shall lead to the corrected frame.

5.1.8.7 Synchronization

The mains zero crossing period shall be:

- 10 ms in single phase systems and $3,\overline{3}$ ms in triple phase systems for a nominal mains frequency of 50 Hz and
- $8,\overline{3}$ ms in single phase systems and $2,\overline{7}$ ms in triple phase systems for a nominal mains frequency of 60 Hz.

By dividing the time base of $3,\overline{3}$ ms and $2,\overline{7}$ ms respectively, by an integer the set of possible bit widths (and bit rates respectively) in triple phase systems shall be calculated:

$$\text{bit rate} = n \cdot 300\,\text{bit/s} \qquad n \in N$$

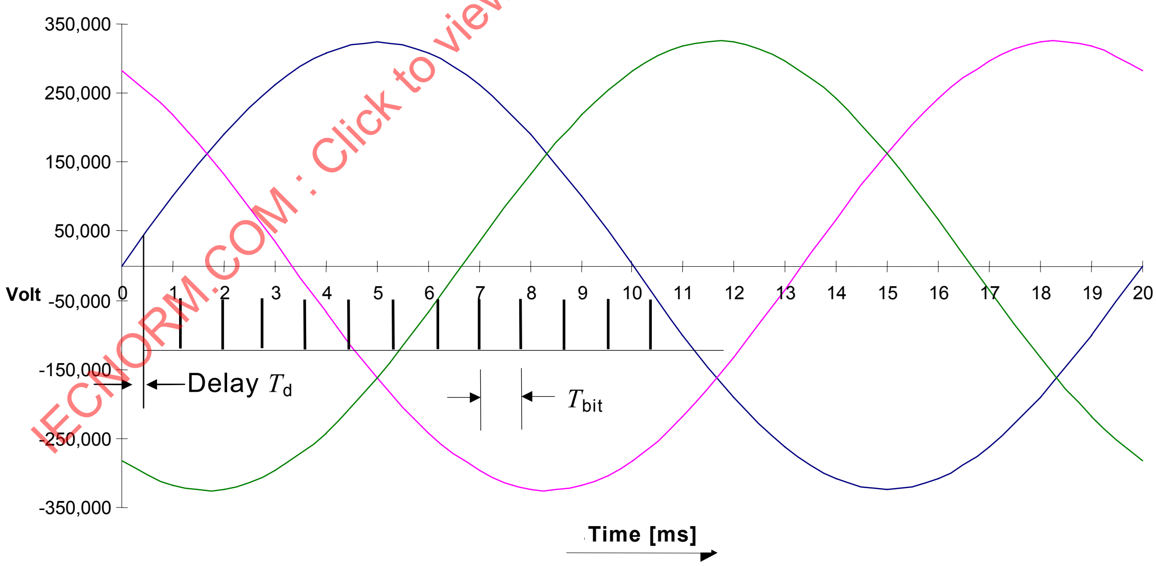


Figure 11 – Three phase system (example for 50 Hz)

The start of a transmission shall not be placed exactly at the mains zero crossing due to internal delays of the coupling circuit. The delay shall, however, not exceed the value shown below.

$$T_d \leq 40\ \mu s$$

In order to compensate deviations of mains frequencies PL110 MAUs shall detect the zero crossing of the mains voltage and measure the actual mains frequency. If the mains frequency (received in the described way) is placed within the permissible tolerance, the bit width shall be calculated by the following formula:

$$\text{actual bit width} = \frac{\dfrac{1}{\text{actual mains frequency}}}{\dfrac{1}{\text{nominal mains frequency}} * 1200}$$

With the help of the first transmitted bit the transmitter shall fix its bit width to the nominal bit width of 833,3 µs. On receiving the first preamble the receiver shall also fix its bit width to the nominal bit width of 833,3 µs and correct the beginning of the following bit by:

$12 \times$ (actual bit width − nominal bit width) for 50 Hz and

$10 \times$ (actual bit width − nominal bit width) for 60 Hz respectively.

5.2 Data link layer type PL110

5.2.1 General

This subclause describes the addressing, frame formats and access control of PL110 medium. Compliance with requirements of this subclause is subject to transient and logical measurement equipment.

5.2.2 Domain address/individual address/group address

Every PL110 device shall have a Domain Address. The Domain Address shall be a two octet number. The most significant octet shall be set to zero, the lower significant octet shall contain the number of the Domain Address.

Request frames with Domain Address zero shall be interpreted as system broadcasts.

Domain Address															
Octet 0								Octet 1							
b_7	B_6	b_5	b_4	b_3	b_2	b_1	b_0	b_7	b_6	b_5	B_4	b_3	b_2	B_1	b_0
0	0	0	0	0	0	0	0	Number							

Figure 12 – Domain Address

Every PL110 device (even a router) shall have a unique Individual Address in a network. The Individual Address shall be a two octet value that consists of an 8-bit sub-network address and an 8-bit device address.

Individual Address															
Octet 0								Octet 1							
b_7	b_6	b_5	B_4	b_3	b_2	b_1	b_0	b_7	B_6	b_5	b_4	b_3	B_2	b_1	b_0
Sub-network address								Device address							

Figure 13 – Individual Address

The most significant bit shall be the main-responder-flag. If the length of the address table is set to zero and the main-responder-flag is set, all incoming group-messages shall be acknowledged and passed to the next layer. If the main-responder-flag is not set all incoming group-messages shall remain unacknowledged and passed to the next layer.

The device address shall be unique within a sub-network. Media couplers shall have the device address zero. End devices shall have the device address 1 to 255.

The sub-network address shall be unique within a network.

The most significant bit shall be the group-responder-flag. If this bit is set all incoming messages with this destination group address shall be acknowledged. There shall be at least one end device within one network with this bit set.

The group address is a 15 bit value that shall not be unique. An end device may have more than one group address.

Every end device belongs to group zero, that is, request frames with destination group address zero shall be interpreted as broadcasts.

Group Address															
Destination Address (high)								Destination Address (low)							
Octet 0								Octet 1							
b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
	Main group				Sub-group										

Figure 14 – Group Address

5.2.3 Frame formats

5.2.3.1 General

Two frame formats shall be supported: the normal telegram frame and the acknowledgement frame. Other frame formats shall not be received. Each frame shall be sent as a sequence of characters. The character that corresponds to octet 0 shall be sent first, the octet with the highest number shall be the last character sent. The individual bits of an octet shall be sent in descending order, that is, the most significant bit (bit 7) shall be sent first. The different frame formats shall differ in the control field.

