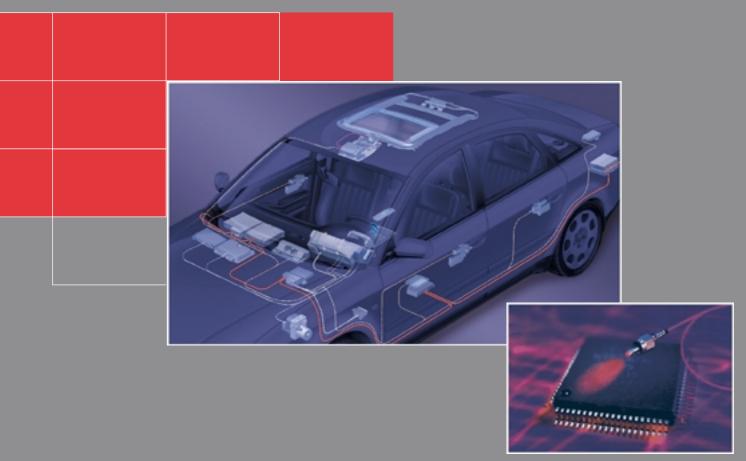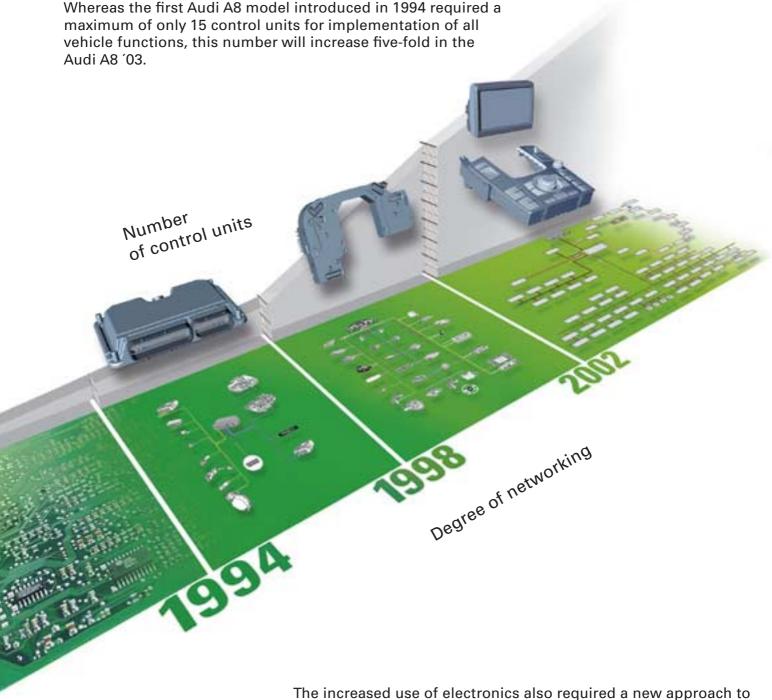**Service.**

New data bus systems – LIN, MOST, Bluetooth™

Self Study Programme 286

The constantly increasing demand for additional functions and convenience in the vehicle calls for the use of ever more wide ranging electronics.

Whereas the first Audi A8 model introduced in 1994 required a maximum of only 15 control units for implementation of all vehicle functions, this number will increase five-fold in the Audi A8 ´03.

Number of control units

2002

1998

Degree of networking

1994

The increased use of electronics also required a new approach to data transfer between the individual control units.

A first important step towards this was the introduction of the CAN data bus at Audi in the mid 1990s.
This system does however have its limitations, particularly with regard to the transmission rates involved in the infotainment sector. The only solution is therefore to employ transmission systems designed to deal with specific requirements. Service and diagnosis functions will also benefit from this development.
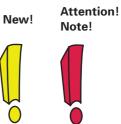
Contents

The Self Study Programme contains information on design features and functions.

The Self Study Programme is not intended as a Workshop Manual! Values given are only intended to help explain the subject matter and relate to the software version applicable at the time of SSP compilation.
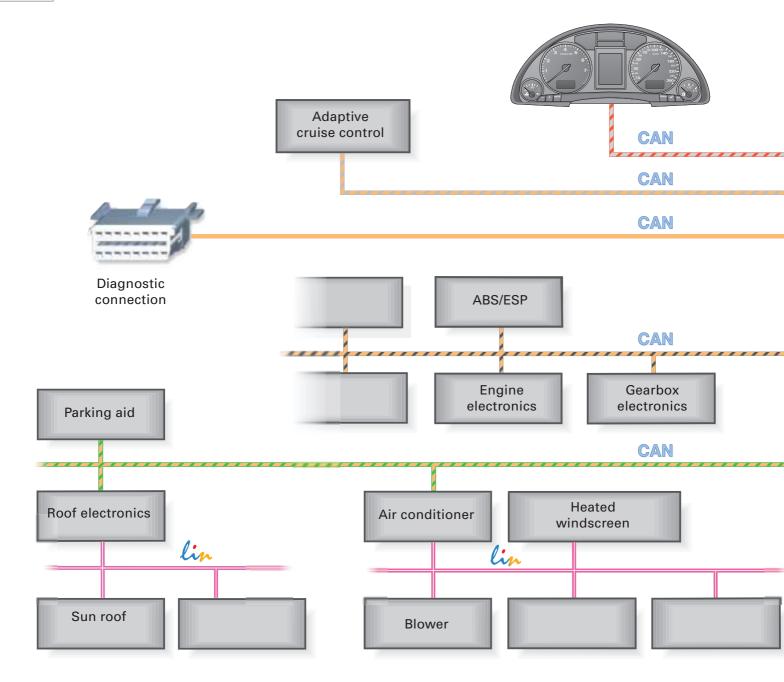
Use should always be made of the latest technical publications when performing maintenance and repair work.

