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Road vehicles — Local Interconnect Network (LIN) —

Part 4:
Electrical physical layer (EPL) specification 12 V/24 V

Véhicules routiers — Réseau Internet local (LIN) —

Partie 4: Spécification de la couche électrique physique (EPL) 12V/24V

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Foreword

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

This second edition cancels and replaces the first edition (ISO 17987-4:2016), which has been technically revised.

The main changes are as follows:

— master and slave terms used for the LIN node types in the ISO 17987 series are replaced within this document with inclusive language terms commander and responder. This also applies for abbreviations and file formats NCF and LDF;

— variables and formulae aligned with the ISO/IEC Directives, Part 2;

— updates of several parameter statements and requirements;

— various parameter values adopted in Annex C;

— editorial updates and several statements improved to avoid ambiguities.

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

The LIN protocol as proposed is an automotive focused low speed universal asynchronous receiver transmitter (UART) based network. Some of the key characteristics of the LIN protocol are signal-based communication, schedule table-based frame transfer, commander/responder communication with error detection, node configuration and diagnostic service transportation.

The LIN protocol is for low-cost automotive control applications as, 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 state 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 responder nodes;

— network description file describing behaviour of communication;

— application programming interface.

The ISO 17987 series 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 the ISO 17987 series.

The ISO 17987 series 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.

The ISO 17987 series provides all documents and references required to support the implementation of the requirements related to the following.

— ISO 17987-1: provides an overview of the ISO 17987 series 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: 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: 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 document): specifies the requirements for implementations of active hardware components which are necessary to interconnect the protocol implementation.

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

— ISO 17987-6: 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: specifies tests to check the conformance of the LIN electrical physical layer implementation (logical level of abstraction) according to this document.

Road vehicles — Local Interconnect Network (LIN) —

Part 4:
Electrical physical layer (EPL) specification 12 V/24 V

1 Scope

This document specifies the 12 V and 24 V electrical physical layers (EPL) of the LIN communications system.

The electrical physical layer for LIN is designed for low-cost networks with bit rates up to 20 kbit/s to connect automotive electronic control units (ECUs). The medium that is used is a single wire for each receiver and transmitter with reference to ground.

Annex A provides recommendations on the LIN physical layer peripheral interface design of type UART and frame controller for commander and responder nodes.

This document includes the definition of electrical characteristics of the transmission itself and also the documentation of basic functionality for bus driver devices.

This document also provides the physical layer definitions for nodes with LIN AA capabilities according to one of the procedures C, D and E.

All parameters in this document are defined for the ambient temperature range from −40 °C to 125 °C.

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 17987-1, *Road vehicles — Local Interconnect Network (LIN) — Part 1: General information and use case definition*

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

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions given in ISO 17987-1 and the following apply.

