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Road vehicles — Local Interconnect Network (LIN) —

Part 8: Electrical physical layer (EPL) specification: LIN over DC powerline (DC-LIN)

Véhicules routiers — Réseau Internet local (LIN) —

Partie 8: Spécification de couche physique électrique (EPL): LIN sur ligne d'alimentation en courant continu (DC-LIN)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 31, *Data communication*.

A list of all parts in the ISO 17987 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 17987 (all parts) specifies the use cases, communication protocol and physical layer requirements of an in-vehicle communication network called Local Interconnect Network (LIN).

The LIN protocol as proposed is an automotive-focused low speed UART-based network (Universal Asynchronous Receiver Transmitter). Some of the key characteristics of the LIN protocol are signal-based communication, schedule table-based frame transfer, master/slave communication with error detection, node configuration and diagnostic service transportation.

The LIN protocol is for low cost automotive control applications, for example door module and air conditioning systems. It serves as a communication infrastructure for low-speed control applications in vehicles by providing:

— signal-based communication to exchange information between applications in different nodes;

— bit rate support from 1 kbit/s to 20 kbit/s;

— deterministic schedule table-based frame communication;

— network management that wakes up and puts the LIN cluster into sleep mode in a controlled manner;

— status management that provides error handling and error signalling;

— transport layer that allows large amount of data to be transported (such as diagnostic services);

— specification of how to handle diagnostic services;

— electrical physical layer specifications;

— node description language describing properties of slave nodes;

— network description file describing behaviour of communication;

— application programmer's interface.

ISO 17987 (all parts) is based on the open systems interconnection (OSI) basic reference model as specified in ISO/IEC 7498-1 which structures communication systems into seven layers.

The OSI model structures data communication into seven layers called (top down) application layer (layer 7), presentation layer, session layer, transport layer, network layer, data link layer and physical layer (layer 1). A subset of these layers is used in ISO 17987 (all parts).

ISO 17987 (all parts) distinguishes between the services provided by a layer to the layer above it and the protocol used by the layer to send a message between the peer entities of that layer. The reason for this distinction is to make the services, especially the application layer services and the transport layer services, reusable also for other types of networks than LIN. In this way, the protocol is hidden from the service user and it is possible to change the protocol if special system requirements demand it.

ISO 17987 (all parts) provides all documents and references required to support the implementation of the requirements related to the following.

— ISO 17987-1: This part provides an overview of the ISO 17987 (all parts) and structure along with the use case definitions and a common set of resources (definitions, references) for use by all subsequent parts.

— ISO 17987-2: This part specifies the requirements related to the transport protocol and the network layer requirements to transport the PDU of a message between LIN nodes.

— ISO 17987-3: This part specifies the requirements for implementations of the LIN protocol on the logical level of abstraction. Hardware related properties are hidden in the defined constraints.

— ISO 17987-4: This part specifies the requirements for implementations of active hardware components which are necessary to interconnect the protocol implementation.

— ISO/TR 17987-5: This part specifies the LIN application programmers interface (API) and the node configuration and identification services. The node configuration and identification services are specified in the API and define how a slave node is configured and how a slave node uses the identification service.

— ISO 17987-6: This part specifies tests to check the conformance of the LIN protocol implementation according to ISO 17987-2 and ISO 17987-3. This comprises tests for the data link layer, the network layer and the transport layer.

— ISO 17987-7: This part specifies tests to check the conformance of the LIN electrical physical layer implementation (logical level of abstraction) according to ISO 17987-4.

— ISO 17987-8: This part specifies the requirements for implementations of the DC powerline electrical physical layer (EPL) for the LIN communications system as well as a conformance test plan for the EPL.

Road vehicles — Local Interconnect Network (LIN) —

Part 8:
Electrical physical layer (EPL) specification: LIN over DC powerline (DC-LIN)

1 Scope

This document specifies an additional electrical physical layer (EPL) for the Local Interconnect Network (LIN) of the ISO 17987 series. It specifies the transmission over DC powerline without affecting the LIN higher layers, hereafter named DC-LIN.