5.2.3.2 L_Data frame

Two L_Data frame formats are available on the PL110 medium. The usage of the different formats depends on the value of the frame format parameter to the link layer (see ISO/IEC 14543-3-2). The standard frame format shall be used if the frame format parameter is 0, otherwise the extended frame format is used.

5.2.3.3 L_Data_Standard frame

5.2.3.3.1 Overview

The structure of the variable length L_Data_Standard frame shall comply with Figure 15.

CTRL	SA	DA	AT, NPCI, LG	TPDU (L_Data)	FCS	DOA
8	16	16	8		8	8

Figure 15 – Format 1s, frame fields with standard fieldname abbreviations

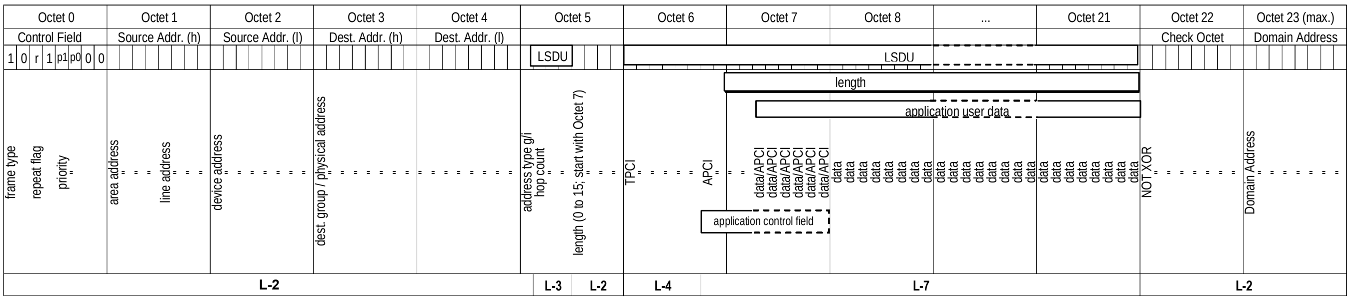


Figure 16 – Format 1s, L_Data_Standard request frame format

5.2.3.3.2 Control field (CTRL)

The first character of each frame shall be the control field. The control field shall contain information about the data link layer service, its priority, a frame type flag and a flag which indicates whether the LPDU is a repeated LPDU (see Figure 17).

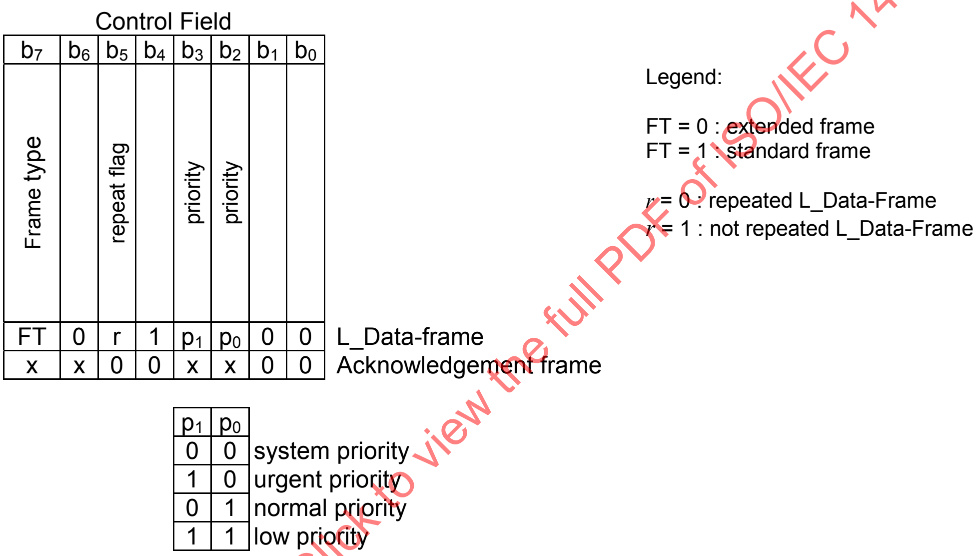


Figure 17 – Control field

The control field shall indicate the type of the request frame, L_Data_Standard, L_Data_Extended or Acknowledgement frame. The two priority bits of the CTRL field shall control the priority of the frame, when two devices start transmission simultaneously.

Repeated L_Data frames shall have the repeat_flag set to zero, non-repeated ones to one.

The control field encoding '01r0p1p000' shall not be used for future extensions of the data link layer PL110 protocol.

5.2.3.3.3 Source address (SA)

The octets one and two of a request frame shall be the high and low octet of the source address. This shall be the Individual Address of the end device that caused the transmission of the frame.

5.2.3.3.4 Destination address and address type (AT)

The destination address (octets three and four) shall define the devices that shall receive the frame. For L_Data_Standard request frames, the destination address may either be an

Individual Address (AT=0) or a group address (AT=1), depending on the destination address type (AT) of octet five.

5.2.3.3.5 Length

The L_Data_Standard request frame format shall have a variable length; the maximum length shall be 24 characters. The length information shall indicate the number of characters (0-14) transported by the L_Data_Standard request frame starting with the octet 7. This means that an L_Data_Standard request frame with length 0 shall end after the sixth octet.

5.2.3.3.6 Check octet

Octet 22 of a request frame shall be the check octet (see Figure 18). This octet shall be created by making an odd parity over the set of corresponding bits belonging to the preceding octets of the frame. This represents a logical NOT XOR function (F in Figure 18) over the individual bits of the preceding octets of the frame.

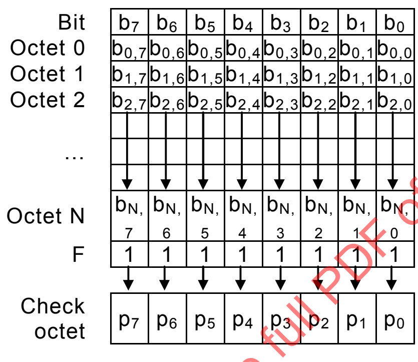


Figure 18 – Check octet

5.2.3.3.7 Domain address

The last octet of an L_Data_Standard request frame shall represent the lowest significant octet of the Domain Address. It shall determine the end devices that shall receive the frame.

5.2.3.4 L_Data_Extended-frame

5.2.3.4.1 General

The extended frame format shall be used for

- messages with APDU > 15 octets (long messages) which do not fit into L_Data_Standard frame because of its limited length and
- messages with extended addressing capabilities used in LTE-HEE mode.

L_Data_Extended frame shall not be used instead of L_Data_Standard frame if encoding capabilities of L_Data_Standard frame are sufficient (e.g., for short frames).