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

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

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

3.1.1
BR_Range_20K
LIN systems which operate at speeds up to 20 kbit/s

3.1.2
BR_Range_20K 12 V
12 V LIN systems which operate at speeds up to 20 kbit/s

3.1.3
BR_Range_20K 24 V
24 V LIN systems which operate at speeds up to 20 kbit/s

3.1.4
BR_Range_10K
LIN systems which operate at speeds up to 10,417 kbit/s

3.1.5
BR_Range_10K 12 V
12 V LIN systems which operate at speeds up to 10,417 kbit/s

3.1.6
BR_Range_10K 24 V
24 V LIN systems which operate at speeds up to 10,417 kbit/s

3.2 Symbols

C'_{LINE}	line capacitance
C_{BUS}	total bus capacitance
$C_{\mathrm{COMMANDER}}$	capacitance of commander node
C_{RXD}	RXD capacitance (LIN receiver, RXD capacitive load condition)
$C_{\mathrm{RESPONDER}}$	capacitance of responder node
$\mathrm{d}^2V/\mathrm{d}t^2$	second derivative of voltage (volt^2 per second^2)
$\mathrm{d}i/\mathrm{d}t$	instantaneous rate of current change (amps per second)
$D_{\mathrm{Rev\_Batt}}$	reverse battery supply protection diode
$D_{\mathrm{ser\_int}}$	serial internal diode at transceiver IC
$D_{\mathrm{ser\_commander}}$	serial commander diode
$F_{\mathrm{TOL\_RES\_COMMANDER}}$	commander bit rate deviation from nominal bit rate
$F_{\mathrm{TOL\_RES\_COMMANDER\_A}}$	commander bit rate deviation from nominal bit rate in BR_Range_20K systems
$F_{\mathrm{TOL\_RES\_COMMANDER\_B}}$	commander bit rate deviation from nominal bit rate in BR_Range_10K systems
$F_{\mathrm{TOL\_RES\_RESPONDER}}$	responder bit rate deviation from nominal bit rate
$F_{\mathrm{TOL\_RES\_RESPONDER\_A}}$	responder bit rate deviation from nominal bit rate in BR_Range_20K systems
$F_{\mathrm{TOL\_RES\_RESPONDER\_B}}$	responder bit rate deviation from nominal bit rate in BR_Range_10K systems
$F_{\mathrm{TOL\_RES\_RESPONDER\_1}}$	responder node 1 bit rate deviation from nominal bit rate
$F_{\mathrm{TOL\_RES\_RESPONDER\_2}}$	responder node 2 bit rate deviation from nominal bit rate
$F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$	responder node to responder node bit rate deviation

F_{TOL_SYNCH}	responder node bit rate deviation from commander node bit rate after synchronization
$F_{TOL\_SYNCH\_A}$	responder node bit rate deviation from commander node bit rate after synchronization in BR_Range_20K systems
$F_{TOL\_SYNCH\_B}$	responder node bit rate deviation from commander node bit rate after synchronization in BR_Range_10K systems
$F_{TOL\_SYNCH\_BDM}$	deviation of synchronized responder bit rate to the commander node bit rate
$F_{TOL\_SYNCH\_1}$	responder node 1 bit rate deviation from commander node bit rate after synchronization
$F_{TOL\_SYNCH\_2}$	responder node 2 bit rate deviation from commander node bit rate after synchronization
$F_{TOL\_UNSYNCH}$	responder node bit rate deviation from nominal bit rate before synchronization
$F_{TOL\_UNSYNCH\_A}$	responder node bit rate deviation from nominal bit rate before synchronization in BR_Range_20K systems
$F_{TOL\_UNSYNCH\_B}$	responder node bit rate deviation from nominal bit rate before synchronization in BR_Range_10K systems
I_{BUS}	current into the ECU bus line
I_{BUS_LIM}	current limitation for driver dominant state driver on $V_{BUS} = V_{BAT\_max}$ into ECU bus line
$I_{BUS\_NO\_BAT}$	current at ECU bus line when V_{BAT} is disconnected
$I_{BUS\_NO\_GND}$	current at ECU bus line when V_{GND_ECU} is disconnected
$I_{BUS\_PAS\_dom}$	current at ECU bus line when driver off (passive) at dominant LIN bus level
$I_{BUS\_PAS\_rec}$	current at ECU bus line when driver off (passive) at recessive LIN bus level
GND_{Device}	GND of ECU
l_{BUS}	total length of LIN bus line
LIN_{Bus}	LIN network
R_{BUS}	total bus-resistor including all responder node and commander node resistors $R_{BUS} = R_{COMMANDER} \| R_{RESPONDER\_1} \| R_{RESPONDER\_2} \|$ to $\| R_{RESPONDER\_N}$
$R_{COMMANDER}$	commander resistor with default range
R_{pull_up}	pull-up resistor
$R_{RESPONDER}$	responder resistor
$R_{RESPONDER\_SMALL}$	precise responder resistor with small range
t_{BFS}	byte field synchronization time
t_{BIT}	basic bit times
t_{EBS}	earliest bit sample time