New!   Attention! Note!

3

Introduction

Topology

Adaptive cruise control

CAN

CAN

CAN

Diagnostic connection

ABS/ESP

CAN

Engine electronics

Gearbox electronics

Parking aid

CAN

Roof electronics

Air conditioner

Heated windscreen
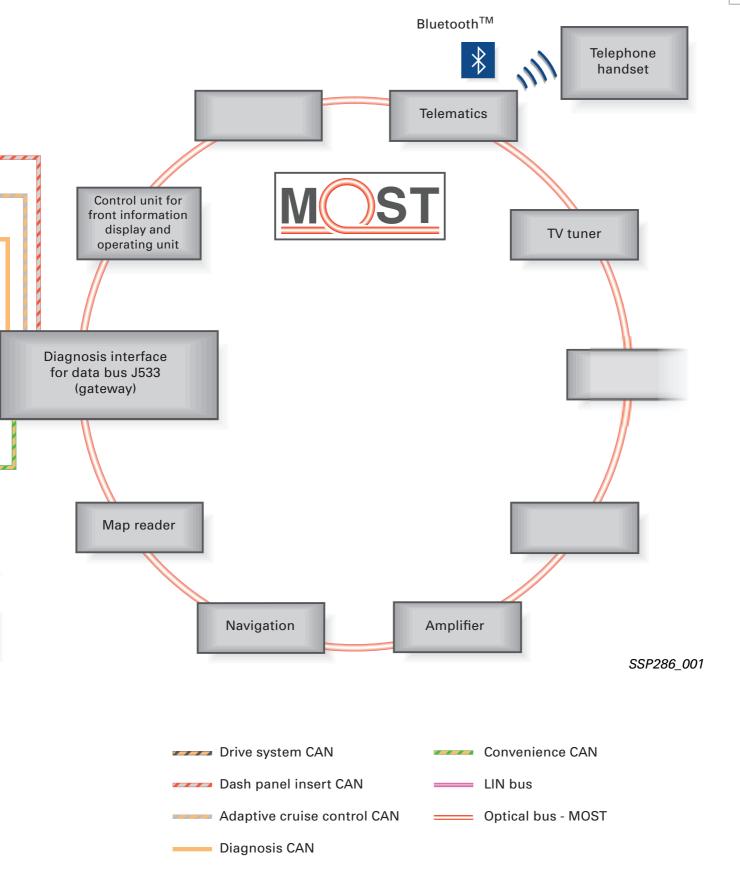
lin

lin

Sun roof

Blower

Working on the basis of the existing level of networking, improved transmission technology is required to deal with the great number of control units and their range of functions as well as the increasing volume of data exchange.

This involves the use of

– The LIN bus (single-wire bus)
– The MOST bus (optical bus)
– The wireless Bluetooth[TM] bus

in addition to the familiar CAN bus.

Bluetooth™

Telematics

Telephone handset

TV tuner

MOST

Control unit for front information display and operating unit

Diagnosis interface for data bus J533 (gateway)

Map reader

Navigation

Amplifier

SSP286_001

Drive system CAN		Convenience CAN	
Dash panel insert CAN		LIN bus	
Adaptive cruise control CAN		Optical bus - MOST	
Diagnosis CAN			

LIN bus

Introduction

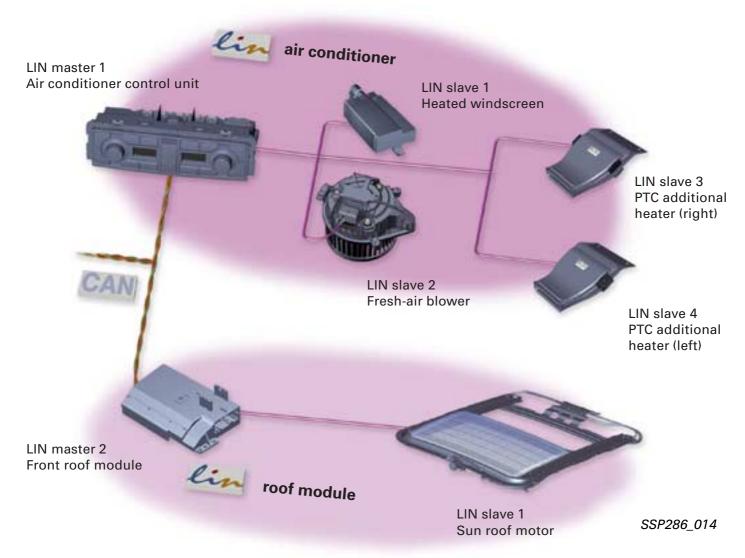LIN stands for **L**ocal **I**nterconnect **N**etwork.

Local Interconnect means that all control units are located within a limited structural space (e.g. roof). This is also referred to as "local sub-system".

Data are exchanged between the individual LIN bus systems in a vehicle by one control unit in each case using the CAN data bus.

The LIN bus system is a single-wire bus. The wire has a basic colour (violet) and a code colour. The wire cross-section is 0.35 mm^2. A screen is not necessary.

