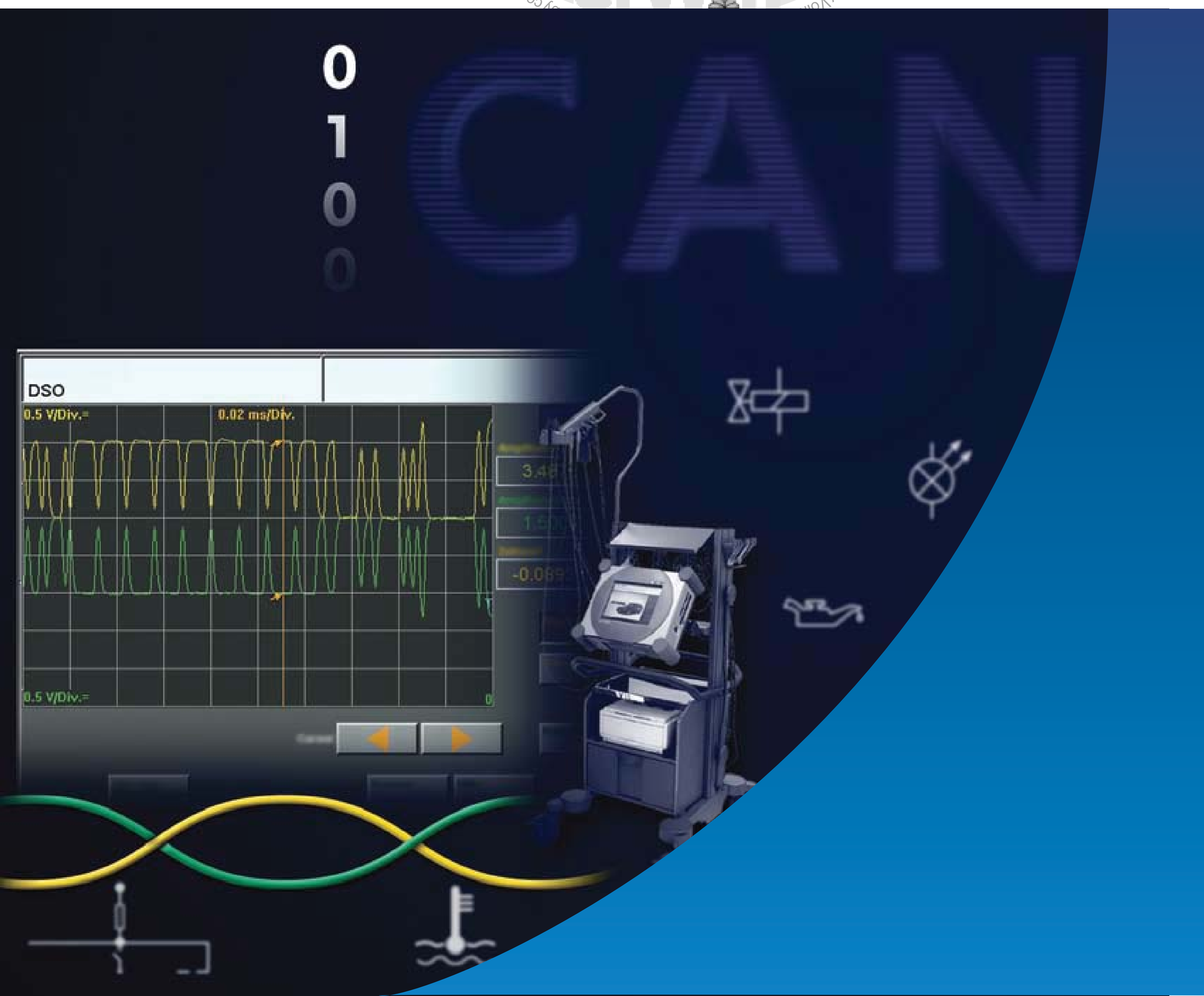
Service Training

Self-Study Program 872803

Volkswagen Data Bus Technologies



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Always check Technical Bulletins and the latest electronic repair information for information that may supersede any information included in this booklet.

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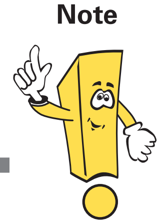
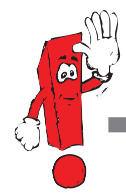


Important!



This Self-Study Program covers information on the Volkswagen Data Bus Technologies.
This Self-Study Program is not a Repair Manual.
This information will not be updated.

For testing, adjustment and repair procedures, always refer to the latest electronic service information.

Notes

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Data Bus Technology

The demand for more luxury features and increased comfort in vehicles creates an ever-increasing need for more capable and more complicated vehicle electronic systems. Data bus technology makes it possible to form a complex network of electronic control modules and sensors that can communicate with each other and share data across the entire network without the size, complexity, expense and other limitations of a conventional wiring harness.

Volkswagen's introduction of Controller Area Network or CAN data bus technology in the mid-'90s was a first, important step toward the exchange of increasing amounts of data between control modules.

The first portion of this Self-Study Program describes basic functions of CAN-bus systems in general, and goes on to cover specific functions, diagnosis and testing for Drivetrain, Convenience and Infotainment CAN bus systems.

The latter portion of this Self-Study Program describes the single wire Local Interconnect Network *(LIN)* data bus, Media Oriented Systems Transport *(MOST)* fiber-optic data bus, and wireless data transmission technology used in the latest Volkswagen vehicles.

Purpose of a CAN-bus System

The CAN-bus system provides the following advantages as an overall system:

– Data exchange between control modules takes place on a uniform platform or *protocol*, with the CAN-bus acting as a *data highway*
– Systems involving several control modules, ESP for example, can be implemented efficiently
– System expansions and additions of optional equipment are easier to implement
– CAN is an open system that permits adaptation to various data transfer media, such as copper wires or fiber-optic cables
– CAN is used on later models for control module diagnosis, replacing the actual K-wire with CAN-bus wires
– System-oriented diagnosis is possible across systems employing several control modules

CAN-Bus Overview

CAN-bus Networking

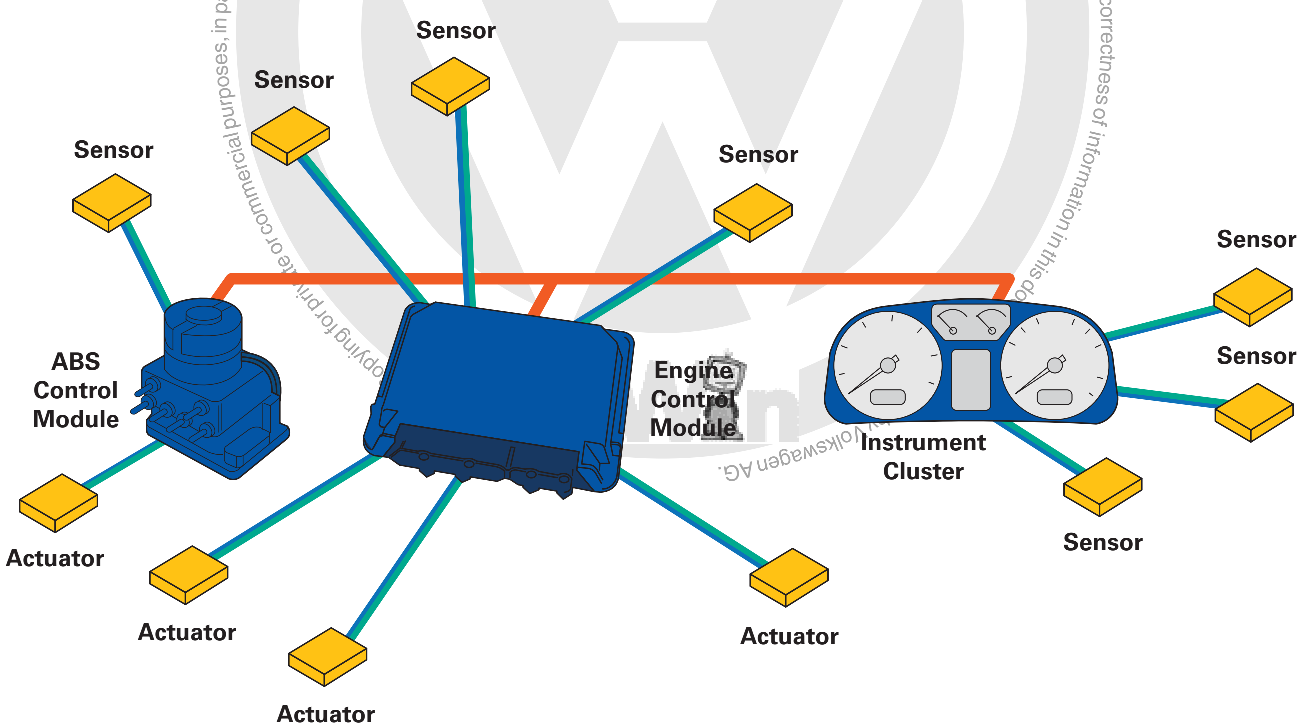
Depending on the model and model year, different CAN-bus systems are used in Volkswagen vehicles.

The first, introduced in the mid-'90s, was a Convenience CAN with a data transfer rate of 62.5 kbits/s *(kilobits per second)*. Next came a Drivetrain CAN using a data transfer rate of 500 kbits/s.

As of model year 2000, more advanced Convenience and Infotainment CAN systems have been introduced, each with a data transfer rate of 100 kbits/s. Additional types of data bus systems, introduced in model year 2005, are covered in this Self-Study Program.

The Convenience and Infotainment CAN systems exchange data with the Drivetrain CAN through the Gateway, which allows for communication between bus systems operating at different data transfer rates.

Drivetrain CAN Network with Three Control Modules



Design and Main Features

Individual electronic control modules are connected in parallel through the CAN-bus system. This results in the following requirements for the design of the overall system:

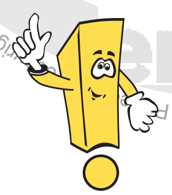
- High level of error protection: transmission interference caused by internal or external sources must be detected with a high degree of certainty
- High availability: if a control module fails, the rest of the system must continue to function as well as possible in order to continue the exchange of information
- High data density: all control modules have the same information status at all times. This means there is no difference in data between the control modules. In case of faults anywhere in the system, all the connected users can be informed with equal certainty
- High data transmission rate: data exchange between networked users must be very fast in order to meet real-time requirements

Signals are sent over the CAN system digitally. Secure transmission is possible at rates of 1000 kbits/s *(kilobits per second)* or more, as seen in the latest Infotainment network. Some CAN systems are fixed at lower data transmission rates to ensure signal quality.

Practical Layout

Due to different demands with respect to the required repeat rate of the signals, the volume of data and its availability *(readiness)*, the three CAN systems used since model year 2000 are configured as follows:

- Drivetrain CAN *(high speed)* at 500 kbits/s networks the control modules in the drivetrain systems
- Convenience CAN *(low speed)* at 100 kbits/s networks the control modules in the convenience system
- Infotainment CAN *(low speed)* at 100 kbits/s networks the information and entertainment systems — radio, telephone and navigation, for example
- 2005> Instrument Cluster CAN-bus and Diagnosis CAN-bus



Note Transmission rates of 1,000 kbits/s and higher are used in the latest Infotainment CAN networks *(MOST)*, which are covered later in this Self-Study Program.

CAN-Bus Overview

Common to All CAN-Bus Systems:

– Systems are all subject to the same regulations for data exchange, such as the defined transfer protocol

– To assure a high degree of protection from electro-magnetic interference, each CAN-bus is made up of entwined two-conductor wiring referred to as a *twisted pair*

– Signals to be sent are stored in the transceiver of a sending control module with different signal levels before being sent to both CAN lines. Not until the differential amplifier of the receiving control module calculates the difference of both signal levels is a single, cleaned signal sent to the CAN receiver of the control module

– First examples of the Infotainment CAN have the same properties as the Convenience CAN. In some models, they are operated through one common pair of wires *(bus)*. In the Phaeton, we will see optical bus systems for the Infotainment network

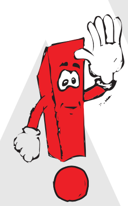
Common to All CAN-Bus Systems:

– Drivetrain CAN is switched OFF by terminal 15 following an after-run period

– Convenience CAN is supplied with power through terminal 30, and must remain on standby. To prevent excessive electrical load, the system switches to sleep mode by switching terminal 15 OFF when it is not required

– Convenience/Infotainment CAN remains operational, thanks to the second wire, if there is a short circuit in the data bus or an open circuit in a CAN wire. In such an instance, the system will switch automatically to single wire operation

– Electrical signals from the Drivetrain CAN and Convenience/Infotainment CAN are different



Important! The Drivetrain CAN should never be electrically connected to the Convenience/Infotainment CAN! The various data bus systems for Drivetrain and Convenience/Infotainment networks should only be connected in the vehicle through the Gateway. The Gateway may be integrated with the Instrument Cluster Control Module or installed as a separate control module.

CAN-Bus Components

The CAN-bus is made up of a controller, a transceiver and two data bus lines.

Apart from the data bus lines, the components are located in the electronic control modules. The main functions of the control modules are the same as before, with the following additional tasks:

CAN Controller

The CAN controller receives transfer data from a micro-computer integrated into the control module.