t_{LBS}	latest bit sample time
$t_{\mathrm{rx\_pd}}$	propagation delay of receiver
$t_{\mathrm{rx\_sym}}$	symmetry of receiver propagation delay rising edge propagation delay of receiver
$t_{\mathrm{rx\_pdf}}$	propagation delay time of receiving node at falling (recessive to dominant) LIN bus edge
$t_{\mathrm{rx\_pdr}}$	propagation delay time of receiving node at rising (dominant to recessive) LIN bus edge
t_{SR}	sample window repetition time
$V_{\mathrm{TH\_dom(max)}}$	maximum dominant threshold of receiving node (volt)
$V_{\mathrm{TH\_dom(min)}}$	minimum dominant threshold of receiving node (volt)
$V_{\mathrm{TH\_rec(max)}}$	maximum recessive threshold of receiving node (volt)
$V_{\mathrm{TH\_rec(min)}}$	minimum recessive threshold of receiving node (volt)
V_{ANODE}	voltage at the anode of the diode
V_{BAT}	voltage across the ECU supply connectors
V_{BATTERY}	voltage across the vehicle battery connectors
V_{BUS}	voltage on the LIN bus
$V_{\mathrm{BUS\_CNT}}$	centre point of receiver threshold
$V_{\mathrm{BUS\_rec}}$	receiver recessive voltage
V_{CATHODE}	voltage at the cathode of the diode
$V_{\mathrm{GND\_BATTERY}}$	battery ground voltage
$V_{\mathrm{GND\_ECU}}$	voltage on the local ECU ground connector with respect to vehicle battery ground connector ($V_{\mathrm{GND\_BATTERY}}$)
V_{HYS}	receiver hysteresis voltage
V_{Rec}	recessive voltage
V_{SerDiode}	voltage drop at the serial diodes
$V_{\mathrm{Shift\_BAT}}$	battery shift
$V_{\mathrm{Shift\_Difference}}$	difference between battery shift and GND shift
$V_{\mathrm{Shift\_GND}}$	GND shift
V_{SUP}	voltage at transceiver supply pins
$V_{\mathrm{SUP\_NON\_OP}}$	voltage which the device is not destroyed; no guarantee of correct operation
$V_{\mathrm{th\_dom}}$	receiver threshold voltage of the recessive to dominant LIN bus edge
$V_{\mathrm{th\_rec}}$	receiver threshold voltage of the dominant to recessive LIN bus edge
$\Delta F/F_{\mathrm{COMMANDER}}$	deviation of node bit rate from the commander node bit rate

$\Delta F/F_{Nom}$	deviation from nominal bit rate
τ	time constant

3.3 Abbreviated terms

AC	alternate current
API	application programming interface
ASIC	application specific integrated circuit
BFS	byte field synchronization
DC	direct current
EBS	earliest bit sample
ECU	electronic control unit
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EPL	electrical physical layer
ESD	electrostatic discharge
EVT	event
GND	ground
LBS	latest bit sample
Max.	maximum
Min.	minimum
OSI	open systems interconnection
Param	parameter
RC	RC time constant τ ($\tau = C_{BUS} \times R_{BUS}$)
RX	Rx pin of the transceiver
RXD	receive data
SR	sample window repetition
TRX	transceiver
Tx	Tx pin of the transceiver
TXD	transmit data
Typ.	typical
UART	universal asynchronous receiver transmitter

4 Conventions

The ISO 17987 series and ISO 14229-7 are based on the conventions specified in the OSI service conventions (see ISO/IEC 10731) as they apply for physical layer, protocol, network and transport protocol and diagnostic services.

5 Electrical physical layer requirements

5.1 Bit rate deviation

5.1.1 General

The bit rate deviation of the LIN medium describes the bit rate deviation from a referenced bit rate. It is the sum of the following parameters:

— inaccuracy of setting the bit rate (systematic failure due to granularity of the configurable bit rate);

— clock deviation over temperature and supply voltage range;

— clock source stability of the responder node starting from the end of the sync byte field up to the end of the entire LIN frame (last sampled bit) when performing synchronization;

— bit time measurement failure of the responder node;

— clock source stability of the commander node starting from the end of the sync byte field up to the end of the entire LIN frame (last transmitted bit).