LOCAL INTERCONNECT NETWORK

The system permits data exchange between one LIN master control unit and up to 16 LIN slave control units.

air conditioner

LIN master 1
Air conditioner control unit

LIN slave 1
Heated windscreen

LIN slave 3
PTC additional
heater (right)

LIN slave 2
Fresh-air blower

LIN slave 4
PTC additional
heater (left)

LIN master 2
Front roof module

roof module

LIN slave 1
Sun roof motor

SSP286_014

6
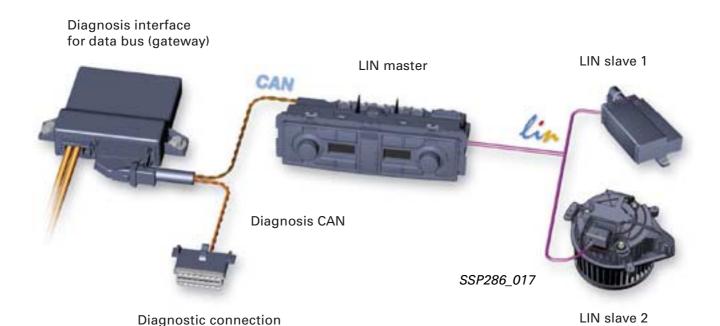
LIN master control unit

The control unit connected to the CAN data bus implements the LIN master functions.

Functions

–   Monitoring of data transfer and data transfer rate.
    The LIN master control unit transmits the header (refer to Page 12).

–   The software contains a cycle specifying when and how often which message is transmitted to the LIN data bus.

–   Implementation of translation function between the LIN control units of the local LIN bus system and the CAN data bus. It is thus the only control unit in the LIN bus system which is connected to the CAN data bus.

–   Diagnosis for the connected LIN slave control units takes place via the LIN master control unit.
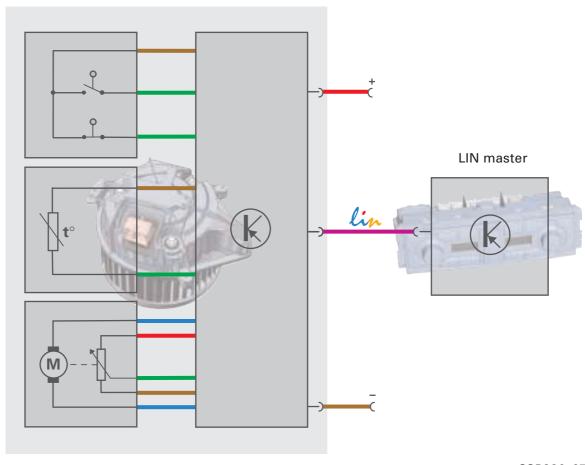
Diagnosis interface
for data bus (gateway)

LIN master

LIN slave 1

CAN

lin

Diagnosis CAN

SSP286_017

Diagnostic connection

LIN slave 2

7

LIN bus

LIN slave control units

LIN slave

Sensors

LIN master

Actuators

SSP286_070

Individual control units, such as the fresh-air blower, or sensors and actuators, for instance tilt sensor or anti-theft alarm sounder, can be used as LIN slave control units within a LIN data bus system.

Integrated sensor electronics evaluate the measured values.
The values are then transmitted as a digital signal by the LIN bus.

Only one pin of the LIN master socket is required for several sensors and actuators.

The LIN actuators are intelligent electronic or electromechanical assemblies which are informed of their tasks by the LIN master control unit in the form of the LIN data signal. The LIN master can interrogate the actual status of the actuators by way of integrated sensors, thus permitting desired/actual comparison.
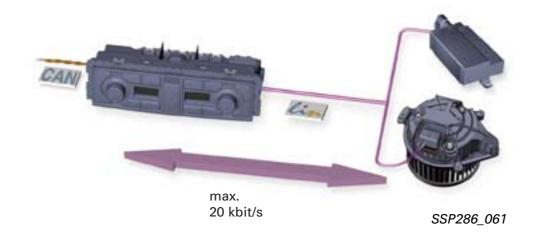
The sensors and actuators only react if the LIN master control unit transmits a header.

8

Data transfer

The data transfer rate is 1 - 20 kbit/s and is specified in the software of the LIN control units. This corresponds to a maximum of one fifth of the data transfer rate of the convenience CAN.
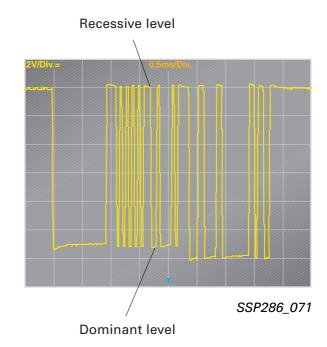

max.
20 kbit/s

SSP286_061

Signal

Recessive level

If no message or a recessive bit is being transmitted on the LIN data bus, the voltage at the data bus wire is roughly equivalent to battery voltage.

Dominant level

For transfer of a dominant bit on the LIN data bus, the data bus wire is connected to earth by a transceiver in the transmitter control unit.
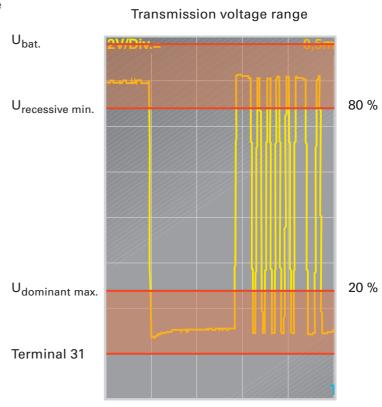
Recessive level

Dominant level

SSP286_071

Differences may be seen between the dominant levels on account of different transceiver designs in the control units.