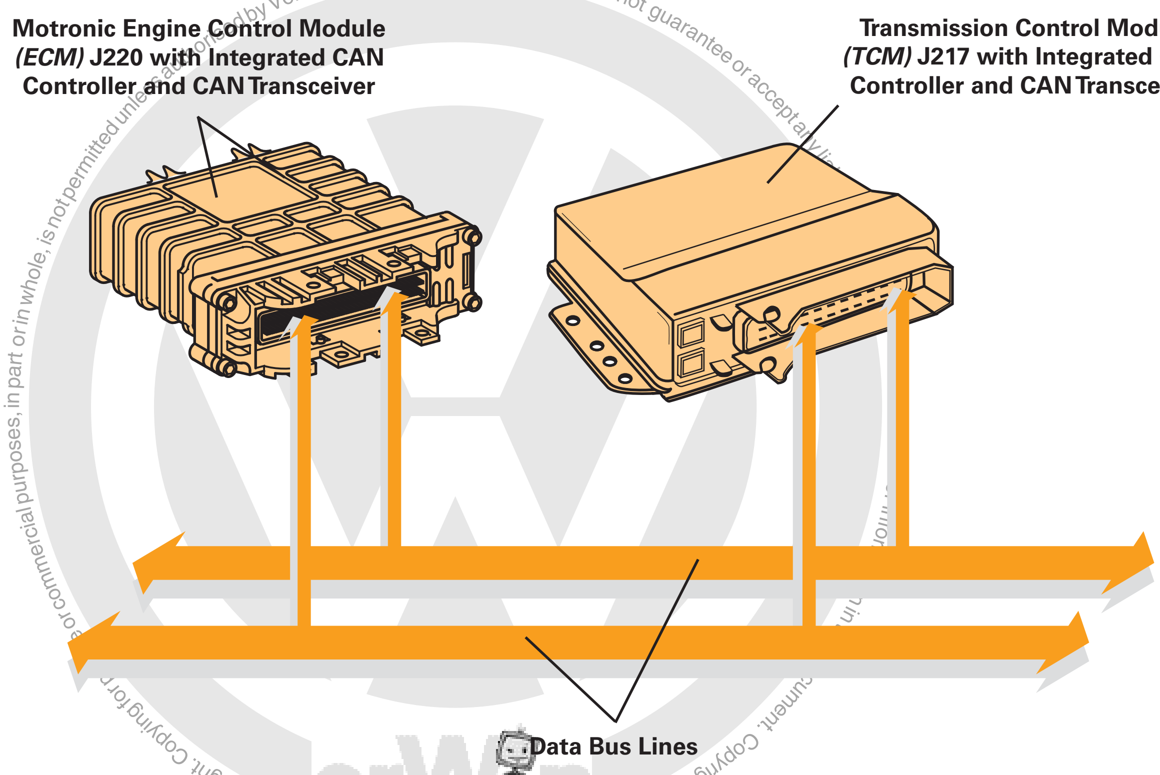
The CAN controller processes this data and relays it to the CAN transceiver. Likewise, the CAN controller receives data from the CAN transceiver, processes it, and relays it to the electronic control module micro-computer.

CAN Transceiver

The CAN transceiver is a combined transmitter and receiver. It converts the data that the CAN controller supplies into electrical signals, sending this data over the data bus lines. Likewise, it receives data and converts this data for the CAN controller.

Data Bus Lines

The data bus lines are bi-directional and transfer data. They are referred to as *CAN-high* and *CAN-low*.

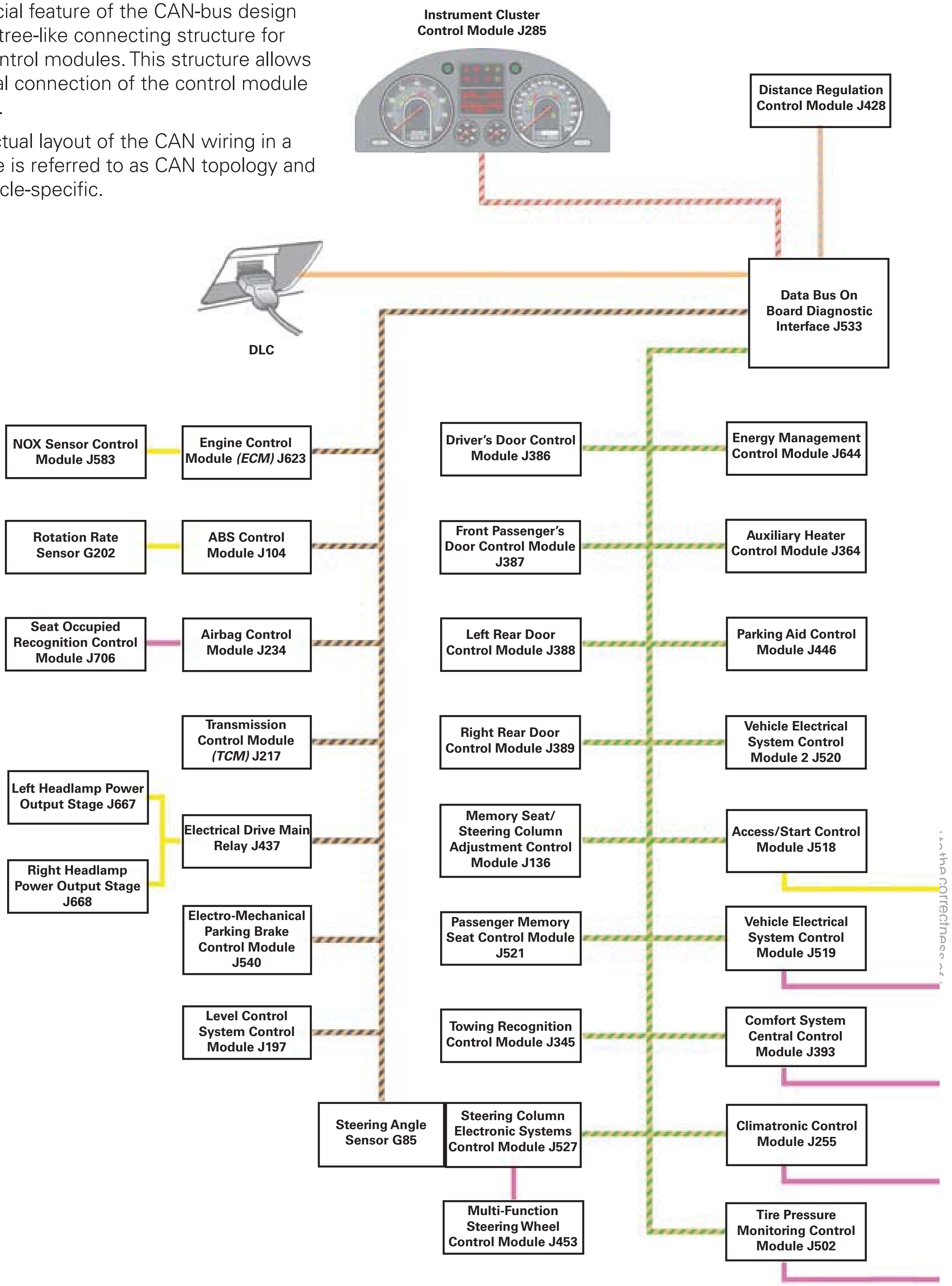


CAN-Bus Overview

CAN-Bus Topology

A special feature of the CAN-bus design is the tree-like connecting structure for the control modules. This structure allows optimal connection of the control module wiring.

The actual layout of the CAN wiring in a vehicle is referred to as CAN topology and is vehicle-specific.



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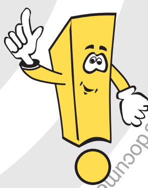
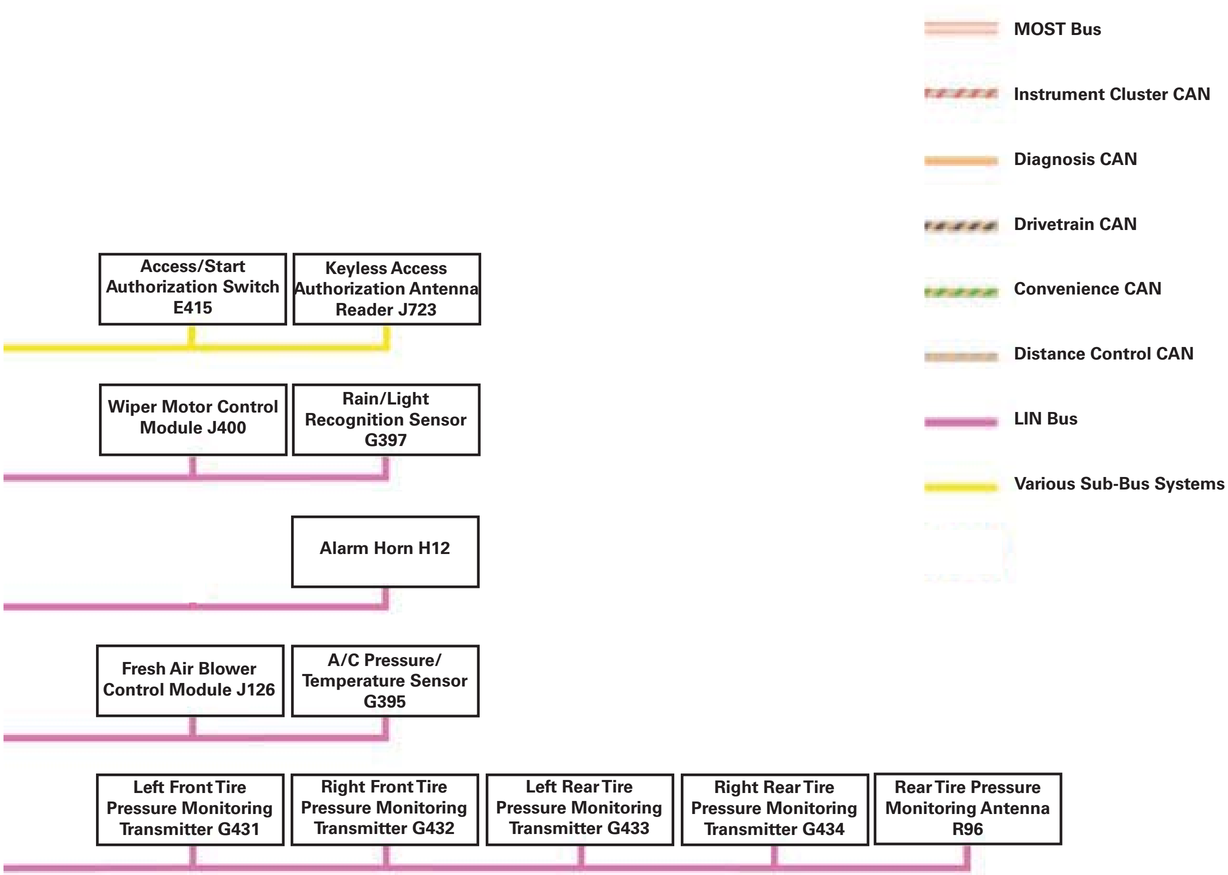


Not all components shown here are installed on every vehicle. Some components may not be available for the North American market.



CAN-Bus Overview

Basic Information Exchange

Information is exchanged between control modules in small packages of data referred to as *messages*. Any control module can send or receive messages.

A message contains information about physical values such as engine speed *(RPM)* or engine coolant temperature. Engine speed in this case is represented as a binary value *(a string of ones and zeroes)*. For example: engine speed of 1800 RPM is represented as 00010101 in binary notation.

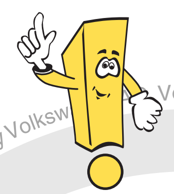
Before being sent, the binary value is converted into a serial bit stream. The bit stream is sent over the TX line *(transmit line)* to the transceiver *(amplifier)*. The transceiver converts the bit stream into voltage values, which are then sent over the bus line one by one.

In the reception process, voltage values are converted back into a bit stream by the transceiver and sent over the RX line *(receive line)* to the control module. The control module then converts the serial binary values back into messages.

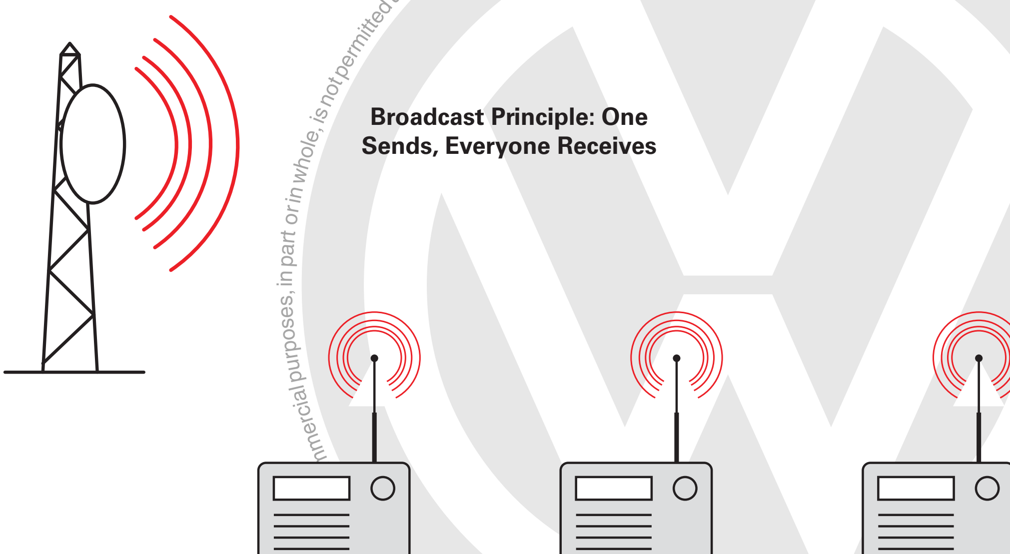
A message sent to the CAN-bus can be received by any control module, and is generally received and evaluated by all other electronic control modules on the particular CAN-bus.

This process relies on what is called the broadcast principle — one sends, everyone receives. The idea is derived from a radio transmitter broadcasting a program that any tuner *(receiver)* can receive.

The broadcasting process ensures that all control modules connected to the CAN-bus have the same information status.



Note For a detailed explanation of data exchange, please see Appendix A, page 90.