The structure of the variable length L_Data_Extended frame shall comply with Figure 19.

CTRL	CTRLE	SA	DA	LG	TPDU (L_Data)	FCS	DOA
8	8	16	16	8		8	8

Figure 19 – Frame fields with standard fieldname abbreviations

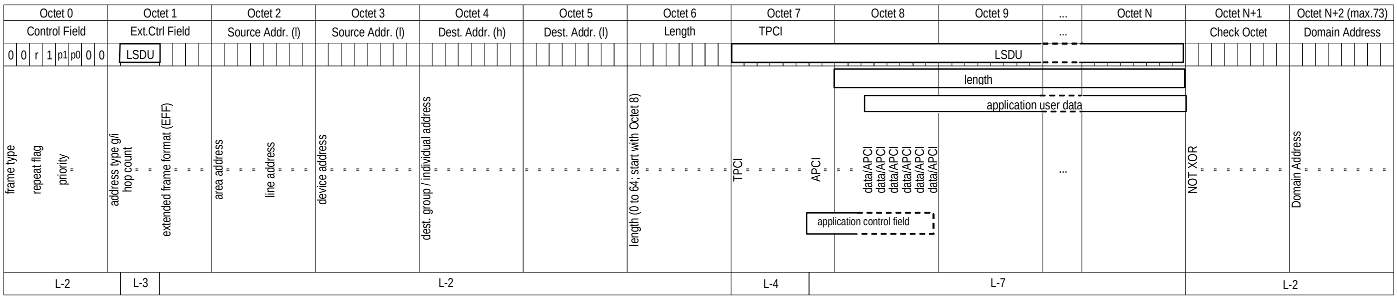


Figure 20 – Format 1e, L_Data_Extended request frame format

The encoding of the fields in the frame is specified in the following subclauses.

5.2.3.4.2 Control field (CTRL)

The common encoding of the Control Field is specified in 5.2.3.3.2.

5.2.3.4.3 Extended Control Field (CTRLE)

If the Frame Type flag FT = 1 in the CTRL field, an extended control field CTRLE shall follow in octet 1.

The CTRLE field shall contain the extended frame format parameter EFF and the Hop Count parameter. Bit 7 shall contain the destination Address Type (AT) flag g/i.

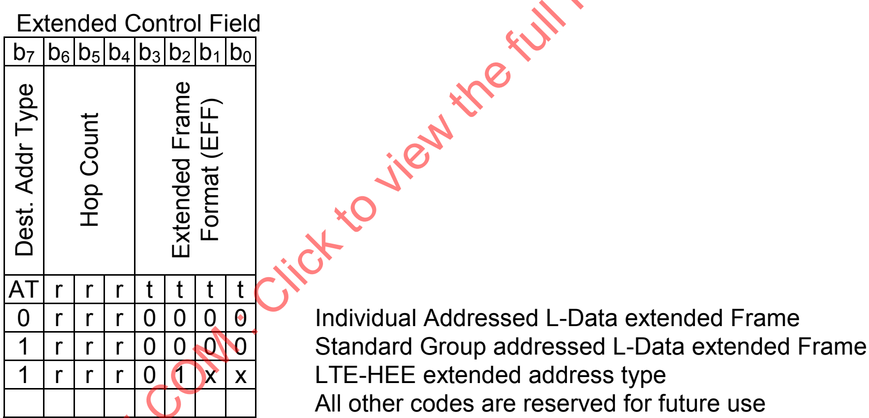


Figure 21 – Extended control field

5.2.3.4.4 Source address (SA)

The octets one and two of a request frame shall be the highest and lowest octet of the source address. This is the Individual Address of the device that caused the transmission of the frame.

5.2.3.4.5 Destination address (DA)

In the L_Data_Extended frame the type of the Destination Address depends on the Address Type (g/i flag) and on the extended frame format parameter EFF of the extended control field CTRLE. With EFF = 0000h, the same address type shall be used as in L_Data_Standard format. With EFF ≠ 0000h, special address formats and tables shall be used.

5.2.3.4.6 Length

The L_Data_Extended request frame format has a variable length. The length information shall indicate the number of characters (0…64) transported by the L_Data_Extended frame starting after the TPCI octet (octet 8). This means that a L_Data_Extended request frame with length 0 shall end after the TPCI octet.

The length information shall be encoded by the combination of the frame type-bit FT in the Control Field and the length field, as specified in ISO/IEC 14543-3-2.

NOTE The possible encoding space (0…255) of the length field is larger than the allowed usable range of 0…64. This limitation of the APDU to 64 octets results from limitations of the Physical Layer (probability for collisions, acceptable response time for all devices).

5.2.3.4.7 Check octet

This is the same as in L_Data_Standard frame (see 5.2.3.3.6).

5.2.3.4.8 Domain address

This is the same as in L_Data_Standard frame (see 5.2.3.3.7).

5.2.3.5 Acknowledgement frame

Octet 0								
Short Ack								
b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	
1	1	0	0	1	1	0	0	ACK
0	0	0	0	1	1	0	0	NACK

Figure 22 – Format 2, short acknowledgement frame format

The short acknowledgement frame format shall consist of an idle time of 15 bit times followed by a single character acknowledging an L_Data.req frame (see also Figure 18). The short acknowledgement shall comply with the coding, as indicated in Figure 22.

The combined coding NACK/Busy is received, when BUSY and NACK are sent simultaneously without collision mechanism. This coding shall be handled as BUSY.

5.2.4 Medium access control

5.2.4.1 General

As it is not possible to implement an absolutely collision free multiple access control in a frequency modulated medium, the PL devices shall use a slotted access technique as described below.

Before a device may start a transmission it shall wait for the line to be idle for the duration of at least 58 bits since the last bit of the preceding data link message cycle. The structure of a data link message cycle depends on the architecture of the installation (installation with or without repeater). In general, a data link message cycle shall consist of a data link request frame and a subsequent data link acknowledgement or a subsequent data link response frame.

If several devices want to start a transmission simultaneously, then an access conflict arises. To solve this conflict, a priority dependent time slot system shall be used:

1) repetitions shall have the highest priority and shall gain access to the bus, before any other device with a pending transmission request;
2) if the bus is not locked by a repetition, an ACK or a NACK frame, then a system or urgent L_Data-request frame shall gain access to the bus;
3) if the bus is not locked by a repetition, system or urgent L_Data-request frames normal / low operational priority, request frames shall gain access to the bus. Supposed that most of

all L_Data-request frames are operational priority frames there are 7 time slots chosen at random to start the transmission.

If a device once gained control of the bus it shall continue transmission until the last bit is transmitted.