9

LIN bus

Reliability

Stable data transfer is guaranteed by specified transmission and reception tolerances with regard to both the recessive and dominant levels.

Transmission voltage range

$U_{bat.}$

$U_{recessive\ min.}$ 80 %

$U_{dominant\ max.}$ 20 %

Terminal 31

SSP286_016

In order to obtain reception of valid signals in spite of interference, the permissible voltage ranges on the reception end are larger.

Reception voltage range

$U_{bat.}$

$U_{recessive\ min.}$ 60 %
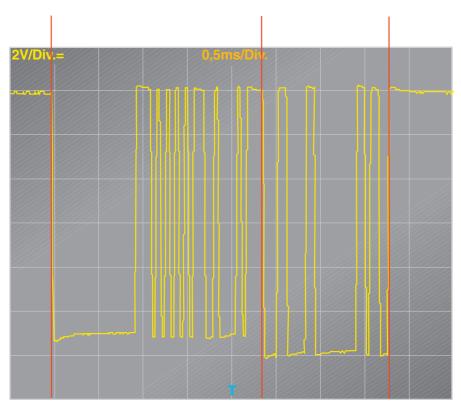
$U_{dominant\ max.}$ 40 %

Terminal 31

SSP286_022

10

Messages

2V/Div.=   0,5ms/Div.

SSP286_072

Message with slave response

In the header, the LIN master control unit requests a LIN slave control unit to transmit information (e.g. switch statuses or measured values).

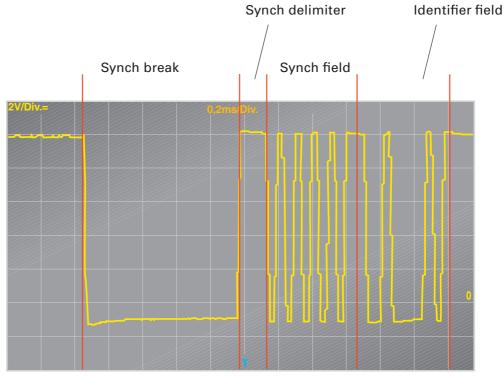The response is transmitted by the LIN slave control unit.

Message with master command

By way of the identifier in the header, the LIN master control unit requests the corresponding LIN slave control units to process the data contained in the response.

The response is transmitted by the LIN master control unit.

LIN bus

Header

Synch delimiter

Identifier field

Synch break

Synch field

SSP286_073

The header is transmitted cyclically by the LIN master control unit.
It can be divided into four sections:

– Synch break
– Synch delimiter
– Synch field
– Identifier field

The **synch break** has a length of at least 13 bit periods and is transmitted with dominant level.

The 13 bit period is necessary to unequivocally indicate the start of a message to all LIN slave control units.

A maximum of 9 dominant bits are consecutively transmitted in the other message sections.

The **synch delimiter** has a length of at least 1 bit and is recessive ($\approx U_{bat.}$).

The **synch field** consists of the bit sequence 0 1 0 1 0 1 0 1 0 1. This bit sequence enables all LIN slave control units to adapt to (become synchronised with) the system clock of the LIN master control unit.

The synchronisation of all control units is essential to proper data exchange. Without synchronisation, the bit values would be inserted at an incorrect location in the message at the receiver.
Data transfer errors would result.

The **identifier field** has a length of 8 bit periods. The first 6 bits contain the identification and the number of data fields (refer to Page 14) of the response.
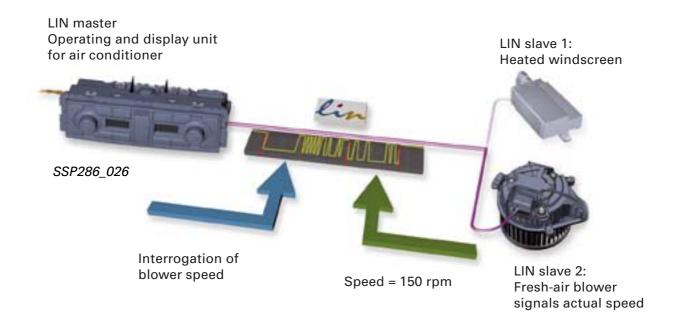The number of data fields in the response can be between 0 and 8.

The last two bits contain the checksum of the first 6 bits for detection of transmission errors. The checksum is required to prevent assignment to an incorrect message in the event of identifier transmission errors.

Response

In the case of a message with slave response, a LIN slave control unit supplies the response with information on the basis of the identifier.
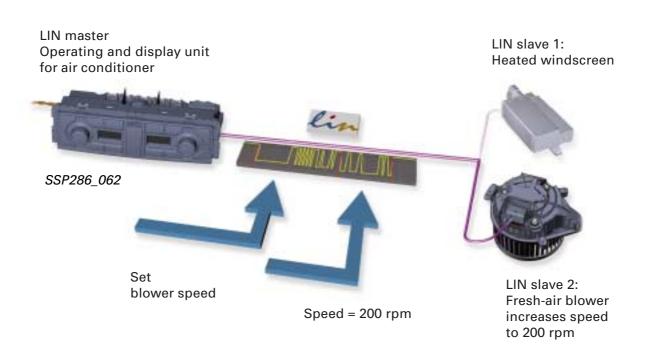
Example:

LIN master
Operating and display unit
for air conditioner

LIN slave 1:
Heated windscreen

SSP286_026

Interrogation of
blower speed

Speed = 150 rpm

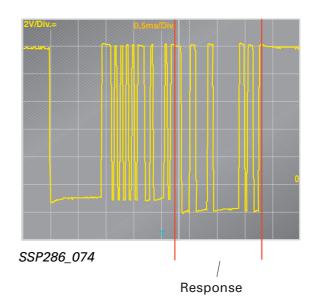LIN slave 2:
Fresh-air blower
signals actual speed

In the case of a message with a data request from the master, the LIN master control unit supplies the response.