Broadcast Principle: One Sends, Everyone Receives

Data Transfer Process

Supplying the Data

The control module provides data to the CAN controller for transfer.

Sending Data

The CAN transceiver receives data from the CAN controller, converts it into electrical signals, and sends them.

Receiving Data

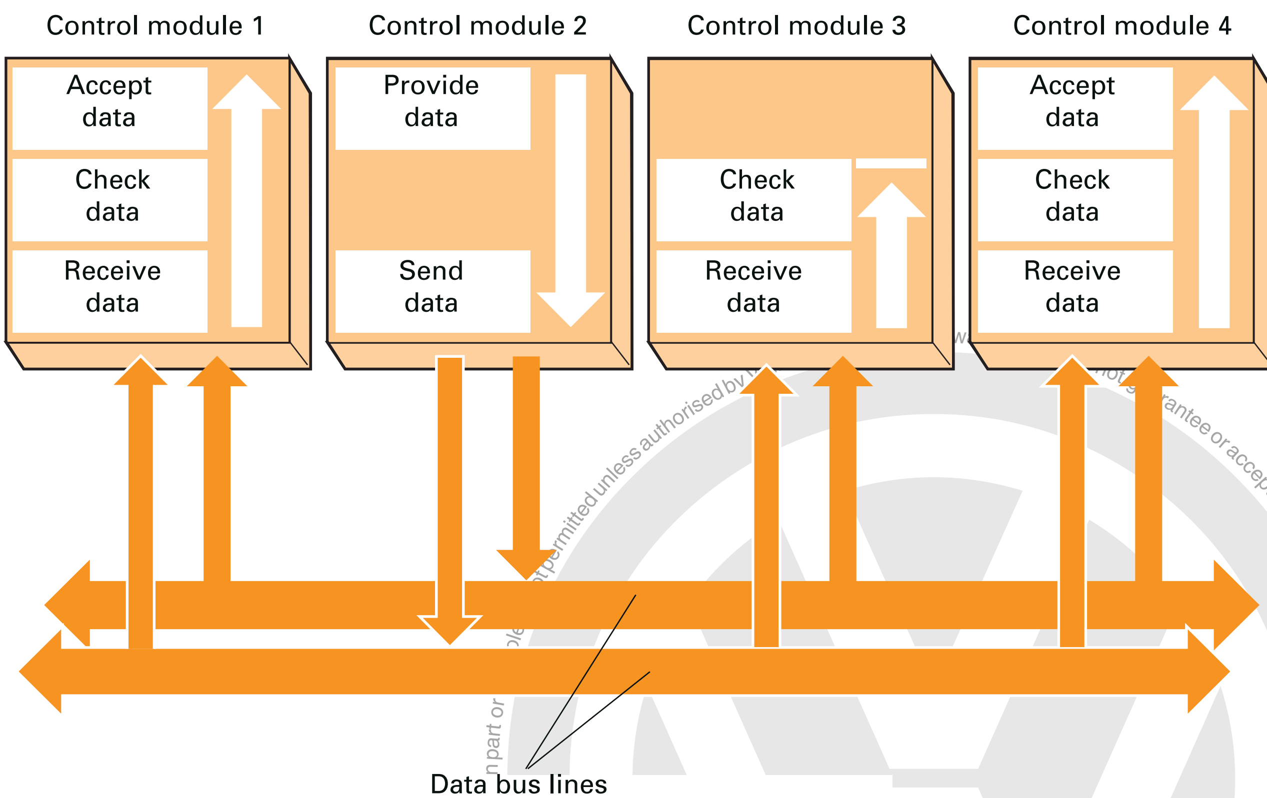
All other control modules networked with the CAN-bus become receivers.

Checking Data

Control modules check whether or not they require the data they have received for their functions.

Accepting Data

If the received data is important, it is accepted and processed. If not, it is ignored.



If more than one control module wants to send its data simultaneously, the system must decide which control module comes first.

Priorities are determined and the data is assigned a "high" or "low" weighting depending on importance by changing a data bit to 1 *(one)* or 0 *(zero)*. The data with the highest priority is sent first.

For safety reasons, the data supplied by the ABS/EDL control module is more important than the data supplied by the transmission control module.

When control modules start sending their data simultaneously, they compare the data bit by bit on the data bus line.

If a control module sends a "low" weighting bit and detects a "high" weighting bit, the control module stops sending and becomes a receiver.

CAN-Bus Overview

What Does the CAN-bus Transfer?

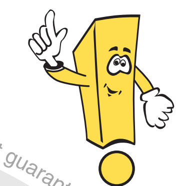
The CAN-bus transfers data between control modules at short intervals using a standardized data protocol, which is subdivided into seven areas.

The data protocol is made up of a long string of bits. The number of bits in the data protocol depends on the size of the data field.

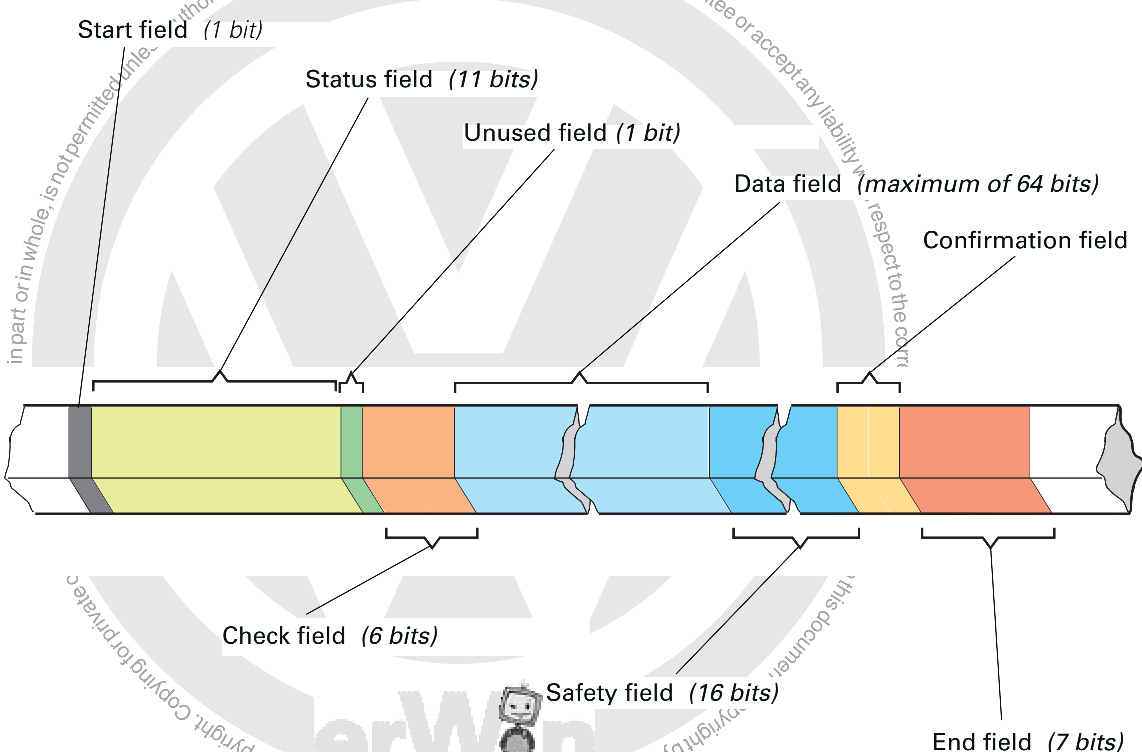
The diagram below shows the format of the data protocol. This format is identical on both data bus lines.

For the sake of simplicity, we will sometimes focus on only one data bus line in this Self-Study Program.

Note



A bit is the smallest unit of information *(one circuit state per unit of time)*. In electronics, this information can only have the value "0" or "1" meaning, for example, "yes" or "no." For a more indepth description of the data bit, please see Appendix B, page 105.



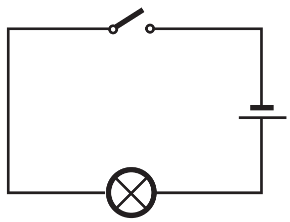
How is the Data Protocol Produced?

The data protocol is made up of a string of several bits. Each bit can only have a status or value of "0" or "1." A light switch circuit provides a simplified example of how a "0" or "1" status is generated.

A switch in the circuit switches a light ON or OFF. This means that the circuit can have two different states.

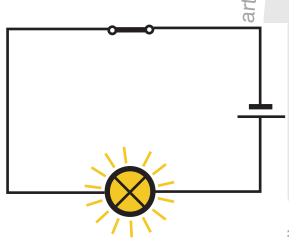
Status of Light Switch Circuit with Value "0"

- Switch OPEN
- Light is OFF

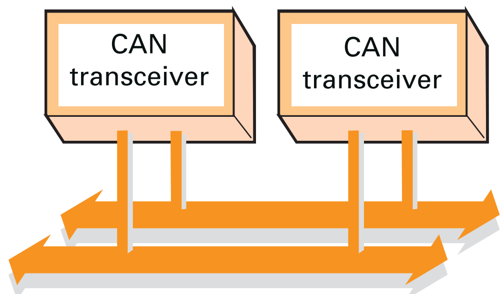


Status of Light Switch Circuit with Value "1"

- Switch CLOSED
- Light is ON

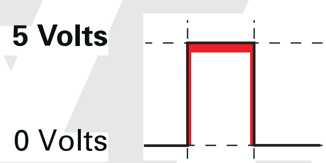


In principle, the CAN-bus functions in exactly the same way. Operation of a CAN transceiver is also based on two different bit states.



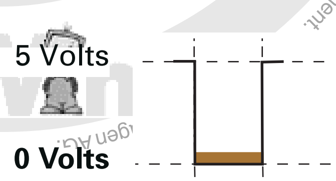
Status of Bit with the Value "1"

- Transceiver OPEN, switched to positive voltage *(approximately 5.0 volts in the Convenience CAN, for example)*
- Voltage is applied to the data bus line



Status of Bit with the Value "0"

- Transceiver CLOSED, switched to Ground
- Approximately 0 volts applied to the data bus line



CAN-Bus Overview

Electrical/Electronic Properties of Data Transfer

Voltage Differences in CAN Wires When Changing Between Dominant and Recessive State

Electrically, data transfer is based on the difference between CAN-high voltage and CAN-low voltage. In a rest state, when there is no data transfer, both CAN-bus wires *(CAN-high and CAN-low)* have the same default signal level.

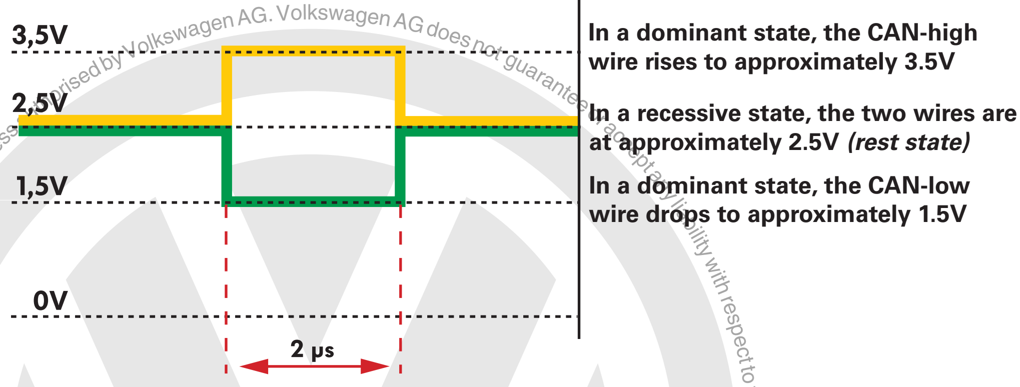
On the Drivetrain CAN, for instance, this level is approximately 2.5 volts. The rest state is also known as the *recessive* state, as it can be changed by any control module connected into the network.

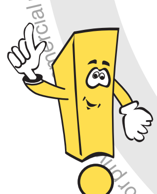
In the active or *dominant* state, voltage of the CAN-high wire increases by a predetermined value *(on the Drivetrain CAN, this is at least 1 volt)*. The voltage of the CAN-low wire drops by the same increment.

This results in a rise in the voltage of the CAN-high wire to at least 3.5 volts *(2.5 volts + 1 volt = 3.5 volts)*, and a drop in the voltage of the CAN-low wire to a maximum of 1.5 volts *(2.5 volts - 1 volt = 1.5 volts)*.

The voltage difference between CAN-high and CAN-low in a recessive state is 0 volts. In a dominant state, the difference is at least 2 volts.

Signal Pattern of the Drivetrain CAN *(Example)*





Note All voltage readings are approximate values. Actual measured values may differ slightly.

How is Data Transferred?

The CAN-bus is wired in parallel with all of the control modules included in the respective CAN system. The two wires CAN-high and CAN-low, are assembled as a twisted pair.

The CAN wires in the wiring harness are colored orange. The CAN-high wire in the Drivetrain CAN has an additional black marking *(orange/black)*. On the Convenience CAN, the additional color is green; on the Infotainment CAN it is violet. The CAN-low wire is always marked brown *(orange/brown)*.

Information is exchanged between the Instrument Cluster Control Module and Data Bus On Board Diagnostic Interface J533 via the Instrument Cluster CAN-bus. These are the only modules on this bus. The CAN-high wire is yellow and the CAN-low wire is brown.

The transfer of data between the VAS 5051/5052 Scan Tools and the Data Bus On Board Diagnostic Interface is through the diagnosis CAN-bus. Always consult the appropriate Wiring Diagram for color codes when diagnosing issues with the various CAN-bus systems.

For reasons of clarity, the CAN wires are shown in this Self-Study Program as completely yellow or completely green, as in a VAS Scan Tool digital storage oscilloscope *(DSO)* display. The CAN-high wire is always displayed as yellow, while the CAN-low wire is always displayed as green.