The DC-LIN EPL uses a high-frequency modulated carrier to propagate UART bytes (byte-oriented) over the DC powerline.

This document specifies the electrical characteristics, the modulation method of the transmission, and how to impose the carrier signal on the DC powerlines.

The DC-LIN EPL supports bit rates of 9 615 bit/s, 10 417 bit/s, and 19 230 bit/s.

The DC-LIN EPL is applicable for a wide range of DC powerlines including 12-V and 24-V operations, allowing communicating between different DC powerlines via a coupling capacitor. A DC-LIN EPL interface to powerline example is described in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 17987-4:2016, *Road vehicles — Local Interconnect Network (LIN) — Part 4: Electrical physical layer (EPL) specification 12 V/24 V*

ISO 17987-6, *Road vehicles — Local Interconnect Network (LIN) — Part 6: Protocol conformance test specification*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test*

3 Terms, definitions, symbols, and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
BR_9_6K
DC-LIN EPL operating at nominal bit rate of 9 615 bit/s

3.1.2
BR_10K
DC-LIN EPL operating at nominal bit rate of 10 417 bit/s

3.1.3
BR_19_2K
DC-LIN EPL operating at nominal bit rate of 19 230 bit/s

3.1.4
byte field
byte that consists of one start bit, eight data bits, and one stop bit

3.1.5
byte field sync preamble
sequence of phase shifts at the beginning of EPL byte field modulation used for byte synchronization

3.1.6
carrier frequency
DC-LIN EPL center frequency that is altered (modulated) to transfer data

3.1.7
coupling capacitor
capacitor for blocking the DC powerline voltage to/from a DC-LIN EPL

3.1.8
DC-LIN EPL RX mode
mode that DC-LIN EPL de-asserts line-out and controls RXD according to signal at line-in

3.1.9
DC-LIN EPL TX mode
mode that DC-LIN EPL controls line-out according to logic state present at TXD

3.1.10
start bit
logic low (‘0’) of the first bit of a byte field

3.1.11
stop bit
logic high (‘1’) of the last bit of a byte field

3.2 Symbols and abbreviated terms

'0'	logical 0
'1'	logical 1
AC	alternate current
API	application programmers interface
B_{data_bit}	byte field data bit signalled on RXD at DC-LIN EPL receiver side
$B_{data\_bit\_local}$	byte field data bit signalled on RXD at DC-LIN EPL transmitter side

B_{del}	break delimiter signalled on RXD at DC-LIN EPL receiver side
B_{del_local}	break delimiter signalled on RXD at DC-LIN EPL transmitter side
$B_{err\_data\_bit\_local}$	byte field error data bit signalled on RXD at DC-LIN EPL transmitter side
$B_{fe\_stop\_bit}$	byte field frame error stop bit signalled on RXD at DC-LIN EPL receiver side
$B_{fe\_stop\_bit\_local}$	byte field frame error stop bit signalled on RXD at DC-LIN EPL transmitter side
$B_{fe\_del\_local}$	break field delimiter frame error signalled on RXD at DC-LIN EPL transmitter side
$B_{fe\_start\_bit\_local}$	byte field frame error start bit signalled on RXD at DC-LIN EPL transmitter side
BR	DC-LIN EPL operating bit rate
B_{start_bit}	byte field start bit signalled on RXD at DC-LIN EPL receiver side
$B_{start\_bit\_local}$	byte field start bit signalled on RXD at DC-LIN EPL transmitter side
B_{stop_bit}	byte field stop bit signalled on RXD at DC-LIN EPL receiver side
$B_{stop\_bit\_local}$	byte field stop bit signalled on RXD at DC-LIN EPL transmitter side
CB_{TX}	consecutive byte field transmission
CF_{max}	maximal number of carrier frequencies implemented in IUT transmit signal
DC	direct current
EPL	electrical physical layer
ESD	electrostatic discharge
fc_i	carrier frequency
FB_{TX}	first byte field transmission
I	in-phase signal component
IUT	implementation under test
bit/s	bit per second
LIN	Local Interconnect Network
line-in	modulated carrier signal input pin to the EPL from the DC powerline
line-out	modulated carrier signal output pin from the EPL to the DC powerline
LT	lower tester
L_{out_lev}	line-out sampled monitoring level
$L_{out\_thr\_lev}$	line-out monitoring peak threshold level
$L_{out\_err\_cond}$	line-out monitoring error condition
max.	maximum
min.	minimum