During reception the data link layer of the receiving device shall check if the device is addressed and it shall control the immediate acknowledgement mechanism. If a transmission error occurs, the transmitting data link layer shall repeat the L_Data-request frame. Errors may occur in either direction, i.e., an L_Data-request frame or an acknowledgement frame may be destroyed.

5.2.4.2 L_Data-request message cycle without repeater

After a specified idle time a PL device shall initiate a message cycle transmitting an L_Data-request frame. If this L_Data-request is received by another PL device it shall check the consistency of the frame and whether it is addressed.

After a time gap of 4 bit after the last bit of the L_Data-request frame the power line device shall start the transmission of an acknowledgement frame. The acknowledgement frame shall have a duration of 32 bit times. By now the message cycle is terminated and the next L_Data-request message cycle may gain access to the bus after at least 58 bit times after the last L_Data-request frame.

If either the L_Data-request frame or the acknowledgement frame has been destroyed and thus an acknowledgement frame has not been received within 39 bit times after the last bit of the L_Data-request frame, the PL device that initiated the message cycle shall start a retransmission with the next bit slot. If the addressed PL device received the repeated L_Data-request frame properly it shall start the transmission of its acknowledgement frame after a time gap of 4 bit duration after the last bit of the repeated L_Data-request frame. Even if either the repeated L_Data-request frame or the acknowledgement frame has been destroyed the message cycle is terminated. There shall be no further repetitions. The next L_Data-request message cycle (system priority) shall not be started after at least 58 bit times after the last bit of the repeated L_Data-request cycle.

5.2.4.3 L_Data-request message cycle with repeater

After a specified idle time a PL device shall initiate a message cycle transmitting an L_Data-request frame. If this L_Data-request is received by another PL device it shall check the consistency of the frame and whether it is addressed. After a time gap of 4 bit duration and after the last bit of the L_Data-request frame, it shall start the transmission of an acknowledgement frame. The acknowledgement frame shall have a duration of 32 bit times.

If the repeater receives an acknowledgement frame within 39 bit times after the last bit of the L_Data-request frame it shall not start a repetition of the L_Data-request frame. By now the message cycle is terminated and the next L_Data-request message cycle may gain access to the bus after at least 58 bit times after the last L_Data-request frame.

If the acknowledgement frame has been destroyed and thus the repeater has not received an acknowledgement frame within 39 bit times after the last bit of the L_Data-request frame the repeater shall start a retransmission with the next bit slot. If the addressed PL BAU received the repeated L_Data-request frame properly it shall start the transmission of its acknowledgement frame after a time gap of 4 bit duration after the last bit of the repeated L_Data-request frame.

If the repeater does not detect bus access (receiving of at least preamble I) within a 22 bit duration and after the last bit of the repeated L_Data-request frame it shall start the transmission of a not acknowledgement frame to inform the source device that the message cycle was not successful. Even if either the repeated L_Data-request frame or the acknowledgement frame has been destroyed the message cycle shall be terminated. There shall be no further repetitions. The next L_Data-request message cycle (system priority) shall not be started after at least 58 bit duration after the last bit of the repeated L_Data-request cycle.

5.2.4.4 L_Data-request access priorities

There shall be 8 different priority dependent time slots to start the transmission of L_Data-request frames. The first slot is reserved for system priority L_Data-requests only. Slots 2 to 8 are reserved for operational priority L_Data-request frames. Each device with a pending operational priority L_Data-request shall choose one slot (2 ≤ selection ≤ 8) at random.

Table 5 – L_Data-request priorities

Slot number	Priority	Start[a]
0	Repeated L_Data-request frame	40
1	System priority	58
2	Operational priority Slot I	74
3	Operational priority Slot II	90
4	Operational priority Slot III	106
5	Operational priority Slot IV	122
6	Operational priority Slot V	138
7	Operational priority Slot VI	154
8	Operational priority Slot VII	170

a Bit times after the last bit of the last L_Data-request frame.