In line with the identifier, the corresponding LIN slave control units process the data for implementation of functions.

Example:

LIN master
Operating and display unit
for air conditioner

LIN slave 1:
Heated windscreen

SSP286_062

Set
blower speed

Speed = 200 rpm

LIN slave 2:
Fresh-air blower
increases speed
to 200 rpm

13

LIN bus

The response consists of 1 to 8 data fields. One data field is made up of 10 bits. Each data field comprises a dominant start bit, a data byte (containing the information) and a recessive stop bit. The start and stop bit are used for post-synchronisation and thus to avoid transmission error.

SSP286_074

Response

Sequence of messages

The LIN master control unit transmits the headers and, in the case of master messages, the responses, cyclically to the LIN bus in accordance with a sequence specified in its software.

Frequently required information is transmitted several times.

Statuses affecting the LIN master control unit may alter the message sequence.

Examples:

– Ignition ON/OFF
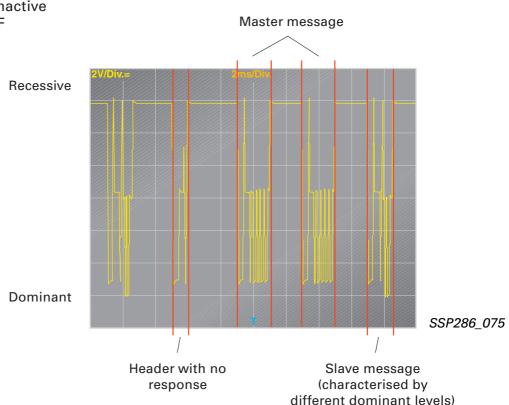– Diagnosis active/inactive
– Side lights ON/OFF

In order to reduce the number of LIN master control unit component options, the master control unit transmits the headers for the control units of a fully equipped vehicle to the LIN bus.

Control units for special equipment not fitted result in headers with no responses on the oscillogram.
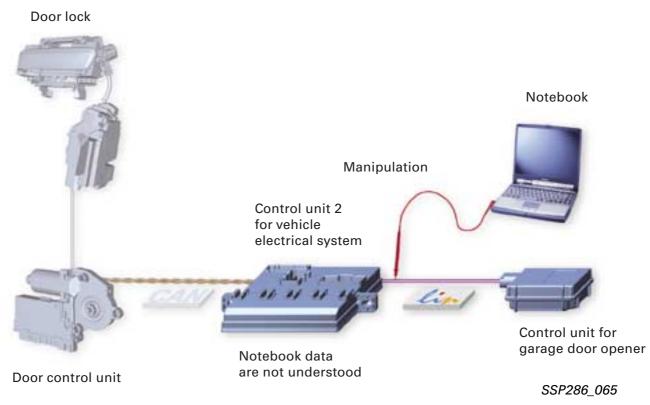
This has no effect on system operation.

Master message

Recessive

Dominant

SSP286_075

Header with no response

Slave message (characterised by different dominant levels)

Anti-theft system

Door lock

Notebook

Manipulation

Control unit 2
for vehicle
electrical system

Control unit for
garage door opener

Notebook data
are not understood

Door control unit

SSP286_065

Data are only transferred in the LIN bus system if the LIN master control unit transmits a header with the appropriate identifier.

The full monitoring of all messages by the LIN master control unit makes it impossible to manipulate any LIN wire on the outside of the vehicle. The LIN slave control unit can only respond.

Thus, for example, the doors cannot be unlocked by way of the LIN bus.

This arrangement makes it possible to install LIN slave control units (e.g. garage door opener control unit in front bumper) on the outside of the vehicle.

LIN bus

Diagnosis

LIN bus system diagnosis is performed by way of the LIN master control unit address word.

The diagnostic data are transferred from LIN slave control units to the LIN master control unit by the LIN bus.

All self-diagnosis functions can be implemented for the LIN slave control units.

Fault location	Fault message	Cause of fault entry
LIN slave control unit e.g. blower control	No signal/ no communication	No data transfer by LIN slave control unit over a period stipulated in LIN master software - Open circuit in wiring or short circuit - Fault in power supply of LIN slave control unit - Incorrect LIN slave or LIN master component option - Fault in LIN slave control unit
LIN slave control unit e.g. blower control	Implausible signal	Checksum error Incomplete message transmission - Electromagnetic interference on LIN wire - Change in capacitance and resistance on LIN wire (e.g. moisture/ dirt at connector housing) - Software problem (incorrect component options)

Introduction

In addition to the familiar CAN bus systems, use has been made for the first time in the Audi A8 ´03 of an optical data bus system.

The name of this data bus system is derived from "Media Oriented Systems Transport (MOST) Cooperation". This is an association formed by various motor vehicle manufacturers, their suppliers and software companies with a view to developing a standard high-speed data transfer system.