P_{byte_length}	nominal length of modulated byte field in t_{BIT}
$P_{data\_bit\_len}$	nominal length of modulated byte field data bit
P_{data}	data bit modulation phases
P_{dh_1}	data bit ‘1’ 1st phase shift
P_{dh_2}	data bit ‘1’ 2nd phase shift
P_{dh_3}	data bit ‘1’ 3rd phase shift
P_{dl_1}	data bit ‘0’ 1st phase shift
P_{dl_2}	data bit ‘0’ 2nd phase shift
P_{dl_3}	data bit ‘0’ 3rd phase shift
P_{ref_consec}	reference phase of consecutive byte transmission
P_{ref_first}	reference phase of the first byte transmission
P_{sync_p}	sync preamble modulation phases
P_{sp_1}	sync preamble 1st phase shift
P_{sp_2}	sync preamble 2nd phase shift
P_{sp_3}	sync preamble 3rd phase shift
P_{sp_4}	sync preamble 4th phase shift
P_{sp_5}	sync preamble 5th phase shift
P_{sp_6}	sync preamble 6th phase shift
P_{sp_7}	sync preamble 7th phase shift
P_{sp_8}	sync preamble 8th phase shift
P_{sp_9}	sync preamble 9th phase shift
P_{sp_10}	sync preamble 10th phase shift
P_{sp_11}	sync preamble 11th phase shift
P_{sp_12}	sync preamble 12th phase shift
P_{sp_13}	sync preamble 13th phase shift
P_{sp_14}	sync preamble 14th phase shift
P_{sp_15}	sync preamble 15th phase shift
P_{sp_16}	sync preamble 16th phase shift
P_{sp_17}	sync preamble 17th phase shift
P_{sp_18}	sync preamble 18th phase shift
$P_{sync\_pre\_len}$	nominal length of modulated byte field sync preamble

Q	quadrature signal component
$\mathrm{R}_{\mathrm{rx\_mode}}$	DC-LIN EPL RX mode
$\mathrm{RX}_{\mathrm{err\_cond}}$	DC-LIN EPL RX node error condition
t_{BIT}	bit time
$t_{\mathrm{break\_field}}$	break field data bits ‘0’ length in t_{BIT}
$t_{\mathrm{l\_out\_mon\_l}}$	line-out monitoring active duration
$t_{\mathrm{l\_out\_mon\_samp}}$	line-out monitoring sample time
$t_{\mathrm{l\_out\_mon\_start}}$	start time of line-out monitoring
$t_{\mathrm{RX\_delay}}$	delay between transmitted byte field over to the DC powerline and the receiver reconstructed byte field from the DC powerline
$t_{\mathrm{RX\_delay\_local}}$	delay between transmitted byte field on TXD and the received byte field on RXD at a DC-LIN EPL node (locally)
$t_{\mathrm{rx\_proc\_max}}$	maximum process time at RX DC-LIN EPL side
$t_{\mathrm{rx\_proc\_min}}$	minimum process time at RX DC-LIN EPL side
$t_{\mathrm{SB\_TX}}$	start time of byte field sync preamble transmission on line-out
$\mathrm{T}_{\mathrm{tx\_mode}}$	DC-LIN EPL TX mode
$t_{\mathrm{txd\_min\_assert}}$	minimum TXD assert (‘0’) time without timeout event (deactivating $\mathrm{T}_{\mathrm{tx\_mode}}$)
$t_{\mathrm{txd\_min\_recover}}$	minimum TXD deassert (‘1’) time after timeout event ($\mathrm{T}_{\mathrm{tx\_mode}}$ remains deactivated)
$\overline{\mathrm{TXD}}$	logical inverted TXD (i.e. '0' becomes '1' and vice versa)
typ.	typical
UT	upper tester
Vpp	volt peak-to-peak
$V_{\mathrm{PWL\_max}}$	maximum rating for the DC powerline
φ	carrier phases
Δfc_i	carrier frequency resolution
°	degree