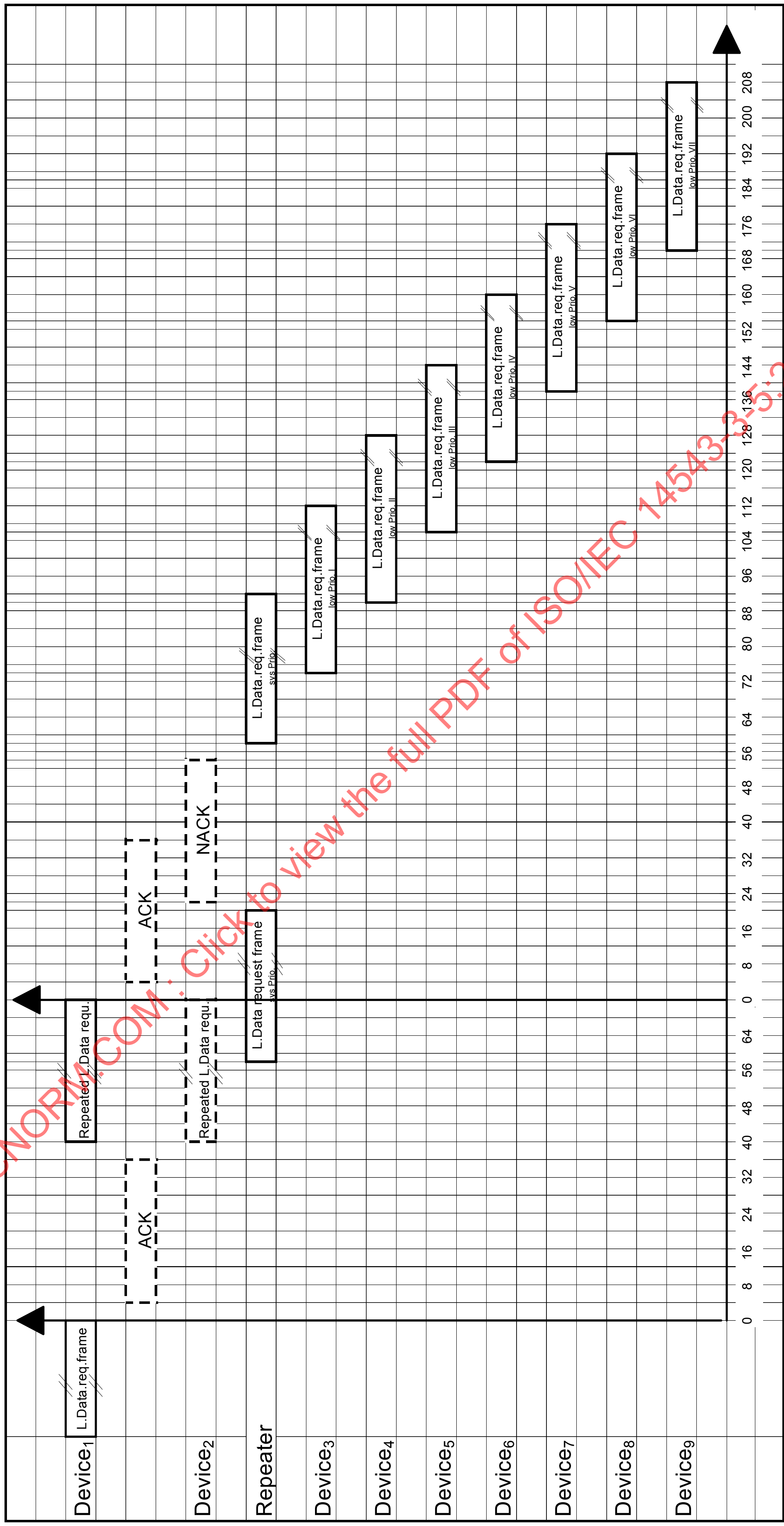


Figure 23 – Timing diagram of an L_Data-request frame

5.2.5 Data link layer services

5.2.5.1 L_Data services

The L_Data service shall be an acknowledged datagram service in case of a single destination in the same physical segment. The local user of layer-2 shall prepare an LSDU for the remote user by filling in the local Individual Address as source address and the local Domain Address as source Domain Address. The local user of layer-2 shall apply the L_Data.req primitive to pass the LSDU to the local layer-2. The local layer-2 shall accept the service request and try to send the LSDU to the remote layer-2 with frame format 1. The destination address may be an Individual Address or a group address (multicast or broadcast). The local layer-2 shall pass an L_Data.con primitive to the local user indicating either a correct or an erroneous data transfer.

Prior to passing the confirmation to the local user, the local layer-2 shall wait for an acknowledgement from the remote layer-2 (frame format 2). If the acknowledgement is a positive acknowledgement (ACK), the local layer-2 shall pass an L_Data.con with l_status = ACK to the local user. If the acknowledge is missing the local layer-2 shall pass an L_Data.con with l_status = not_ok to the local user. In all other cases, that is, acknowledgement is NAK or invalid or time-out after 36 bit times the local layer-2 shall repeat once after 40 bit times. If it fails, the local layer-2 shall pass an L_Data.con with l_status = not_ok to the local user.

If the request frame received is correct (see 5.2.7.2), the remote layer-2 shall send an acknowledge and pass the LSDU with an L_Data.ind primitive to the remote user. If the request frame received is not correct, the remote layer-2 shall not send an acknowledgement.

L_Data.req(domain_address, destination_address, DAF, priority, l_sdu)

domain_address:	This parameter value shall contain the source and destination domain_address.
destination_address:	This parameter value shall either be an Individual Address or a group address.
DAF:	This parameter value shall contain the destination_address flag indicating whether the destination_address is an Individual Address or group address.
priority:	This parameter value shall indicate system, urgent, normal or low operational priority.
l_sdu:	This parameter value shall contain the user data to be transferred by layer-2.

L_Data.con(l_status)

l_status: ok:	This parameter value shall indicate that the requested frame was sent successfully.
not_ok:	This parameter value shall indicate that the transmission of the frame did not succeed.

L_Data.ind(domain_address, source_address, destination_address, DAF, priority, l_sdu)

domain_address:	This parameter value shall contain the source and destination domain_address.
source_address:	This parameter value shall contain the Individual Address of the end device that requested the L_Data service.
destination_address:	This parameter value shall contain the Individual Address or a group address of this device.
DAF:	This parameter value shall contain the destination_address flag indicating whether the destination_address is a physical (0) or group address (1).
priority:	This parameter value shall indicate system, urgent, normal or low operational priority.
l_sdu:	This parameter value shall contain the user data that has been transferred by layer-2.

A router shall have a unique Individual Address, acknowledge layer-2 services and transmit the layer-2 request frames to the other side, if the end device associated with the destination address of the frame is located on the other side. Thus receiving an acknowledgement will not guarantee that the destination (the end device) has received the L_Data.req, but it indicates that at least destination or a router received it.

5.2.5.2 L_Sys_Data service

The L_Sys_Data service shall be implemented as an unacknowledged datagram service. The local user of layer-2 shall prepare a LSDU for the remote user by filling in the local Individual Address as source address and the system-broadcast Domain Address (0000h) as source Domain Address. The local user of layer-2 shall apply the L_Sys_Data.req primitive to pass the LSDU to the local layer-2. The local layer-2 shall accept the service request and try to send the LSDU to the remote layer-2 with frame format 1. The destination address shall be a broadcast group address. The local layer-2 shall pass an L_Sys_Data.con primitive to the local user indicating a correct data transfer. The local layer-2 shall always repeat the L_Sys_Data.req once before passing a positive confirmation to the local user.

If the request frame received is correct (see 5.2.7.2), the remote layer-2 shall pass the LSDU with an L_Sys_Data.ind primitive to the remote user. If the request frame received is not correct the remote layer-2 shall not send an acknowledgement.

L_Sys_Data.req (system_broadcast, source_address, destination_address, DAF, priority, l_sdu)

domain_address:	This parameter value shall contain the system broadcast Domain Address 0000h.
source_address:	This parameter value shall contain the Individual Address of the end device that requested the L_Data service.
destination address:	This parameter value shall contain the broadcast group address 0000h.
DAF:	This parameter value shall contain the destination_address flag always indicating a group address (value '1').
priority:	This parameter value shall contain the system, urgent, normal or low operational priority.
l_sdu:	This parameter value shall contain the user data to be transferred by layer-2.

L_Data.con (l_status)

l_status:	ok:	This parameter value shall indicate that the requested frame was sent successfully.

L_Data.ind (system_broadcast, source_address, destination_address, DAF, priority, l_sdu)

domain_address:	This parameter value shall contain the system broadcast domain_address 0000h.
source_address:	This parameter value shall contain the Individual Address of the end device that requested the L_Data service.
destination address:	This parameter value shall contain the broadcast group address.
DAF:	This parameter value shall contain the destination_address flag always indicating a group address (value '1').
priority:	This parameter value shall contain the system, urgent, normal or low operational priority.
l_sdu:	This parameter value shall contain the user data that has been transferred by layer-2.