Representation of CAN-High and CAN-Low Wires as Twisted Pair

CAN-Bus Overview

Properties and Special Features of the Drivetrain CAN

The Drivetrain CAN, operating at a data transfer rate of 500 kbits/s, serves as a means of networking the various control modules for the drivetrain.

Examples of control modules on the Drivetrain CAN are:

- Engine Control Module
- ABS Control Module
- Transmission Control Module
- Airbag Control Module
- Headlamp Range Control Module

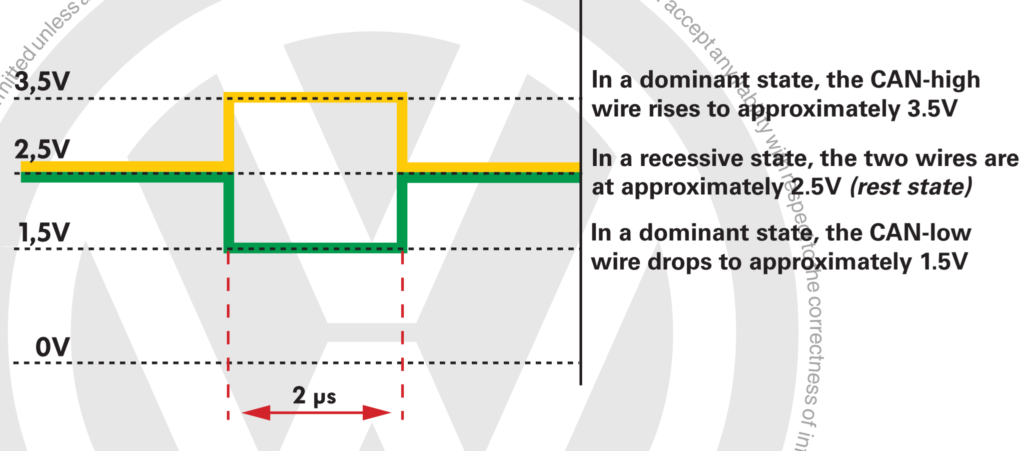
The Drivetrain CAN is, like all CAN wires, a twisted pair. It has a data transfer rate of 500 kbits/s. For this reason, it is also referred to as a high speed CAN.

Data is exchanged between the control modules through the CAN-high and CAN-low wires of the Drivetrain CAN. Data messages are sent from the control modules with a repeat rate that is generally in a range of 10–25 ms.

The Drivetrain CAN is activated through terminal 15 *(ignition)*. When the ignition is switched OFF, the Drivetrain CAN is powered during a short after-run period, then completely deactivated.

If either of the wires of the Drivetrain CAN fail due to an open circuit, short circuit or short circuit to battery positive, the Drivetrain CAN will not transmit data. The Drivetrain CAN, unlike the Comfort/Infotainment CAN, will not operate in single wire mode.

Signal Pattern of the Drivetrain CAN

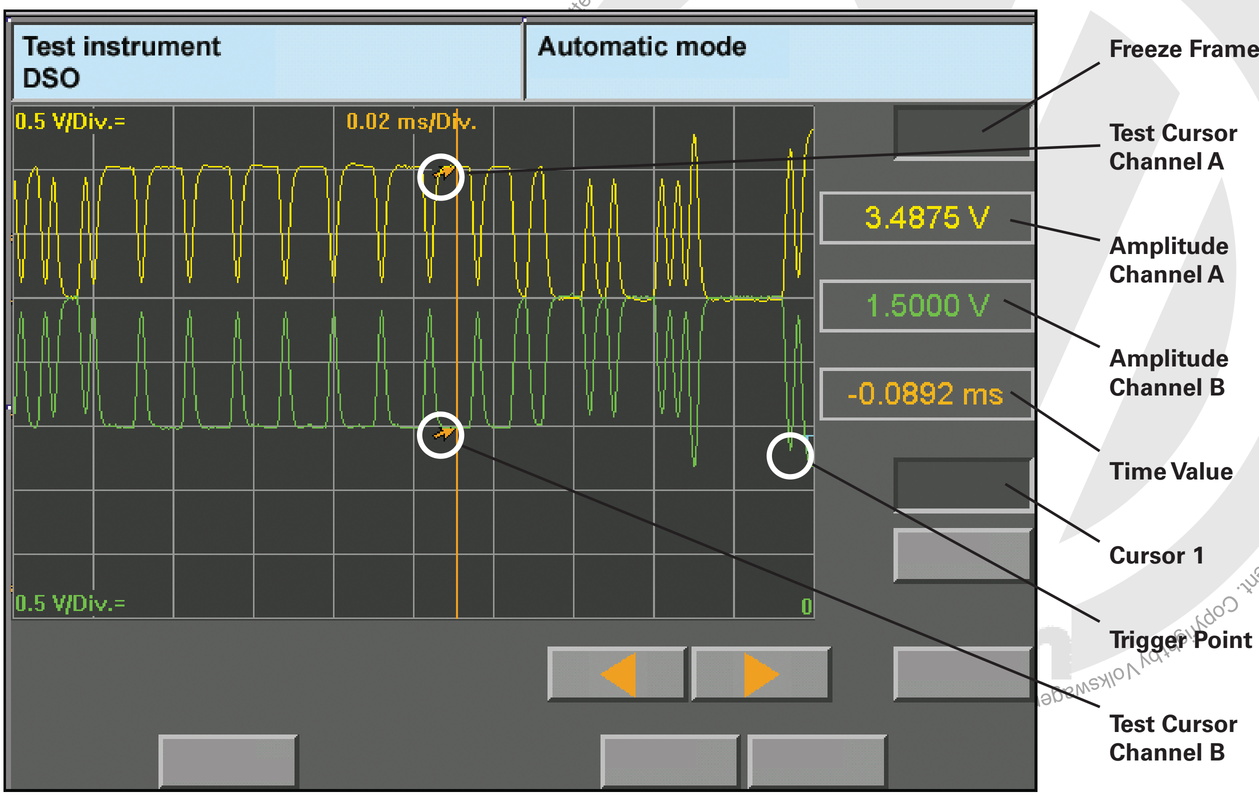


μs = micro-second

Signal Pattern of the Drivetrain CAN

The diagram below shows the pattern of a real CAN signal, recorded with the digital storage oscilloscope *(DSO)* from a VAS Scan Tool.

The combined signal pattern indicates the recessive level of 2.5 volts. The dominant voltage at CAN-high is approximately 3.5 volts. At CAN-low it is approximately 1.5 volts.



Dominant and recessive levels alternate

V_{CAN} high at 3.48V, V_{CAN} low at 1.5V

Setting: 0.5/Div., 0.02ms/Div.

CAN-Bus Overview

Properties and Special Features of the Convenience/Infotainment CAN

The Convenience/Infotainment CAN, operating at a data transfer rate of 100 kbits/s, serves as a means of networking the various control modules associated with the convenience and infotainment systems.

Examples of control modules on the Convenience/ Infotainment CAN are:

– Climatronic control module

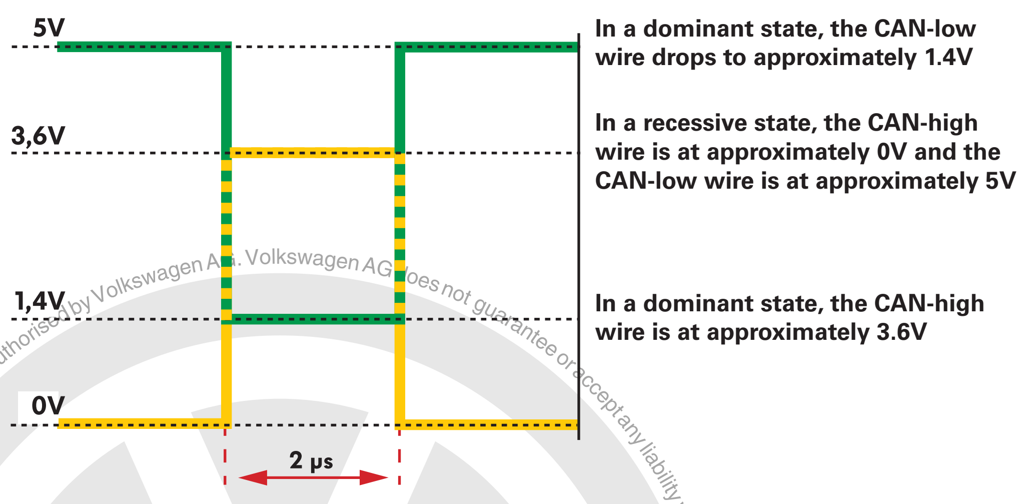
– Door control modules

– Radio/Navigation display control module

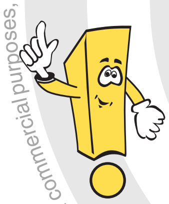
The Convenience/Infotainment CAN is, like all CAN-bus wires, a twisted pair and has a data transfer rate of just 100 kbits/s, which is why it is also referred to as a low speed CAN.

Data is exchanged between the control modules through the CAN-high and CAN-low wires of the Convenience/Infotainment CAN. The Convenience CAN and Infotainment CAN can be operated on a common pair of CAN-high and CAN-low wires because the two systems have the same transfer rate. On later models, Infotainment data is also transferred on an optical bus.

Signal Pattern of the Convenience/Infotainment CAN



μs = micro-second



Note

All voltage readings are approximate values. Actual measured values may differ slightly.

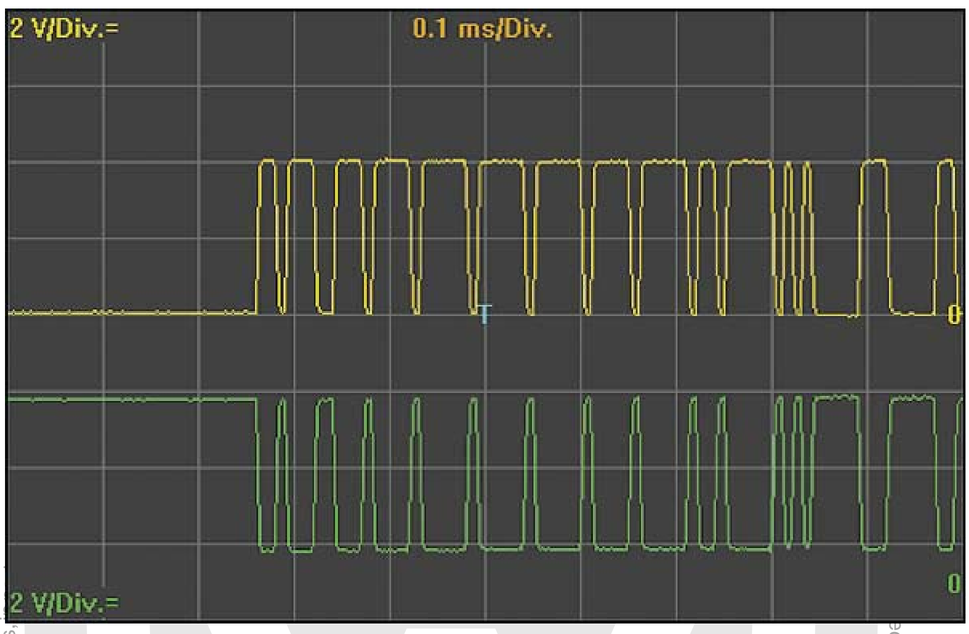
Differential Data Transfer on the Convenience/ Infotainment CAN

In order to provide greater resistance to electromagnetic interference and reduced power consumption on the low speed CAN, the Convenience/Infotainment CAN is different from the Drivetrain CAN in some key ways.

First, the CAN-high and CAN-low signals are independent. This was accomplished using independent drivers *(output amplifiers)* in the electronic control modules. The CAN-high and CAN-low wires of the Convenience/Infotainment CAN are not connected to each other through resistors. They no longer influence each other, but work independently.

There is no common medium voltage. The CAN-high signal is 0 volts in a recessive state *(rest state)*, and greater than or equal to 3.6 volts in a dominant state. For the CAN-low signal, the recessive level is 5 volts and the dominant level is less than or equal to 1.4 volts. After differential build-up in the differential amplifier, the recessive level is 5 volts and the dominant level is 2.2 volts. The combined difference in voltage between the recessive and dominant levels *(voltage rise)* is therefore greater than or equal to 7.2 volts.

Signal Pattern Image on VAS 5051 DSO *(Freeze Frame)*



For reasons of clarity, displays of the CAN-high and CAN-low signals are separated. This is indicated by the different zero points in the DSO image. The different rest states for CAN-high and CAN-low are clearly visible.

Dominant and recessive levels alternate

V_{CAN} high at 3.6V, V_{CAN} low at 1.4V

Setting: 2V/Div., 0.1ms/Div.