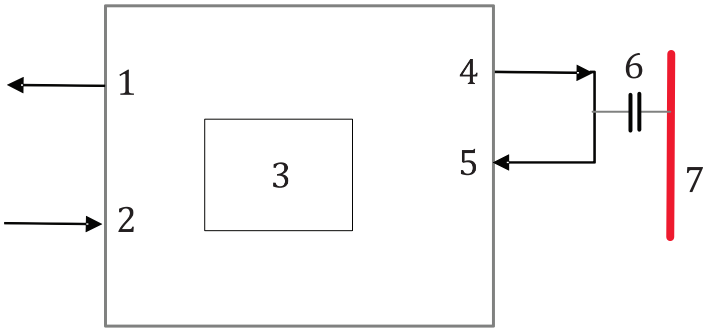
4 Electrical physical layer requirements

4.1 General

The DC-LIN EPL is the physical media access sub-layer, which links the data link layer as standardized in ISO 17987-3 and the DC powerlines (physical medium dependent sub-layer). Figure 1 depicts an example of a DC-LIN EPL. The EPL consists of a modem, which encodes the data from the data link layer into the modulated carrier signal that is coupled to the DC powerline. The modem also decodes the received data on the DC powerline and provides this to the data link layer at the receivers. Follow the DC-LIN EPL conformance test plan in Annex B.

The DC-LIN EPL transmitter encodes each byte field sent by the data link layer on TXD into a modulated carrier signal, which is transferred over the DC powerline. The modulation consists of a predefined combination of phase shifts according to the byte field modulation scheme specified in 4.2.2.

The DC-LIN EPL receiver decodes the received modulated byte from the DC powerline and signals it on RXD to the data link layer.



Key

1 RXD receive data pin
2 TXD transmit data pin
3 modem
4 line-out
5 line-in
6 coupling capacitor
7 DC powerline

Figure 1 — Example of a DC-LIN EPL

4.2 Transmitter characteristics

4.2.1 Transmit signal specification

The transmit signal shall be constructed as the sum of up to four (redundant) selectable modulated carrier frequencies.

The definition of the transmit signal is given in Formula (1).

Definition of the formula:

$$\text{Transmit signal} = \sum_{i=1}^{n} A \times \cos\left[\left(360° \times fc_i \times t\right) + \varphi(t)\right] \quad (1)$$

where

A is the gain amplitude of the carrier signal in volts;

t is the time in seconds;

fc_i is the selected carrier frequency;

$\varphi(t)$ is the carrier frequency phase; $\varphi(t)$ = 0°, 90°, 180°, 270°;
$\varphi(t)$ changes as a function of the byte field modulation scheme;

n is the maximal carrier frequency selection per transmit signal;
n = 1, 2, 3, 4.

Table 1 specifies the DC-LIN EPL carrier frequency.

Table 1 — Carrier frequency specification

Parameter	Description	Min.	Max.	Unit	Accuracy
fc_i	Carrier frequency band	5	30	MHz	±0,02 %
Δfc_i	Carrier frequency resolution	0,1	0,1	MHz	

In essence, fc_i ∈{5 MHz; 5,1 MHz; 5,2 MHz; ... 29,8 MHz; 29,9 MHz; 30 MHz}.