5.2.6 Parameters of layer-2

The following parameters influence the behaviour of layer-2 and are required inside layer-2 in order to operate correctly:

Domain Address	address shared by all devices belonging to the same installation
Individual Address:	unique device address
address table	address table with group address(es) of this end device

5.2.7 Data link layer protocol

5.2.7.1 Assemble/disassemble frame

Before transmitting a frame on the line, the Data Link Layer shall assemble service parameters into an LPDU.

It shall also ensure the following mapping:

- the frame type shall be calculated from the frame format parameter as defined in ISO/IEC 14543-3-2 and put into FT flag in the CTRL field;
- for the extended frame format the EFF field shall be taken from the frame format parameter as defined in ISO/IEC 14543-3-2 and put into EFF field in CTRLE;
- the length information shall be calculated from octet_count parameter and put into LG field on octet 6;
- the parameters' priority and repeat flag shall be put into CTRL field;
- destination address and LSDU parameters shall be introduced in the frame;
- the address type AT shall be put into CTRLE field (group address flag g/i);
- the network layer information shall be put into CTRLE field;
- source address and check octet shall be introduced.

When receiving a PDU, the Data Link Layer shall carry out the reverse operation:

- it disassembles the frame into parameters to be transmitted in an L_Data.ind frame;
- it regenerates the address type from the value of the CTRLE.g/i flag;
- it generates the octet_count parameter from the value of CTRL and LG fields.

5.2.7.2 Checking for correct request frames

If the received domain address matches the own domain address and the destination address of a request frame corresponds to the individual address or one of the group addresses of a PL110 device, the receiver of the frame shall check if the frame is correct. A frame shall be interpreted as correct if all of the following conditions are fulfilled:

- every UART character has a correct start/stop bit (otherwise: framing error) and parity bit (otherwise: parity error);
- every bit of a UART character has a correct signal timing (otherwise: bit error);
- the check octet has the correct value;
- the length of the frame is between 7 and 23 (or 73) characters.

5.2.7.3 Consequences of priority operation and fairness for duplication prevention

Table 5 shows that a repeated low priority L_Data request frame shall be treated with lower priority than, for instance, a non-repeated urgent priority L_Data request, when the data link layer line idle detection occurs at the same time.

This implies that if an ACK to a non-repeated low or normal priority request frame is corrupted and another device in the same line at the same time wants to transmit an urgent priority L_Data request to the ACKing device, then the ACKing device might lose the knowledge, that the subsequent repeated low or normal priority frame is a duplicate.

The following mechanisms may be used to remedy this:

- reduction of medium noise as much as necessary to avoid corrupted ACKs;
- avoiding urgent priority frames as much as possible.

Internal or external user application programming should take into account the possibility that in rare cases a duplicated L_Data service may occur.

The receiver of a repeated frame shall discard it, if it was received correctly before. A repeated frame shall have the same source address as the preceding frame (that also applies to the repeater) but with the repeat_flag set to 0.

5.2.7.4 State machine of layer-2

After power on, a device shall not receive or transmit frames. The layer-2 state machine shall synchronise to the mains frequency by measuring the time between two zero crossings. After the time that elapses between two zero crossings the layer-2 state machine shall be in the idle state where layer-2 shall work as described in the above subclauses (receive and transmit frames).

5.2.8 Layer-2 of a repeater

There are three different modes in data link layer, as follows:

1) data-link layer without repeater;
2) data-link layer with a repeater;
3) data-link layer of a repeater.

The data link layer shall differ in timing and structure of a data-link message cycle, depending on whether or not a repeater is installed in the network. A message cycle shall consist of at least an L_Data frame followed by an acknowledgement frame. If the acknowledgement frame to an L_Data frame is missing in a specified timeslot, the L_Data frame shall be repeated (depending on the data link layer mode, by the PL device itself when a repeater is missing, or by the repeater). If the acknowledgement frame is not sent again within its timeslot, the repeater shall transmit a NACK frame to signal the loss of the L_Data frame.

If a repeater repeats a received L_Data frame the repeat flag in the control field (transmitted Octet 0) shall be set to zero.

The source address shall not be modified by the repeater, that is, the source address of the transmitting PL device shall remain unchanged.

The repeater shall only repeat L_Data frames within its own Domain Address. In addition, the repeater shall consider itself as a member of the Domain Address 0000h. Though not recommended, several repeaters of adjacent Domain Addresses may be installed within receiving range.

6 Requirements for HES Class 1, PL132

6.1 General

This clause describes the physical layer characteristics of the PL132 powerline signalling which operates in the frequency band 125 kHz to 140 kHz as described in EN 50065-1 and which has a nominal centre frequency of 132 kHz. The PL132 transmission method shall send a high-frequency signal on the mains wiring between the phase and neutral conductors.

At least regulation of frequency allocation and access protocols are required for coexistence on the medium. Bit transmission is achieved by frequency modulation and bit coding.

In the underneath Physical Layer description, the composition of the full datagram used to transport a frame is specified.

In the Data Link Layer error description, the detection encoding and the determination of bit frame corruption are described, next to protocols dealing with repetition of transmission and acknowledgement.

Rules for sending frames by gaining access to the medium according to the PL132 access protocol are defined in the underneath Data Link Layer description. These specifications conform to EN 50065-1.

As PL132 shall comply with EN 50065-1, the specifications of this standard are not copied or explained here. Only complements to EN 50065-1 are specified. Refer to EN 50065-1 for basic specifications related to transmitter level and medium access protocol.

6.2 Physical layer PL132

6.2.1 Medium definition

Fixed and portable wiring devices which incorporate powerline signalling function shall meet the relevant national requirements which apply to these devices when delivered without powerline signalling capability.

6.2.2 Topology and medium

The physical topology and the medium of PL132 shall be the same as that of the electric power distribution network (as installed in the building). In Europe, this network is mainly based on a star topology (although in the UK, a ring topology is more common).

When used on a single phase mains network the carrier shall be injected between phase and neutral. When used on a three phase mains network the signal shall be injected between one phase and neutral (an additional optional phase coupler according to EN 50065-4-6 may be used).

6.2.3 Datagram service

6.2.3.1 Transmission method

6.2.3.1.1 Modulation

Minimum Shift Keying (MSK or FSK with low frequency deviation) shall be used as modulation with:

- centre frequency 132,5 kHz ± 0,2 % (± 0,25 kHz);
- deviation ± 600 Hz ± 1 %.

6.2.3.1.2 Coding

Coding is No-Return-to-Zero (NRZ).

The lower frequency represents a logical “1”.

6.2.3.1.3 Bit rate

Bit rate is 2 400 bits/s.