On-chip clock may achieve a frequency deviation of better than ±14 % with internal calibration. This bit rate deviation better than ±14 % is sufficient to detect a break field in the message stream. The subsequent bit rate adaptation using the sync byte field ensures the proper reception and transmission of the message. The on-chip oscillator shall allow for accurate bit rate measurement and generation for the remainder of the message frame, taking into account effects of anything, which affects the bit rate, such as temperature and voltage drift during operation.

The bit rates on the LIN bus are specified in the range of 1 kbit/s to 20 kbit/s. The specific bit rate used on a LIN bus is defined as the nominal bit rate, F_{Nom}.

In case a non-LIN electrical physical layer (e.g. CAN physical medium attachment (PMA) as specified in ISO 11898-2) is used, the bit rate can be adjusted.

5.1.2 12 V LIN systems: parameters

Table 1 defines the bit rate deviation from nominal bit rate.

Table 1 — Bit rate deviation from nominal bit rate

Number	Bit rate deviation	Name	$\Delta F/F_{Nom}$
Param 1	Commander node (deviation from nominal bit rate)	$F_{TOL\_RES\_COMMANDER}$	<±0,5 %
Param 2	Responder node without making use of synchronization (deviation from nominal bit rate)	$F_{TOL\_RES\_RESPONDER}$	<±1,5 %
Param 3	Initial deviation of responder node bit rate from the nominal bit rate according to 5.2.2.1. This is required for a reliable break field detection to enter synchronization procedure.	$F_{TOL\_UNSYNCH}$	<±14 %

Table 2 defines the responder node bit rate deviation from commander node bit rate.

Table 2 — Responder node bit rate deviation from commander node bit rate

Number	Bit rate deviation	Name	$\Delta F/F_{\mathrm{COMMANDER}}$
Param 4	Deviation of responder node bit rate from the commander node bit rate after synchronization; it is relevant for nodes making use of synchronization. Any responder node shall stay within this deviation for all fields of a frame which follow the sync byte field.	$F_{\mathrm{TOL\_SYNCH}}$	<±2 %

Table 3 defines the bit rate deviation for responder to responder communication.

Table 3 — Bit rate deviation for responder to responder communication

Number	Bit rate deviation	Name	$\Delta F/F_{\mathrm{COMMANDER}}$
Param 5	For communication between any two nodes (i.e. data stream from one responder to another responder), their bit rate shall not differ by more than $F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$. The condition shall be checked for: a) $\lvert F_{\mathrm{TOL\_RES\_RESPONDER\_1}} - F_{\mathrm{TOL\_RES\_RESPONDER\_2}} \rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; b) $\lvert F_{\mathrm{TOL\_SYNCH\_1}} - F_{\mathrm{TOL\_SYNCH\_2}} \rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; c) $\lvert (F_{\mathrm{TOL\_RES\_COMMANDER}} + F_{\mathrm{TOL\_SYNCH\_1}}) - F_{\mathrm{TOL\_RES\_RESPONDER\_2}} \rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$.	$F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$	<±2 %

5.1.3 24 V LIN systems: parameters

The required accuracy is dependent on the used bit rate range. See Table 15 and ISO 17987-2.

Table 4 defines the bit rate deviation from nominal bit rate in BR_Range_20K systems.

Table 4 — Bit rate deviation from nominal bit rate in BR_Range_20K systems

Number	BR_Range_20K bit rate deviation	Name	$\Delta F/F_{\mathrm{Nom}}$
Param 39	Commander node deviation from nominal bit rate. The nominal bit rate F_{Nom} is defined in the LDF or NCF.	$F_{\mathrm{TOL\_RES\_COMMANDER\_A}}$	<±0,3 %
Param 40	Responder node without making use of synchronization (deviation from nominal bit rate) For communication between any two nodes, their bit rate shall not differ by more than ±0,6 %.	$F_{\mathrm{TOL\_RES\_RESPONDER\_A}}$	<±0,3 %
Param 41	Deviation of responder node bit rate from the nominal bit rate before synchronization; it is relevant for nodes making use of synchronization and direct break field detection.	$F_{\mathrm{TOL\_UNSYNCH\_A}}$	<±14 %

Table 5 defines the bit rate deviation for responder nodes from commander node in BR_Range_20K systems.