CAN-Bus Overview

CAN Transceiver on the Convenience/Infotainment CAN

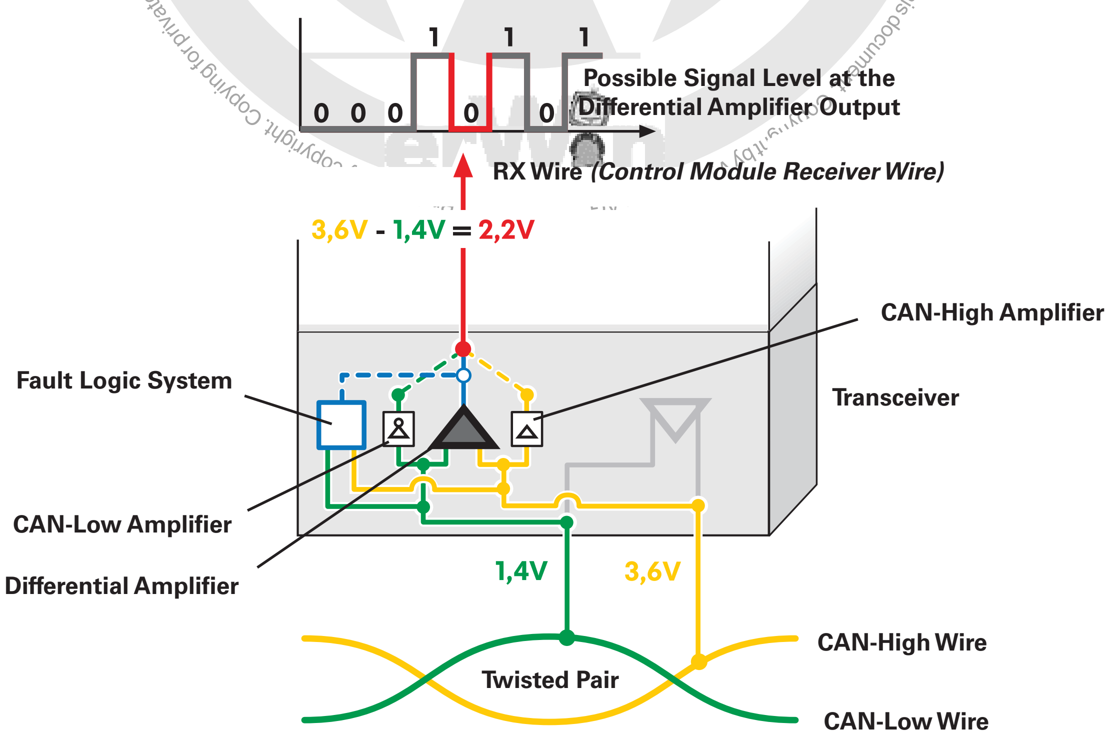
A CAN transceiver connected to and operating on the Convenience/Infotainment CAN works much the same way as a transceiver on the Drivetrain CAN. The only differences are that different signal levels are sent, and measures are taken to revert to CAN-high or CAN-low alone if there is a fault *(single wire operation)*. Short circuits are still detectable between CAN-high and CAN-low and, in the case of a fault, the CAN-low driver is switched OFF. If this happens, CAN-high and CAN-low wires have the same signal.

The data transfer of data on the CAN-high and CAN-low wires is monitored by the fault logic system integrated into the transceiver.

The fault logic system evaluates the input signals of both CAN wires. If there is a fault, such as an open circuit in one CAN wire, it will be detected by the fault logic system and only the intact wire is used by the control module for CAN by evaluation *(single wire operation)*.

For normal operation, the CAN-high signal "minus" CAN-low is evaluated. The effects of simultaneous disturbances in both wires of the Convenience/ Infotainment CAN are thereby minimized as effectively as on the Drivetrain CAN.

Design of Convenience/Infotainment CAN Transceiver

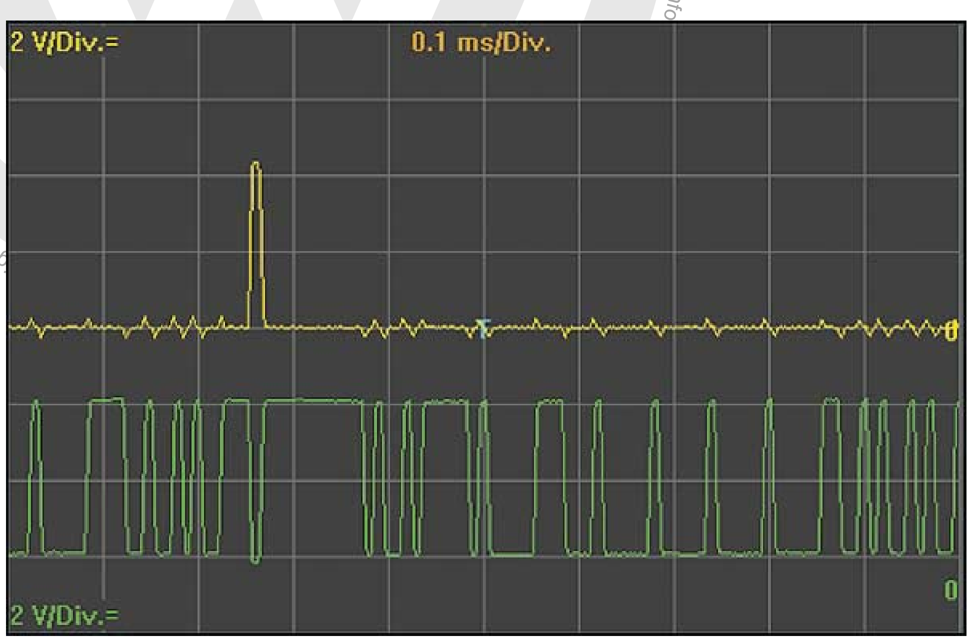


Convenience/Infotainment CAN in Single Wire Operation

If either of the CAN wires of the Convenience CAN-bus fails due to an open circuit, short circuit or short circuit to battery positive, the system switches to single wire operation. During single wire operation, only the signals of the remaining intact CAN wire are evaluated. In this way, the Convenience/Infotainment CAN remains operational.

The actual CAN evaluation in the control module is unaffected by single wire operation. Using a special fault output, the control module provides information as to whether the transceiver is in normal or single wire operation.

Signal Pattern on DSO During Single Wire Operation *(Freeze Frame)*

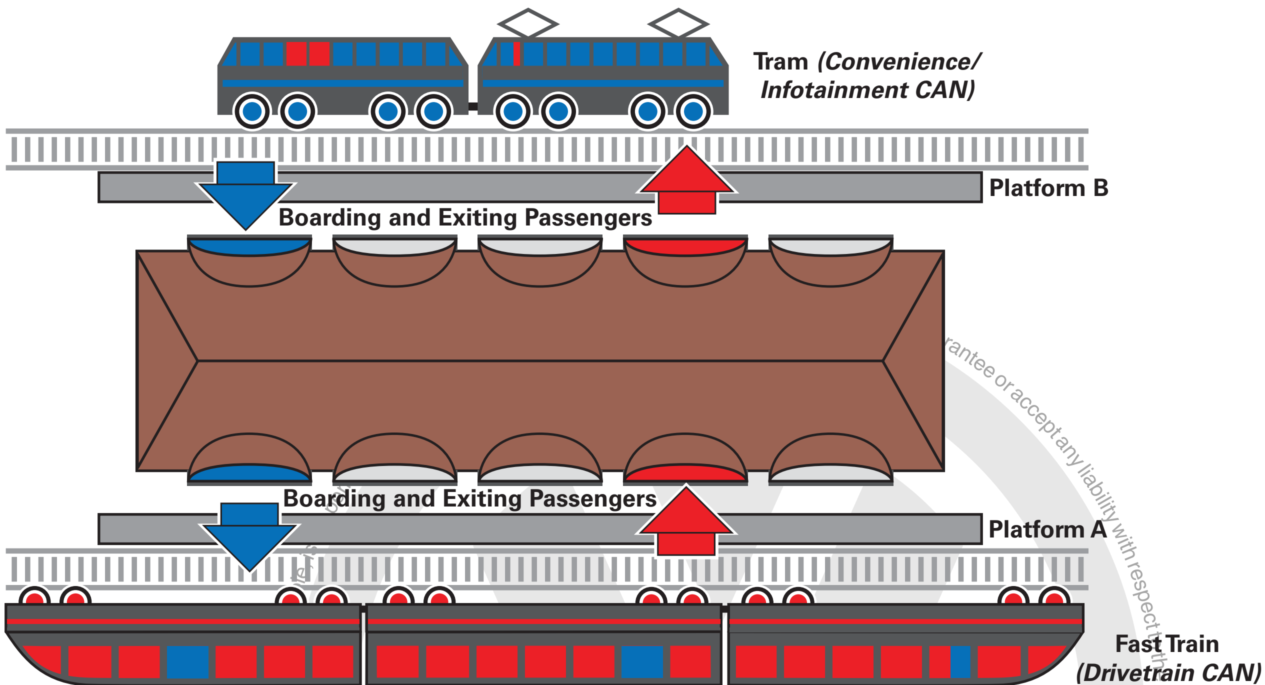


Data Bus On Board Diagnostic Interface

Data Bus On Board Diagnostic Interface J533 *(Gateway)* Networking

The Drivetrain CAN cannot be connected directly to the Convenience/Infotainment CAN due to the different signal levels and resistance levels. In addition, the different data transfer rates of the various data bus systems make it impossible for control modules to evaluate the different signals.

Conversions are necessary to allow the different data bus systems to communicate with each other. These conversions are carried out by Data Bus On Board Diagnostic Interface J533, also known as the Gateway.



The principle of the Gateway can be compared to a railway system.

At platform A *(the Gateway)* of the railway, a fast train arrives *(Drivetrain CAN, 500 kbits/s)* with several hundred passengers on board. At platform B, a slower train is already waiting *(Convenience/ Infotainment CAN, 100 kbits/s)*.

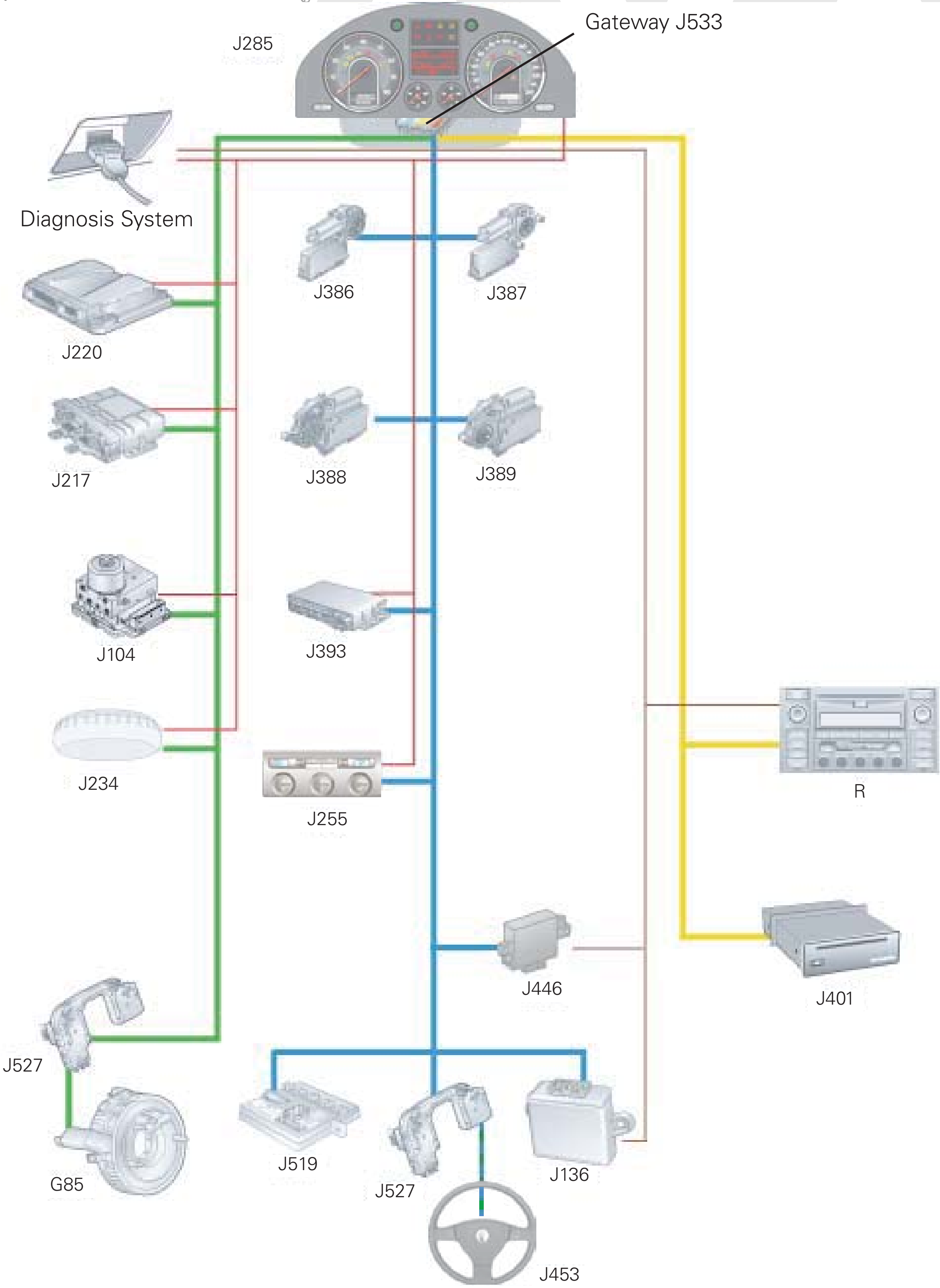
A number of passengers change from the fast train to the slower train and some passengers from the slower train have transferred to the faster train.

The function of the railway platform is to allow the passengers to change trains to take them to their chosen destination at different speeds. This describes the role of the Gateway in networking.

The main role of the Gateway is to exchange information between both systems at different speeds.