MOST

Media Oriented Systems Transport

The term "Media Oriented Systems Transport" signifies a network featuring media-oriented data transport. This means that, in contrast to the CAN data bus, address-oriented messages are transmitted to a specific receiver.
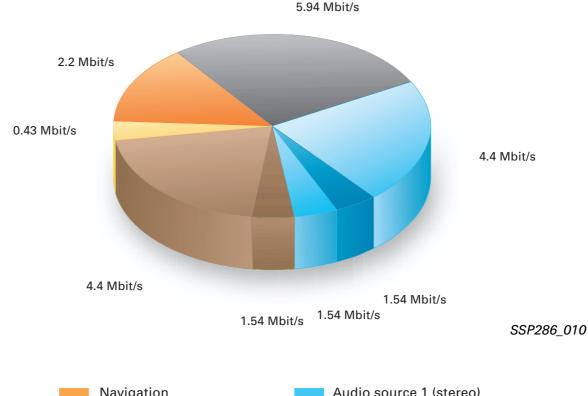
This technique is used in Audi vehicles for the transfer of infotainment system data.

The infotainment system offers a wide range of modern **info**rmation and enter**tainment** media as outlined below.

DVD - Video

DAB - Digital radio

Telephone
Telematics

Central display
and control

TV reception

CD/DVD navigation

Internet
Email

Minidisc/CD audio

SSP286_008

17

MOST bus

Transfer rates of media

5.94 Mbit/s

2.2 Mbit/s

0.43 Mbit/s

4.4 Mbit/s

4.4 Mbit/s

1.54 Mbit/s

1.54 Mbit/s

1.54 Mbit/s

SSP286_010

▪ Navigation	▪ Audio source 1 (stereo) e.g. via rear right headphones
▪ Telephone (GSM)	▪ Audio source 2 (stereo) e.g. via rear left headphones
▪ Video (MPEG)	▪ Audio source 3 (surround sound) e.g. via digital sound system
▪ Video, reduced (MPEG)	▪ Not used

Optical data transfer is an appropriate means of implementing a complex infotainment system as the CAN data bus systems used to date cannot transmit data quickly enough and thus not in the volume required.

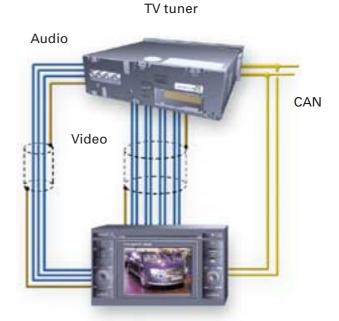The video and audio applications result in transfer rates of many Mbit/s.

A transfer rate of roughly 6 Mbit/s is required just to transmit a digital TV signal with stereo sound.

The MOST bus permits transfer rates of 21.2 Mbit/s.

18

In the past such information (e.g. video and audio) could only be transmitted in the form of an analog signal, increasing the scope of harness wiring required.

CAN bus systems have a maximum data transfer rate of 1 Mbit/s. Consequently, it was only possible to use CAN bus systems to transmit the control signals.

SSP286_002

The optical MOST bus enables data to be exchanged between the components concerned in digital form.
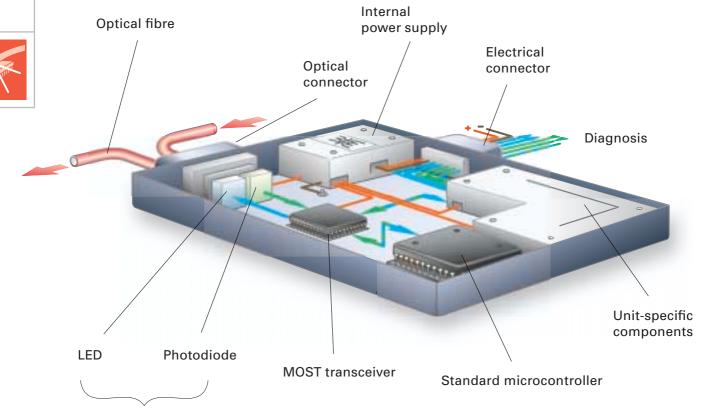
In addition to fewer wires and less weight, light wave transmission provides a far higher data transfer rate.

In comparison to radio waves, light waves have very short wavelengths. In addition, they neither generate nor are susceptible to electromagnetic interference waves.

These factors permit a high data transfer rate and a high level of interference immunity.

SSP286_003

MOST bus

Design of control units

Optical fibre

Internal power supply

Optical connector

Electrical connector

Diagnosis

LED   Photodiode

MOST transceiver

Standard microcontroller

Unit-specific components

Transmitter and receiver – Fibre Optical Transmitter (FOT)

SSP286_011

Components of control units in MOST bus

– Optical fibre - optical connector

By way of this connector, the light signals pass into the control unit or the light signals generated are conveyed to the next bus user.

– Electrical connector

This connector is responsible for the power supply, ring fault diagnosis (refer to Page 41 onwards) and input and output signals.

– Internal power supply

The supply voltage fed into the control unit by the electrical connector is distributed to the components by the internal power supply system. This enables individual components in the control unit to be deactivated to reduce closed circuit current.