Table 5 — Bit rate deviation for responder nodes from commander node in BR_Range_20K systems

Number	BR_Range_20K bit rate deviation	Name	$\Delta F/F_{\mathrm{COMMANDER}}$
Param 42	Deviation of responder node bit rate from the commander node bit rate after synchronization; it is relevant for nodes making use of synchronization. Any responder node shall stay within this deviation for all fields of a frame which follow the sync byte field.	$F_{\mathrm{TOL\_SYNCH\_A}}$	<±0,6 %
Param 43	For communication between any two nodes (i.e. data stream from one responder to another responder), their bit rate shall not differ by more than $F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$. The condition shall be checked for: a) $\lvert F_{\mathrm{TOL\_RES\_RESPONDER\_1}} - F_{\mathrm{TOL\_RES\_RESPONDER\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; b) $\lvert F_{\mathrm{TOL\_SYNCH\_1}} - F_{\mathrm{TOL\_SYNCH\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; c) $\lvert (F_{\mathrm{TOL\_RES\_COMMANDER\_A}} + F_{\mathrm{TOL\_SYNCH\_1}}) - F_{\mathrm{TOL\_RES\_RESPONDER\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$.	$F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$	<±0,6 %

Table 6 defines the bit rate deviation from nominal bit rate in BR_Range_10K systems.

Table 6 — Bit rate deviation from nominal bit rate in BR_Range_10K systems

Number	BR_Range_10K bit rate deviation	Name	$\Delta F/F_{\mathrm{Nom}}$
Param 44	Commander node deviation from nominal bit rate. The nominal bit rate F_{Nom} is defined in the LDF or NCF.	$F_{\mathrm{TOL\_RES\_COMMANDER\_B}}$	<±0,5 %
Param 45	Responder node without making use of synchronization (deviation from nominal bit rate) For communication between any two nodes, their bit rate shall not differ by more than ±2,0 %.	$F_{\mathrm{TOL\_RES\_RESPONDER\_B}}$	<±1,5 %
Param 46	Deviation of responder node bit rate from the nominal bit rate before synchronization; it is relevant for nodes making use of synchronization and direct break field detection.	$F_{\mathrm{TOL\_UNSYNCH\_B}}$	<±14 %

Table 7 defines the bit rate deviation for responder nodes from commander node in BR_Range_10K systems.

Table 7 — Bit rate deviation for responder nodes from commander node in BR_Range_10K systems

Number	BR_Range_10K bit rate deviation	Name	$\Delta F/F_{\mathrm{COMMANDER}}$
Param 47	Deviation of responder node bit rate from the commander node bit rate after synchronization; it is relevant for nodes making use of synchronization. Any responder node shall stay within this deviation for all fields of a frame which follow the sync byte field.	$F_{\mathrm{TOL\_SYNCH\_B}}$	<±2,0 %
Param 48	For communication between any two nodes (i.e. data stream from one responder to another responder), their bit rate shall not differ by more than $F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$. The following conditions shall be checked for: a) $\lvert F_{\mathrm{TOL\_RES\_RESPONDER\_1}} - F_{\mathrm{TOL\_RES\_RESPONDER\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; b) $\lvert F_{\mathrm{TOL\_SYNCH\_1}} - F_{\mathrm{TOL\_SYNCH\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$; c) $\lvert (F_{\mathrm{TOL\_RES\_COMMANDER\_B}} + F_{\mathrm{TOL\_SYNCH\_1}}) - F_{\mathrm{TOL\_RES\_RESPONDER\_2}}\rvert < F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$.	$F_{\mathrm{TOL\_RESPONDER\_to\_RESPONDER}}$	<±2,0 %