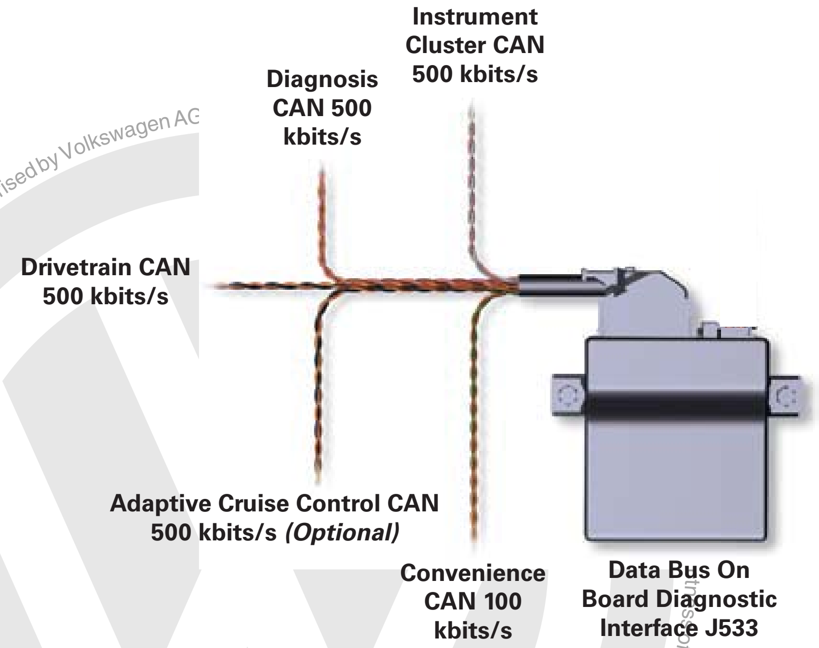
Data Bus On Board Diagnostic Interface

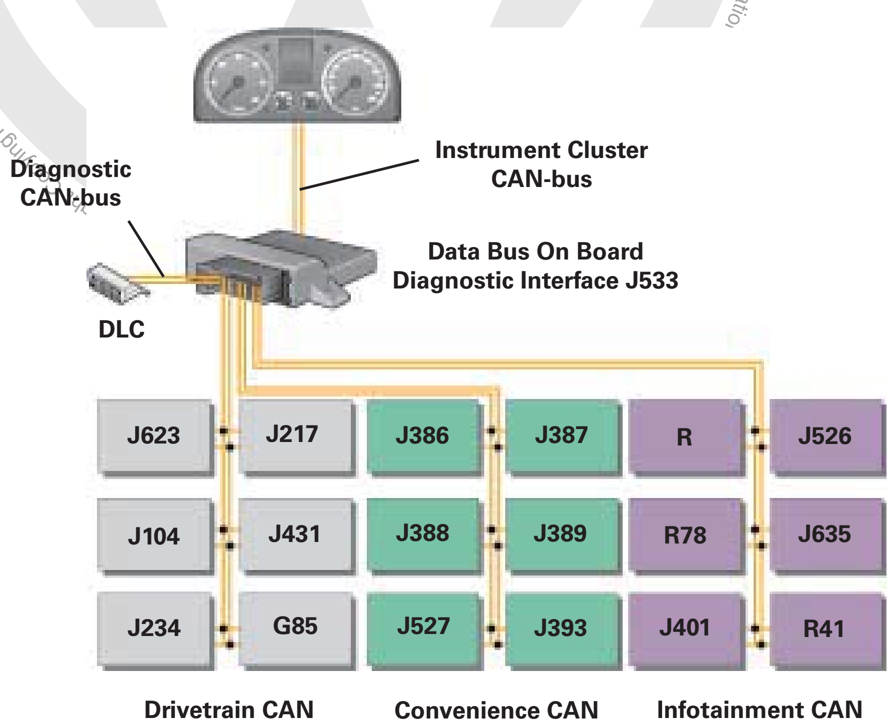
On earlier model year Volkswagen vehicles, J533 was located inside Instrument Cluster J285 and was accessible through VAS Scan Tools using Address Word 17.



Data Bus On Board Diagnostic Interface

On later model year Volkswagen vehicles, J533 is a separate control module which can be addressed through VAS Scan Tools using Address Word 19.





Data Bus On Board Diagnostic Interface

Master Functions

J533 is the master for:

– Drivetrain CAN continued operation

– MOST ring break diagnosis

– Data bus system Sleep and Wake-Up operation

Drivetrain CAN Continued Operation

Operation of several control modules continues after the ignition is switched OFF. J533 broadcasts a command to end operation to the Drivetrain CAN following an after-run period.

MOST Ring Break Diagnosis

J533 is the diagnosis manager for the MOST bus *(discussed later in this book)*. The interface is responsible for Ring Break Diagnosis and sends the diagnosis data in the MOST bus to J533.

Ring Break Diagnosis for the MOST bus is initiated with a Final Control Diagnosis Output Check Diagnosis in J533.

Data Bus System Sleep and Wake-Up Operation

On later Volkswagen models, J533 is the master control module for Sleep and Wake-Up modes. When all the control modules on the Convenience CAN indicate “sleep readiness,” the Gateway sends the sleep command to the CAN-bus and the control modules change to sleep status. The sleep status of the individual control modules and bus systems can be read in the measuring value blocks of J533.

CAN-Bus Fault Diagnosis

Diagnostic Information

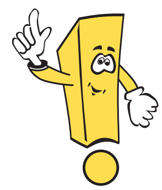
CAN-bus systems are very reliable. Messages such as “Drivetrain data bus defective” may be displayed by VAS Scan Tools, indicating a need for CAN diagnosis. Further indications of fault causes may be provided by the Gateway measuring value blocks.

The starting point for diagnosis is always Guided Fault Finding using the VAS 5051. Malfunctioning control modules can cause results similar to those caused by data bus faults, but fault messages stored in the Gateway can be used as a benchmark for diagnosis.

Continuity checks of the Drivetrain CAN can be carried out using an ohmmeter. For the Convenience/ Infotainment CAN, the VAS 5051 DSO function is always required.

On later model Volkswagen vehicles, it is possible to access the Gateway directly through Address Word 19 using VAS Scan Tools. On earlier vehicles, access to the Gateway is through the instrument cluster or vehicle electrical system control module, using Address Word 17.

Note



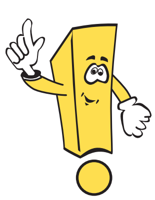
Assignment of measuring value blocks may deviate from the example shown!

Always check Guided Fault Finding for current vehicle information.

	1	2	3	4
		Drivetrain CAN		
125	Engine control unit	Gearbox control unit	ABS control unit	---
126	Steering angle sensor	Airbag control unit	Electric steering *)	Diesel pump control unit *)
127	Central electrics *)	Four-wheel drive electronics *)	Distance regulation electronics	---
128	Battery management	Electronic ignition lock	Self-levelling system	Damper control
129	---	---	---	---
		Convenience CAN		
130	Single wire/ dual wire	Central convenience electronics	Driver door control unit	Front passenger control unit
131	Rear left door electronics	Rear right door electronics	Driver memory seat electronics	Central electronics
132	Dash panel insert *)	Multi-function steering wheel	Climatronic	Tyre pressure monitoring
133	Roof electronics	Front pass. memory seat electr.	Rear memory seat electronics	Park distance regulation
134	Auxiliary heater *)	Electronic ignition lock	Wiper electronics	---
135	Tow hitch control unit *)	Centr. operator display unit, front	Centr. operator display unit, rear	---
		Infotainment CAN		
140	Single wire/ dual wire	Radio	Navigation	Telephone
141	Voice activation *)	CD changer *)	Gateway *)	Telematics *)
142	Operator display unit, front	Operator display unit, rear	---	Dash panel insert *)
143	Digital sound system	Multi-function steering wheel *)	Auxiliary heater	---

*) Special equipment/ vehicle type

Note



A display of 0 means there IS NO communication with the Gateway.

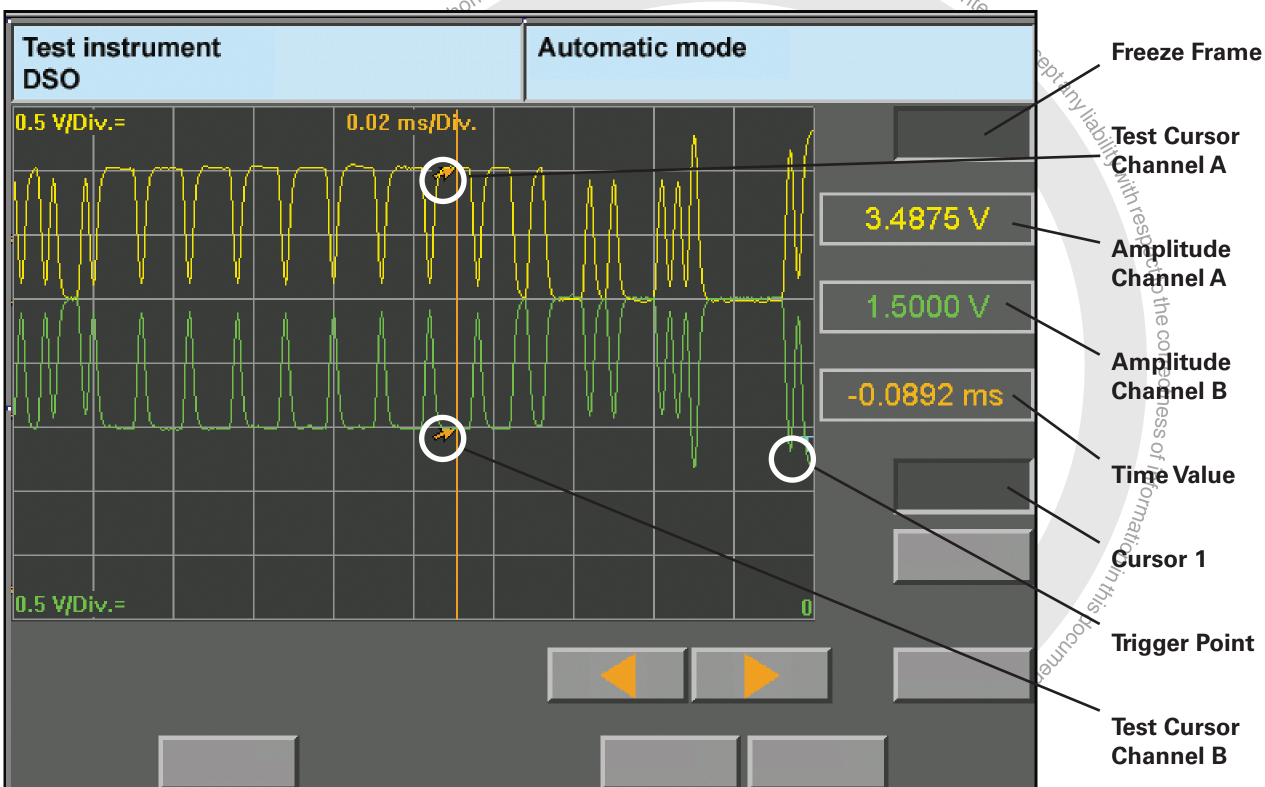
A display of 1 means there IS communication with the Gateway.

DSO Representation of CAN Signals

Data Transfer on the Drivetrain CAN

Through the VAS 5051, the Drivetrain CAN is displayed at the highest resolution *(0.02 ms/Div and 0.5V/Div)* and the image is then saved *(freeze frame)*. Due to problems with resolution, the measurement should not be carried out in atypical peak areas *(at the extreme ends of the image, for example)*.

Representation of Drivetrain CAN on the VAS 5051 DSO



The test cursor should be positioned in the middle of one of the flat impulses to achieve a reliable test value. The displayed measurement shows a Drivetrain CAN that has just reached the specified value.

It should be noted that the measured signal values are determined by the individual control modules. As a result, completely different voltages can be measured during measurements that follow in succession. If the signals from other control modules are displayed, differences of 0.5V are not uncommon.

CAN-Bus Fault Diagnosis

Data Transfer on the Convenience/ Infotainment CAN

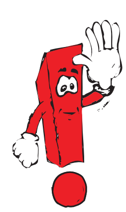
Unlike representation of CAN data on the Drivetrain CAN, different zero points on the CAN-bus are selected below. The CAN-high wire is shown in yellow and the CAN-low wire is shown in green. Triggering occurs here at a CAN-high level of approximately 2V.

It should be noted that the measured signal values are also determined by individual control modules on the Convenience/Infotainment CAN. Subsequent measurements could result in completely different voltages.

Representation of Convenience/Infotainment CAN on the VAS 5051 DSO

Trigger Point

Important!



Unlike the Drivetrain CAN, the Convenience/Infotainment CAN always has voltage when the vehicle battery is connected. Checking for an open circuit or short circuit can be done using an ohmmeter only when the vehicle battery has been disconnected.

DSO Displays for the Drivetrain CAN

When you encounter a stored DTC, such as "Drivetrain data bus defect," it is sometimes necessary to investigate the problem with the DSO. It is then possible to determine where the problem is located, and whether it stems from a physical problem such as a short circuit in the wiring.

Conditions That Can Be Analyzed Using DSO Displays:

1 Short circuit between CAN-high and CAN-low

2 Short circuit between CAN-high and positive voltage

3 Short circuit between CAN-high and Ground

4 Short circuit between CAN-low and Ground

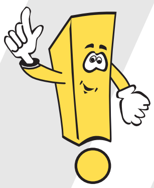
5 Short circuit between CAN-low and positive voltage

6 Open circuit in CAN-high data path

7 Open circuit in CAN-low data path

It is important not to over-analyze the waveforms. You are only looking for voltage differences from a normal signal to determine the electrical fault.

Note



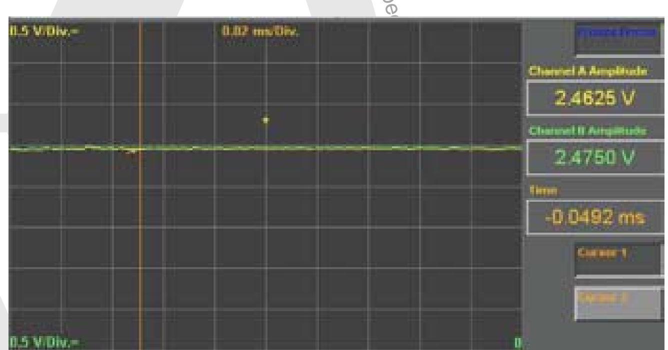
In each of the following DSO displays, Channel A was used to display voltage on the CAN-high wire while Channel B was used to monitor voltage levels on the CAN-low wire!