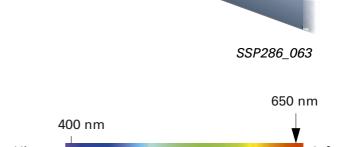– Transmitter and receiver – Fibre Optical Transmitter (FOT)

This consists of a photodiode and a light-emitting diode.
Incoming light signals are converted by the photodiode into a voltage signal which is relayed to the MOST transceiver. The function of the light-emitting diode is to convert MOST transceiver voltage signals into light signals.

The light waves generated have a wavelength of 650 nm and are visible as red light.

The data are transmitted by means of light wave modulation.

This modulated light is then conducted through the optical fibre to the next control unit.

SSP286_063

400 nm

650 nm

Ultra-violet

Infra-red

SSP286_004

– MOST transceiver

The MOST transceiver consists of two components, namely the **trans**mitter and re**ceiver**.

The transmitter conveys the messages to be transmitted to the FOT in the form of a voltage signal.

The receiver accepts the voltage signals from the FOT and conveys the required data to the standard microcontroller (CPU) of the control unit.

Non-required messages from other control units pass through the transceiver without data being conveyed to the CPU. The messages are transmitted in unaltered form to the next control unit.

– Standard microcontroller (CPU)

The standard microcontroller (CPU) is the central processing unit of the control unit. It contains a microprocessor which controls all the major functions of the control unit.

– Unit-specific components

These components are responsible for the implementation of functions specific to the control unit, e.g. CD drive, radio tuner.
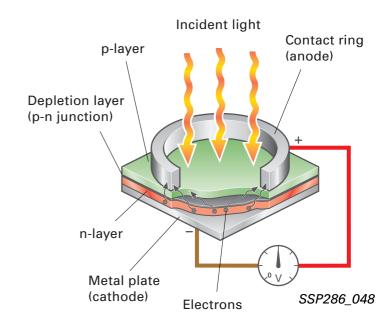
Photodiode

This is designed to convert the light waves into voltage signals.

Design

The photodiode has a p-n junction, onto which light can be focused. On account of a heavily doped p-layer, the depletion layer extends almost exclusively into the n-layer.

There is a contact (anode) at the p-layer. The n-layer is applied to the metallic base (cathode).

Function

The energy associated with the penetration of light or infrared rays into the p-n junction results in the formation of free electrons and holes. These give rise to a flow of current across the p-n junction.
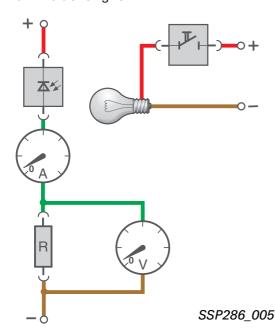
Consequently, the more light which strikes the photodiode the higher will be the current flowing through it.

This process is referred to as the internal photoelectric effect.

Incident light
p-layer
Contact ring (anode)
Depletion layer (p-n junction)
n-layer
Metal plate (cathode)
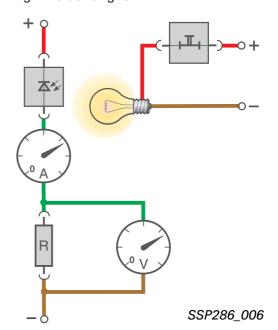Electrons

SSP286_048

In reverse direction, the photodiode is connected in series with a resistor.

An increase in the current flowing through the photodiode on account of more light striking it increases the drop in voltage at the resistor. The light signal has thus been converted to a voltage signal.

Low incident light

SSP286_005

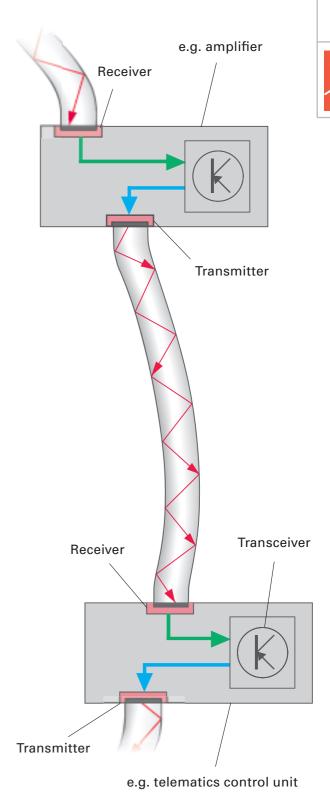High incident light

SSP286_006

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Optical fibre

The optical fibre is designed to convey the light waves generated in the transmitter of one control unit to the receiver of another control unit.

Development of the optical fibre was based on the following criteria:

– Light waves travel in straight lines and cannot be bent. However, they have to be routed through bends in the optical fibre.

– The distance between transmitter and receiver may be several metres – Attenuation (refer to Page 27).

– The optical fibre must not be susceptible to damage caused by mechanical impact (vibration, assembly work).

– The optical fibre must operate reliably despite the great temperature fluctuations in the vehicle.

Requirements to be met by optical fibres used for transmitting light signals:

– The optical fibre must conduct the light waves with a low level of attenuation.

– The light waves have to be routed through bends in the optical fibre.

– The optical fibre must be flexible.