The accumulated bit time short term deviation shall be less than 4×10^{-3} (deviation over 100 bits shall not exceed ± 160 µs) and the long term deviation shall be less than 10^{-3} for frames over 100 bits (e.g., it shall not exceed ± 420 µs over 1 000 bits).

6.2.3.2 Frame encapsulation

6.2.3.2.1 General

A special 2-level encapsulation mechanism, both for the octet level and for the frame level, is used to increase reliability of applications in PL132.

Considering that the line noise can cause considerable data transitions at the receiver demodulator each datagram has a specific structure (see Figure 24).

A frame to be transmitted is encapsulated with preamble and header fields. Both are chosen in such a way as to have a low probability of mistaking one header for another or wrongly detecting noise or preamble as the header.

Moreover, error detection and correction codes are used.

A forward error correcting code (FEC) is used to protect each octet against burst noise. With majority-logic decoding, the FEC is capable of correcting a three bit burst in a block of 14. This corresponds to a 1,25 ms burst every 5,84 ms (a powerline half-cycle equals 8,4 ms at 60 Hz and 10 ms at 50 Hz).

Additionally, the Frame Check Sequence of Data Link Layer (FCS) (see 6.3.3.2.2) allows to detect errors not corrected at Physical Layer level.

The datagram end is determined from the length information encoded in the transported frame or is intrinsic in the case of an acknowledgement.

In each octet, the most significant bit (of the most significant octet of a word) is sent first (b_7 = msb, b_7, ..., b_0, FEC_5, .., FEC_0).

6.2.3.2.2 Preamble

The datagram preamble is a 16-bit field equalling AAAAh.

6.2.3.2.3 Header

Two different forms of headers are used to identify whether the message is a datagram or a datagram acknowledgement and to differentiate between messages compliant with the PL132 specification and those of other powerline signalling protocols. Correct reception of a header indicates the start of a datagram.

The header for a datagram is 1C53h whilst that for a datagram acknowledgement is 1CA1h.

6.2.3.2.4 Forward error correction

Systematic code words from the (14,8) shortened cyclic code (from the (15,9) code) with the generator

$$G_{(x)} = x^6 + x^5 + x^4 + x^3 + 1$$

shall be used (see "MACCHI ET GUILBERT" in bibliography). The bits are computed in decreasing order (from 7 to 0).

The FEC bits are replaced by their ones' complement to guarantee a transition within every code word; this allows the maintenance of synchronization during long datagrams. The code words are used end-to-end (non-interleaved) to form the complete datagram package. The preamble and header are not coded (see Figure 24). This shall be overlaid by the datagram fields as laid down in 6.3.1.

Preamble	Header	Encoded Frame							Postamble
Preamble (16)	Header (16)	Data (8)	**FEC** (6)	Data (8)	**FEC** (6)	Data (8)	**FEC** (6)	etc.	Postamble

NOTE **Bold** letters denote ones' complements.

Figure 24 – Complete frame encapsulation (Datagram)

6.2.3.2.5 Postamble

The postamble is a 2 bit field 'xx' where x is the complement of the last bit of the FEC of the last octet.

6.2.3.3 Physical layer service definitions

The **Ph-Data** Service results in the connectionless transfer of a single Physical Service Data Unit (Ph-SDU) to the client of a corresponding Physical Layer in another device, connected to the same network segment.

Three primitives are defined:

- Ph-Data.Request shall be used to transmit a Frame;
- Ph-Data.Indication shall be used to receive a Frame;
- Ph-Data.Confirm is a local primitive generated by the originating Physical Layer for its own client to indicate that the Physical Layer is satisfied with the transmission.

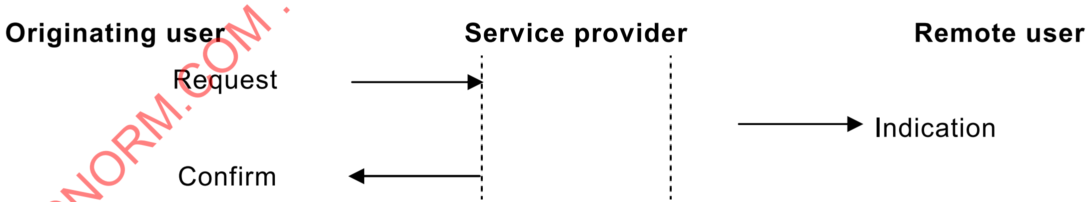


Figure 25 – Overview of primitives

Table 6 – Parameters for Ph-Data service

Parameter name	Request	Indication	Confirm
Ph-Service_Class	M	M	-
Ph-SDU	M	M	C1
Ph-Result	-	-	M
M = mandatory - = not used C1 mandatory when ACK has been received, else optional			

The Ph-Service_Class parameter is a single octet representing an unsigned number with the following meaning:

Table 7 – Ph-Service class parameters

Ph-Service_Class value	Meaning
0	This parameter value shall be used to signal a Datagram header (1C53h)
1	This parameter value shall be used to signal a datagram ACK header (1CA1h)
Others	Reserved

The Ph-SDU parameter contains the data to be transmitted or received. It consists of an unnumbered sequence of bits. It is mandatory both in the Ph-Data.Request and Ph-Data.Indication primitives. It is mandatory in the Ph-Data.Confirm primitive if the Physical Layer receives an acknowledgement Frame and has to send the transmitted FCS to the Data Link Layer; else it is optional.

The Ph-Result parameter shall be transferred by the local Ph-Data.Confirm primitive back to the client layer that issued the Ph-Data.Request primitive, to indicate to that client the result of its request. It consists of a single octet representing an unsigned number, with the following meanings:

Table 8 – Ph-Result values

Ph-Result value	Meaning
1	This parameter value shall be used to signal a datagram ACK timeout.
2	This parameter value shall be used to signal a datagram ACK detected.
0thers	Reserved

6.3 Data link layer type powerline 132

6.3.1 Frame format

6.3.1.1 Frame type summary

Each frame is a sequence of octets.

There are two frame formats, as follows:
1) a variable length frame format (L_Data Frame) (see Figure 27 and Figure 31);
2) an acknowledgement frame format (ACK) (see Figure 34).

In the following representation of frames, the octets situated on the left side are transmitted first.

6.3.1.2 Variable length L_Data frame format

Two L_Data frame formats are available on the PL132 medium. The usage of the different formats depends on the value of the frame format parameter to the Link Layer (as specified in ISO/IEC 14543-3-2). The standard frame format shall be used if the frame format parameter is 0, otherwise the extended frame format shall be used.

6.3.1.3 L_Data_Standard frame

6.3.1.3.1 Overview

The structure of the variable length L_Data_Standard-frame is shown in Figure 30.