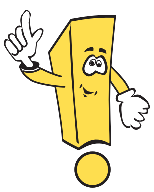
CAN-Bus Fault Diagnosis

Short Circuit Between CAN-High and CAN-Low

A short circuit between CAN high and CAN low pulls and holds voltages at the recessive level.

- CAN high recessive amplitude is normal
- CAN low recessive amplitude is normal
- No dominant amplitudes are visible
- Bus communication is not possible
- Resistance in a short circuit between high and low does not affect communication until the resistance becomes so low that it is essentially a direct short
- This fault will affect all control modules on the bus



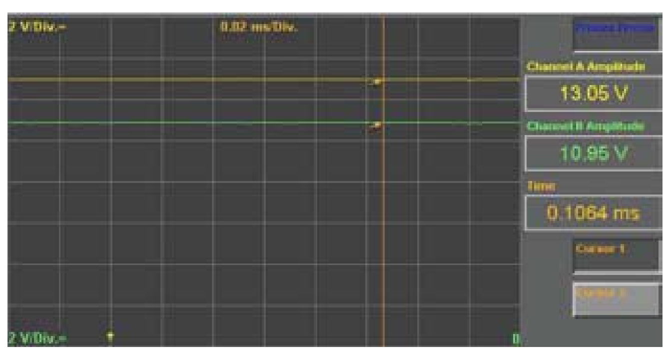


Note Do not separate CAN wires from the wiring connector unless this is the only available option for making required measurements.

Short Circuit Between CAN-High and Battery Positive *(+)* Voltage

A short circuit to positive in CAN high pulls both CAN high and CAN low wires to approximately the amplitude of the positive voltage source, which is 13 volts in this example.

- CAN high recessive amplitude is too high
- CAN low recessive amplitude is too high
- No dominant amplitudes are present
- Bus communication is not possible
- This fault will affect all control modules on the bus
- Note Channel A and Channel B voltage divisions



Short Circuit Between CAN-High and Ground

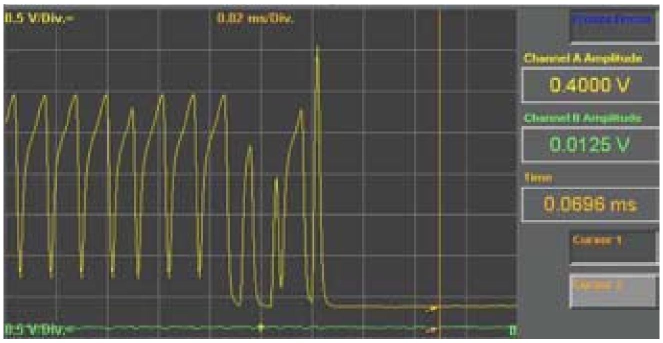
A short circuit to ground in CAN high pulls both CAN high and CAN low wires to 0 volts, although small voltage fluctuations may still be visible in CAN low.

- CAN high recessive amplitude is too low
- CAN low recessive amplitude is too low
- CAN high has no dominant amplitude
- Bus communication is not possible
- This fault will affect all control modules on the bus

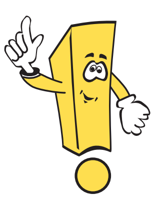
Short Circuit Between CAN-Low and Ground

A short circuit to ground in CAN low pulls the CAN low wire to 0 volts. The recessive voltage for CAN high is also pulled to 0 volts. Short circuits to ground and power will not damage the control module because it is internally over current protected.

- CAN high recessive amplitude is too low
- CAN low recessive amplitude is too low *(CAN low zero point raised slightly for clarity)*
- CAN low has no dominant amplitude
- Bus communication may be possible
- This fault will affect all control modules on the bus



Note



In each of these DSO displays, Channel A was used to display voltage on the CAN-high wire while Channel B was used to monitor voltage levels on the CAN-low wire!

CAN-Bus Fault Diagnosis

Short Circuit Between CAN-Low and Positive *(+)* Voltage

A short circuit to positive in CAN low pulls both CAN high and CAN low wires to approximately the amplitude of the positive voltage source, which is 12.65 volts in this example.

– CAN high recessive amplitude is too high

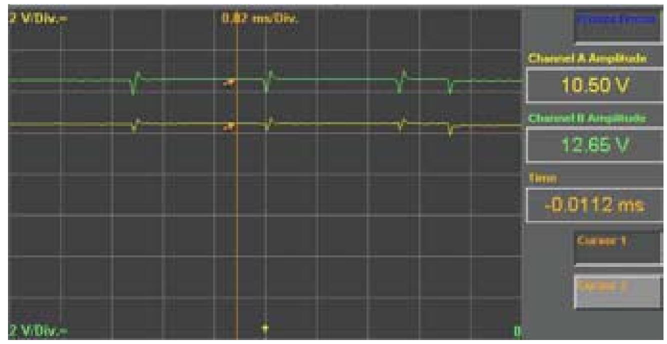
– CAN low recessive amplitude is too high

– No dominant amplitudes are visible

– Bus communication is not possible

– This fault will affect all control modules on the bus

– Notice the Channel A and B voltage division settings

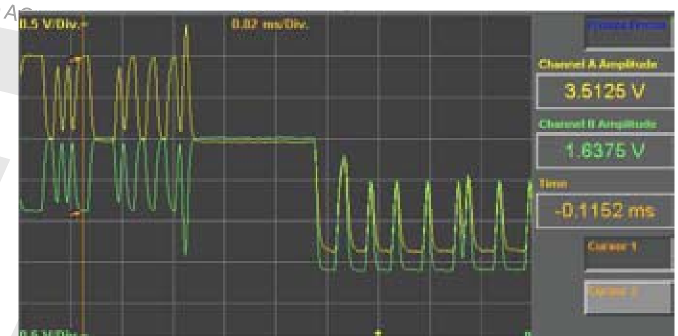


Open Circuit in CAN-High Signal Path

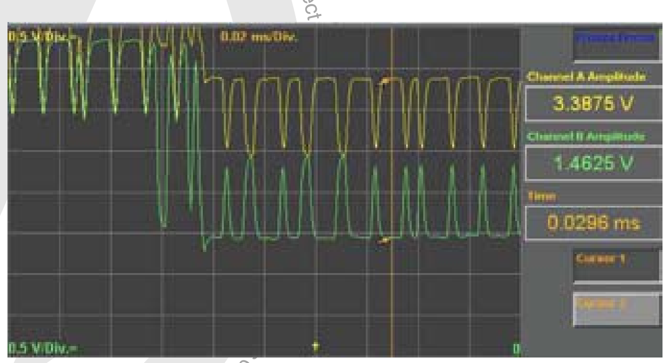
– CAN high dominant amplitude is too low *(right side of screen)*

– CAN high dominant amplitude decreases instead of increasing *(right side of screen)*

– Bus communication is possible for control modules that can communicate with both CAN wires



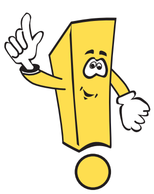
Open Circuit in CAN-Low Signal Path



At 0.02 ms/Div. you will see a normal looking waveform *(right side of screen)*, with sporadic asymmetrical waveforms *(left side of screen)*. It's not as easy to see here as it is at 5 ms/Div. because it took a while for the asymmetrical portion to be displayed.

- CAN high recessive amplitude is too high *(left side of screen)*
- CAN low recessive amplitude is too high *(left side of screen)*
- CAN low dominant amplitude increases instead of decreasing *(left side of screen)*
- Bus communication is possible between control modules that can communicate with both CAN wires

Note



This screen shows one CAN wire open. When both CAN wires are open it may not be possible to see an asymmetrical waveform with the DSO.

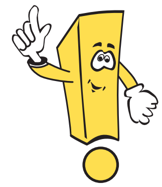
CAN-Bus Fault Diagnosis

DSO Displays for the Convenience/ Infotainment CAN

In responding to stored DTCs, indicating problems such as "Convenience data bus defect," it will be necessary to use the DSO to isolate the problem, identify where the defect is located, and determine whether it stems from a physical problem such as a short circuit between two wires.

Also significant is that the Convenience/Infotainment CAN support single-wire operation. This means that when responding to a stored DTC such as "Convenience data bus in single-wire operation" it will be necessary to use the DSO to determine which of the two CAN-bus wires is the source of the problem.

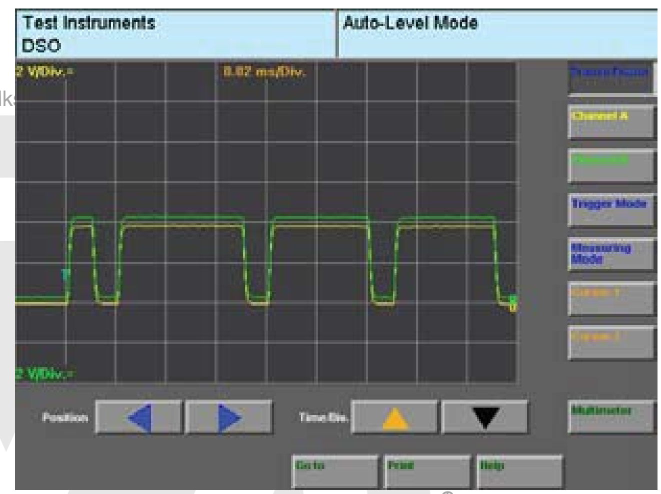
Note

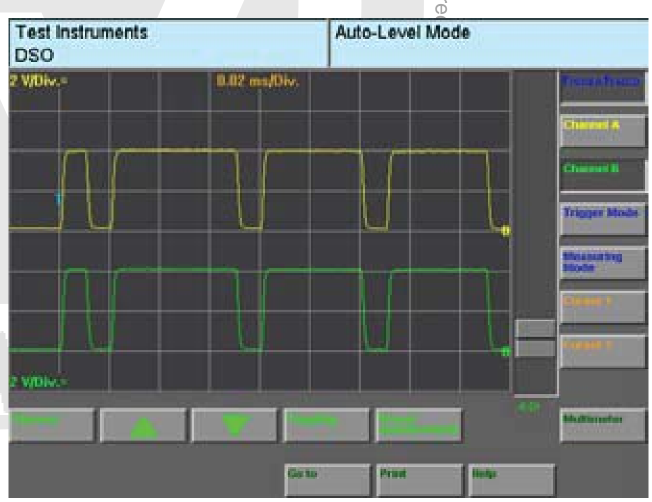


In each of the following DSO displays, Channel A was used to display voltage on the CAN-high wire while Channel B was used to monitor voltage levels on the CAN-low wire!

Short Circuit Between CAN-High and CAN-Low

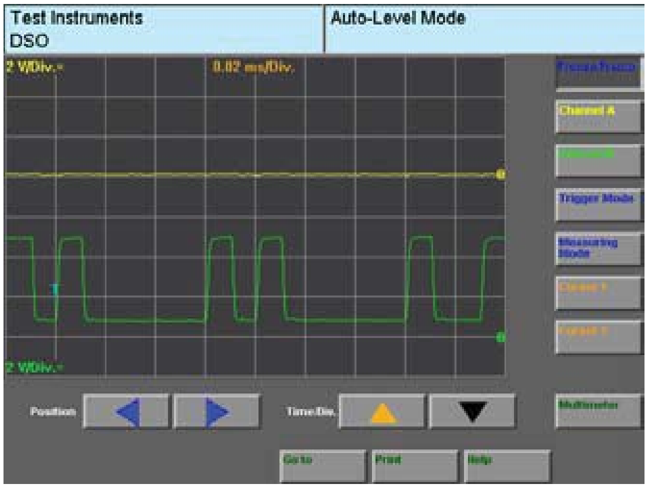
This short circuit means that voltage levels on the CAN-high and CAN-low wires are the same, A short circuit between a CAN-high and a CAN-low wire will affect the entire Convenience/Infotainment CAN. The Convenience/Infotainment CAN responds to this error by reverting to single-wire operation. This means that all data communications must be expedited by modulating voltage levels in just a single wire *(refer to section on test data blocks)*. The control module then interprets this voltage by using ground as its baseline reference. In the first DSO display *(top)*, the zero-level axes for Channel A and Channel B are superimposed. This display makes it easy to see that the voltage levels being transmitted through the CAN-low and CAN-high lines are identical. The second DSO display *(bottom)* shows the same signal with the zero-level axes at mutual offset.





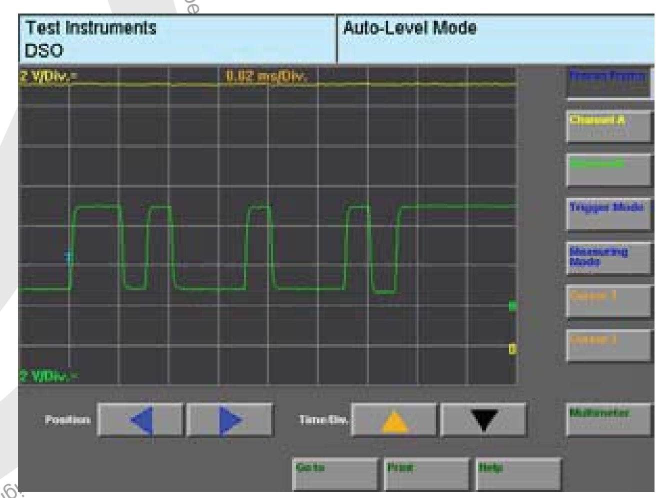
Short Circuit Between CAN-High and Ground

This short circuit pulls the voltage on the CAN-high wire to 0 volts, while voltage levels on the CAN-low wire remain normal. This defect causes the entire Convenience/Infotainment CAN to revert to single-wire operation. At first glance, one might also conclude that the problem could be an open CAN-high wire, but the actual DSO display for an open wire has a different appearance.