– The optical fibre must operate reliably in the temperature range between - 40 °C and 85 °C.

e.g. amplifier

Receiver

Transmitter

Receiver

Transceiver

Transmitter

e.g. telematics control unit

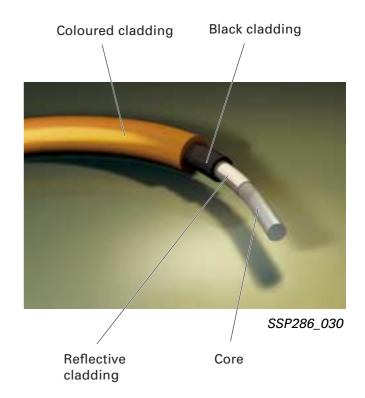*SSP286_020*

Design of optical fibre
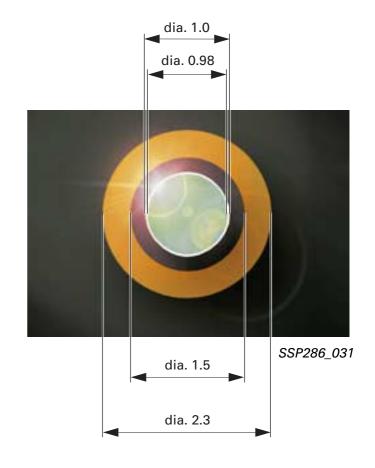
The optical fibre consists of several layers.

The core forms the central part of an optical fibre. It is made of polymethyl methacrylate and represents the actual light conductor, through which the light passes with virtually no losses by way of the total reflection principle. This principle is explained in greater detail in the following.

The optically transparent fluoropolymer cladding around the core is required for total reflection.

The black polyamide cladding protects the core against external incident light.

The coloured cladding is used for identification, protection against mechanical damage and thermal protection.

Coloured cladding   Black cladding

SSP286_030

Reflective cladding   Core

dia. 1.0

dia. 0.98

SSP286_031

dia. 1.5

dia. 2.3

24

Transmission of light waves in optical fibre

Straight optical fibre

The optical fibre conducts some of the light waves in a straight line through the core.

Most of the light waves are conveyed in a zigzag pattern as a result of the total reflection occurring at the core surface.

Curved optical fibre

The total reflection occurring at the core cladding boundary causes the light waves to be reflected and thus conducted through the bend.
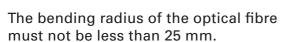
Total reflection

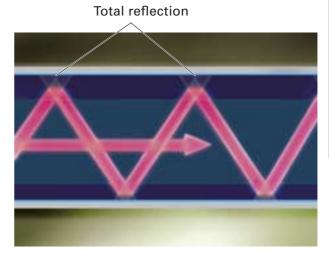*SSP286_032*

Total reflection

If a beam of light strikes a boundary layer between materials with higher and lower refractive indices at a shallow angle, the beam is fully reflected, i.e. total reflection takes place.

In an optical fibre, the material of the core has a higher refractive index than that of the cladding, with the result that total reflection takes place within the core.
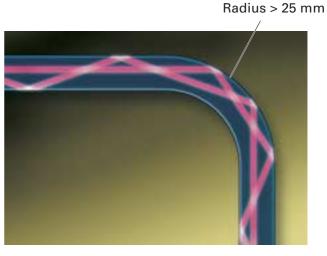
This effect is governed by the angle of the light waves striking the boundary from inside. If this angle becomes too steep, the light waves will leave the core and high losses will occur.

This situation is encountered if the optical fibre is excessively bent or kinked.
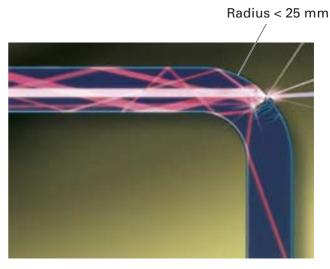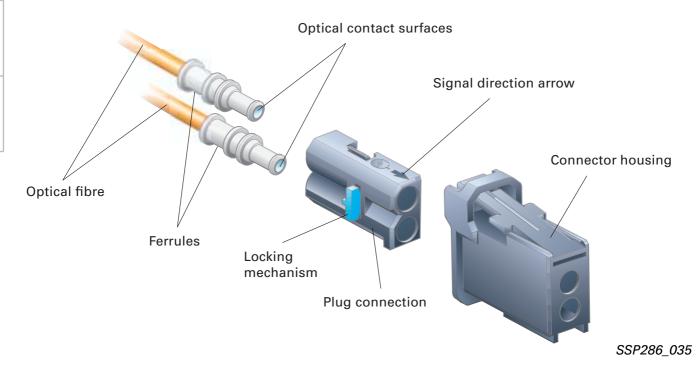
Radius > 25 mm

SSP286_033

Radius < 25 mm

The bending radius of the optical fibre must not be less than 25 mm.

SSP286_034

25

Connector

Optical contact surfaces

Signal direction arrow

Connector housing

Optical fibre

Ferrules

Locking mechanism

Plug connection

SSP286_035

Use is made of special optical connectors to link the optical fibres to the control units. A signal direction arrow on the plug connection indicates the input (to the receiver).

The connector housing creates the link with the control unit.

The light is transmitted by the end face of the core to the transmitter/receiver in the control unit.

At the optical fibre production stage, laser-welded plastic ferrules or crimp-type brass ferrules are fitted to secure the optical fibre in position in the connector housing.
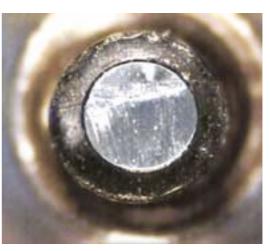
Optical end face

To minimise transmission losses, the end face of the optical fibre must be

– smooth
– perpendicular and
– clean.

This can only be achieved using a special cutting tool.

Dirt and scratches on the cut face cause higher losses (attenuation).

SSP286_081