DOA	CTRL	SA	DA	NPCI, LG	TPDU (L_Data)	FCS
16	8	16	16	8		16

Figure 26 – Frame fields with standard fieldname abbreviations

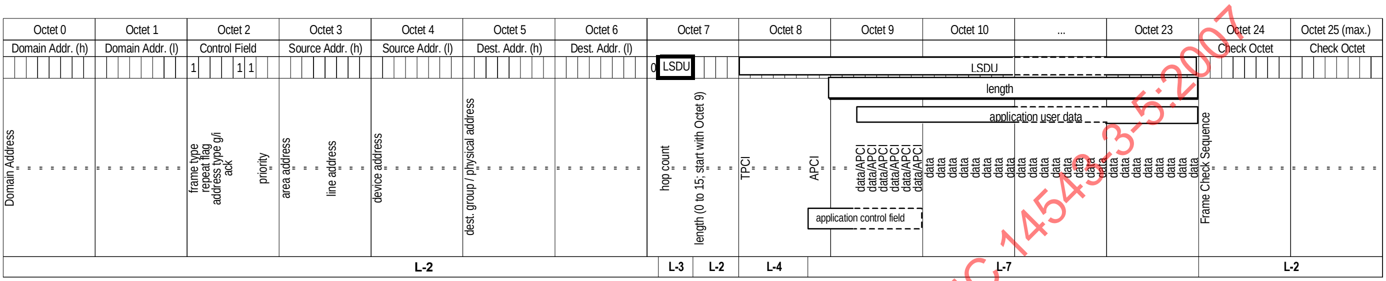


Figure 27 – L_Data request standard frame format

The encoding of the fields of the frame shall be implemented as specified in the subclauses below.

6.3.1.3.2 Domain address (DOA)

A 16-bit address is allocated to each domain.

The domain address 0000h shall be used for broadcast.

6.3.1.3.3 Control field (CTRL)

The control field contains the information about the Layer-2 service. It includes its priority, identification of Group or Individual Addresses (Address Type AT), a flag indicating whether the LPDU is a repeated LPDU and a flag indicating if an acknowledgement is requested, see Figure 28.

It shall also differentiate standard and extended frames by the frame type (FT) flag.

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
FT	rep	g/i	ack	1	1	pr_1	pr_0

Figure 28 – Control field

FT:	Frame Type:	0 : extended frame	
		1 : standard frame	
rep :	Repeat flag :	0 : immediate retransmission	
		1 : first transmission	
g/i :	Group Address Flag :	Address Type (AT):	
		0 : individual frame	
		1 : group frame	
ack :	Acknowledge request :	0 : no Layer-2 ack requested	
		1 : Layer-2 ack requested	
pr :	Medium Access Priority :	11b : low	(mandatory for long frames, burst traffic...)
		01b : normal	(default for short frames)
		10g : urgent	(reserved for urgent frames)
		00b : system	(reserved for high priority system configuration and management procedures)
		The two priority bits of the control field indicate the priority of the frame. It has no effect on PL132 but enables routers to reuse the same priority when retransmitting the frame.	

6.3.1.3.4 Source address (SA)

The source address is the individual address of the device that requested the transmission of the frame.

6.3.1.3.5 Destination address (DA) and group address flag (g/i)

The destination address determines the device(s) that shall receive the frame. For L_Data request frames, the destination address can either be an Individual Address (CTRL.g/i=0) or a Group Address (CTRL.g/i=1), depending on the group address flag (g/i) of the octet "CTRL".

6.3.1.3.6 Network protocol control information (NPCI)

This field is a composite octet containing a reserved bit, routing information (Hop Count, HC) and length information (LG):

b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
0	HC_2	HC_1	HC_0	LG_3	LG_2	LG_1	LG_0

Figure 29 – NPCI field

Bit 7 shall be set to 0.

The L_Data request frame format can have a variable length, the maximum length is 22 characters. This enables to transport an APDU of up to 14 octets.

The LG subfield indicates the APDU-length coded as defined in ISO/IEC 14543-3-1.

NOTE The APDU-length is the number of characters (0 to 15) of the APDU transported by the L_Data request frame starting with the seventh octet.

6.3.1.3.7 L_DATA (TPDU)

This field contains the transported Data octets and correspond to TPDU.

6.3.1.3.8 Frame check sequence (FCS)

The last two octets of a request frame transport the frame check sequence.

6.3.1.4 L_Data_Extended-frame

6.3.1.4.1 General

The extended frame format shall be used for

- messages with APDU > 15 octets (long messages) which do not fit into L_Data_Standard frame because of its limited length and
- messages with extended addressing capabilities used in LTE-HEE mode.

L_Data_Extended frame shall not be used instead of L_Data_Standard frame if encoding capabilities of L_Data_Standard frame are sufficient (e.g., for short frames).

The structure of the variable length L_Data_Extended frame complies with Figure 30.

DOA	CTRL	CTRLE	SA	DA	LG	TPDU (L_Data)	FCS
16	8	8	16	16	8		16

Figure 30 – Frame fields with standard fieldname abbreviations

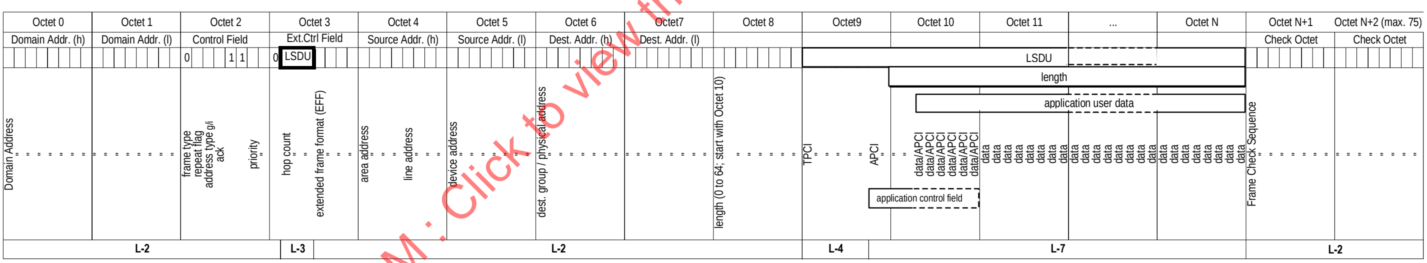


Figure 31 – L_Data_ Extended request frame format

6.3.1.4.2 Domain address (DOA)

The encoding of the Domain Address Field is specified in 6.3.1.3.2.

6.3.1.4.3 Control field (CTRL)

The encoding of the Control Field is specified in 6.3.1.3.3.