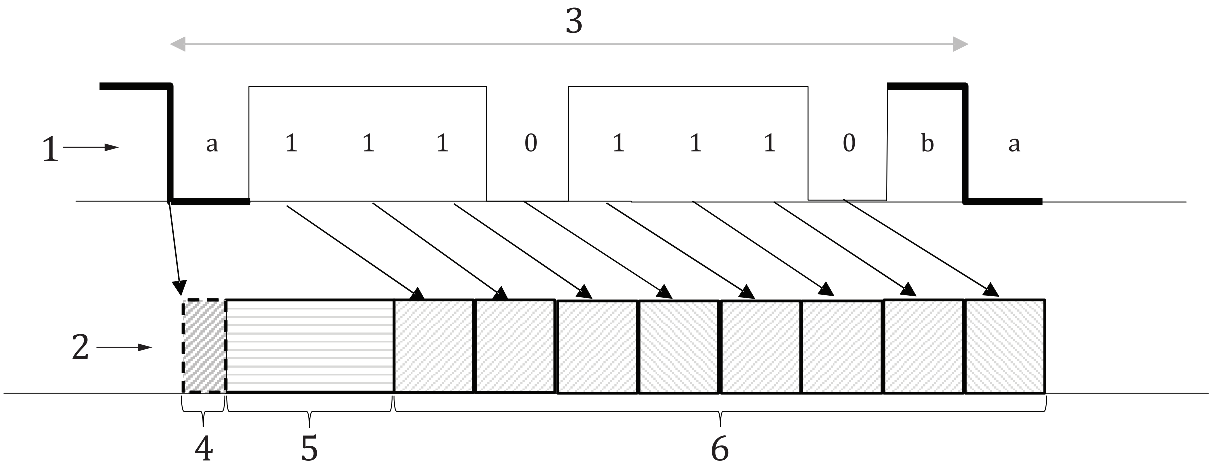
4.2.2 Byte field modulation scheme

4.2.2.1 Byte field modulation scheme structure

A byte field modulation scheme shall consist of a byte field sync preamble modulation (specified in 4.2.2.3) and a byte field data bit modulation (specified in 4.2.2.4). A first byte field modulation shall start with a dedicated reference phase (specified in 4.2.2.2).

A byte field start bit and stop bit shall not be included in a byte field modulation scheme. At receiving nodes, the DC-LIN EPL shall reconstruct both the start bit and stop bit artificially on RXD (see 4.4).

Figure 2 depicts a byte field modulation scheme structure.



Key

1 TXD DC-LIN node A

2 DC powerline

3 byte field

4 reference phase

5 byte field sync preamble

6 8 modulated data bits

[a] Start.

[b] Stop.

Figure 2 — Byte field modulation scheme structure

The byte field modulation scheme shall consist of a sequence of ±90° phase shifts while $L_{out\_err\_cond}$ is inactive (see 4.2.2.3 and 4.2.2.4).

While $L_{out\_err\_cond}$ is active, and only after completion of byte field sync preamble transmission, the transmit signal shall consist of no phase shifts (i.e. constant phase transmission) for the remaining field transmission time (see 4.5.3).

Figure 3 specifies the transmitting phases for 0°, 90°, 180°, and 270° [i.e. $\varphi(t)$].

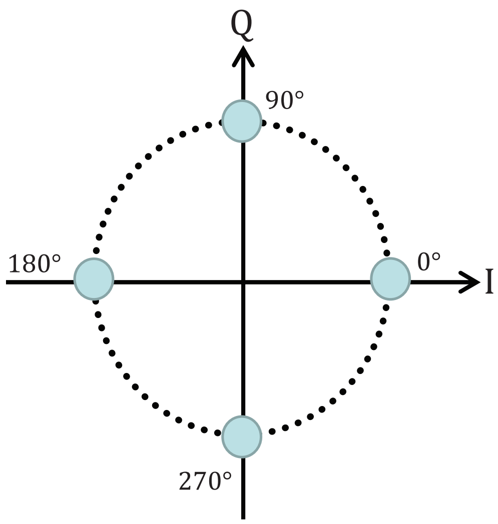


Figure 3 — Transmitter phase's definition