Short Circuit Between CAN-High and Battery Positive *(+)* Voltage

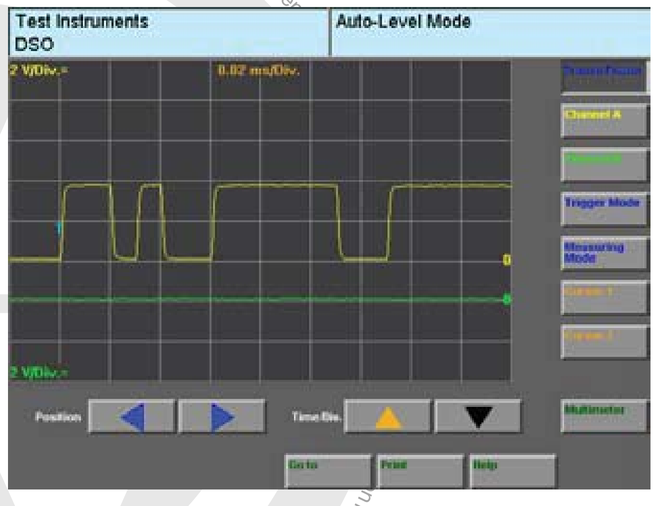
This short circuit means that voltage on the CAN-high wire has risen to approximately 12 volts, or battery voltage. Voltage levels on the CAN-low wire remain normal. This defect causes the entire Convenience/Infotainment CAN to revert to single-wire operation.



CAN-Bus Fault Diagnosis

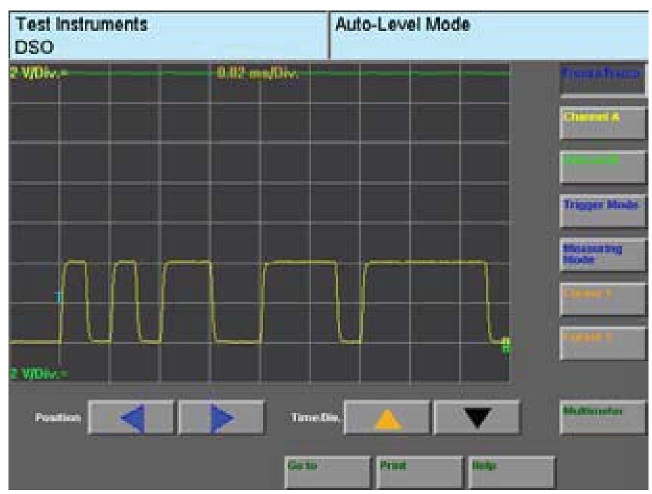
Short Circuit Between CAN-Low and Ground

The short circuit causes the voltage on the CAN-low wire to fall to 0, while voltage levels on the CAN-high wire remain normal. This defect causes the entire Convenience/Infotainment CAN to revert to single-wire operation. At first glance, one might also conclude that the problem could be an open CAN-low wire, but the actual DSO display for an open wire has a different appearance.



Short Circuit Between CAN-Low and Battery Positive *(+)* Voltage

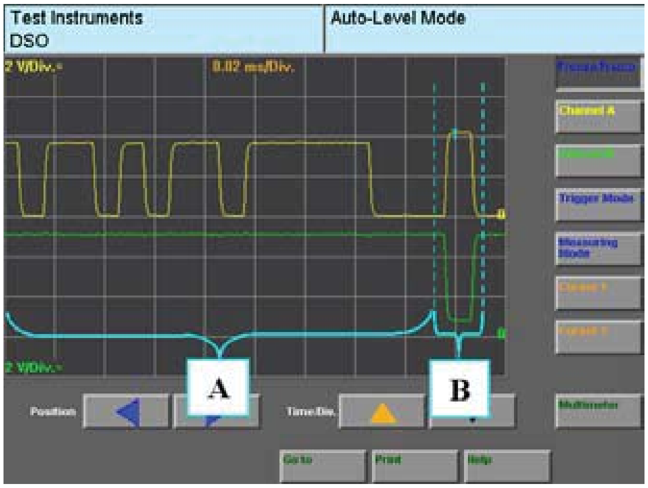
This short circuit means that voltage on the CAN-low wire has risen to approximately 12 volts, or battery voltage. Voltage levels on the CAN-high wire remain normal. This defect causes the entire Convenience CAN or Infotainment CAN to revert to single-wire operation.



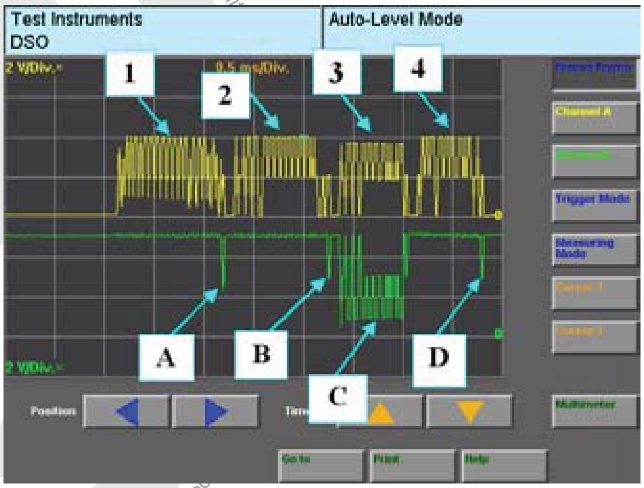
Open Circuit on CAN-Low Signal Path

Voltage levels on the CAN-high wire are normal. A recessive voltage of 5 volts can be observed on the CAN-low wire along with a dominant 1 volt for a duration of one bit. This dominant signal voltage is transmitted by electronic control modules when they correctly receive an intact message. This means that the DSO display pattern shown is actually composed of transmissions from several control modules. Thus, component "A" is part of a message currently being transmitted by a control module.

The receiving control modules confirm correct reception of an intact message with a dominant voltage in time slot "B" *(Acknowledge signal)*. At "B" all of the control modules that have received the message intact simultaneously transmit a dominant voltage. This explains the somewhat greater voltage differential on this bit.



This second DSO illustration shows the same defect using a lower time sweep. Here we see that the message "1" is only transmitted on the CAN-high wire, although the acknowledgement signal is also sent on the CAN-low wire at point "A." The same applies for the message "2" and the acknowledgement signal "B." Message "3" is transmitted on both wires. At "3" the corresponding voltage appears on the CAN-low wire. Messages "A," "B," and "D" are transmitted in single-wire operation, while the message "C" is sent in the two-wire mode.

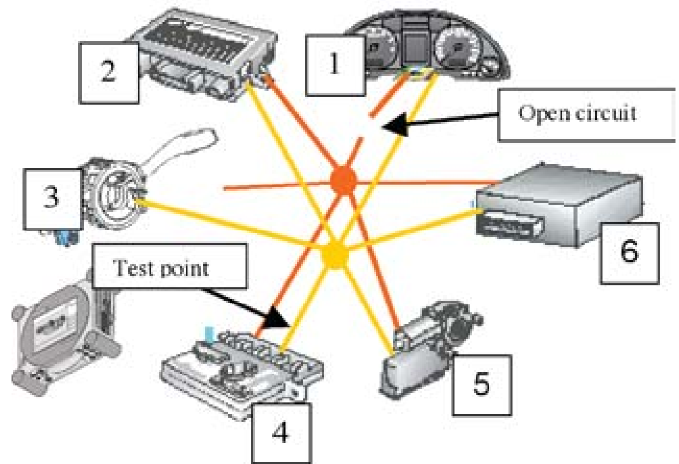


CAN-Bus Fault Diagnosis

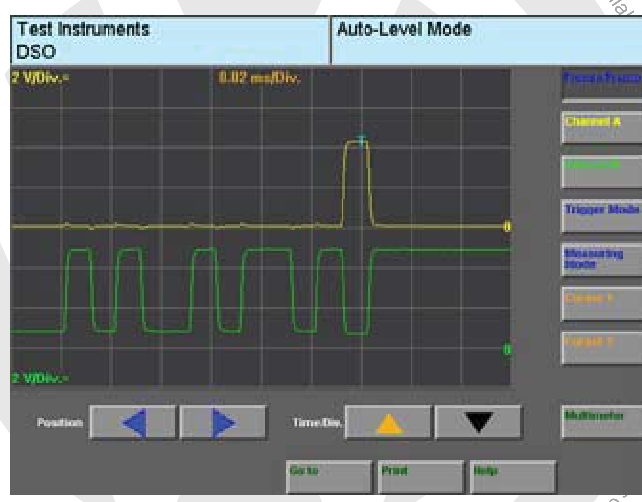
Owing to the open circuit, when control module 1 transmits a message, the other control modules will be able to receive it in single-wire operation only *("1," "2" and "4" in the lower DSO display, page 35)*. Through the link to the test connection on control module 4, the DSO portrays the single-wire transmission from control module 1.

If control modules 2, 3, 4, 5 and 6 now acknowledge reception, the DSO will show this on both channels *("A," "B" and "D" in the lower DSO display, page 35)*, as there is no open circuit between these control modules.

If, for example, control module 2 transmits a message, all other control modules with the exception of control module 1 will receive it in two-wire mode *("3" and "C" in the lower DSO display, page 35)*. Meanwhile, control module 1 receives the message in single-wire operation.



Open Circuit in CAN-High Wire

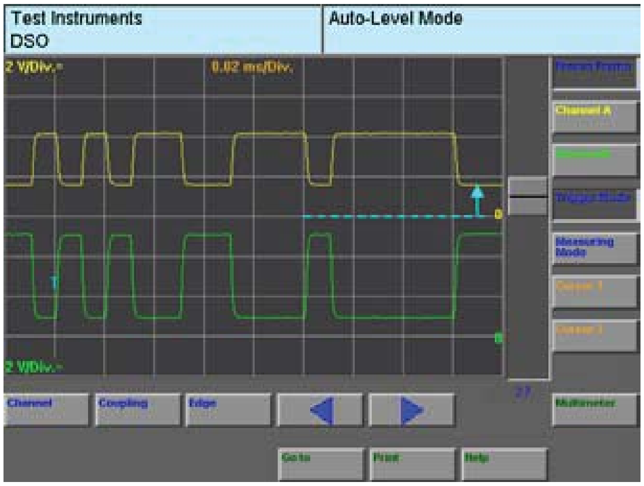


DSO Displays for Short Circuits with Contact Resistance

The short circuits portrayed up to this point have been direct shorts without contact resistance. In the real world, however, short circuits are often caused by abraded insulation on the wiring. If this kind of wire then comes into gentle contact with Ground or positive voltage, which frequently happens in the presence of moisture, there will be “contact” or “transition” resistance at this point. The following DSO displays show this kind of short circuit with its contact resistance.

Short Circuit from CAN-High to Battery Positive (+) Voltage with Contact Resistance

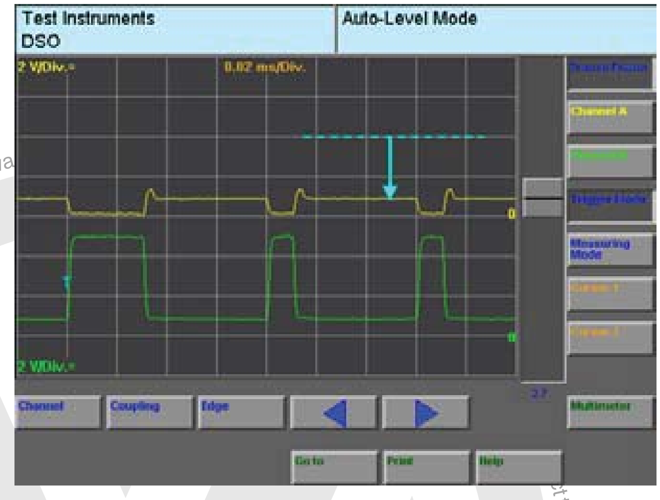
CAN-high shorting to positive with contact resistance shifts the recessive voltage in the CAN-high signal path toward positive voltage. As we see from the DSO display, the recessive voltage in the CAN-high line has increased from its normal level of roughly 0 volts to approximately 1.8 volts. This figure of 1.8 volts will vary according to the resistance at the short. Lower levels of resistance correspond to higher recessive voltage levels. This trend culminates in voltage equal to battery voltage when there is no transition resistance at the point of the short circuit.



CAN-Bus Fault Diagnosis

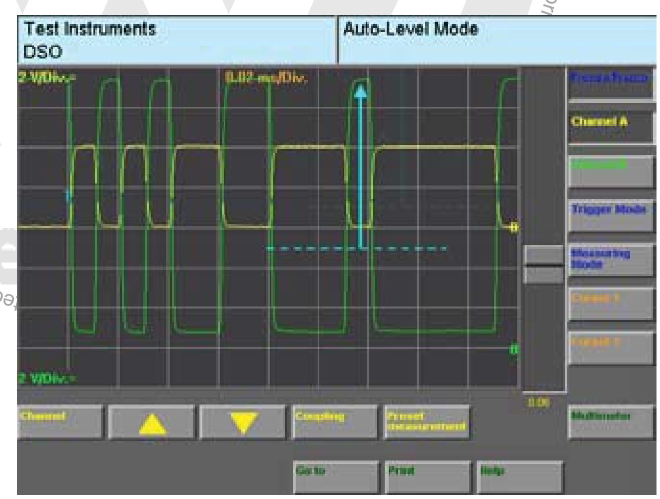
Short Circuit from CAN-High to Ground with Contact Resistance

This short circuit from CAN-high to Ground with contact resistance shifts the dominant voltage in the CAN-high signal path toward Ground. The DSO display shows how the dominant CAN-high voltage has shifted from its usual level of roughly 4 volts to approximately 1 volt. The 1-volt figure will actually vary according to the level of contact resistance at the short. Lower levels of resistance will lead to lower dominant voltage levels. This trend culminates at a level of 0 volts in cases where there is no transition resistance.



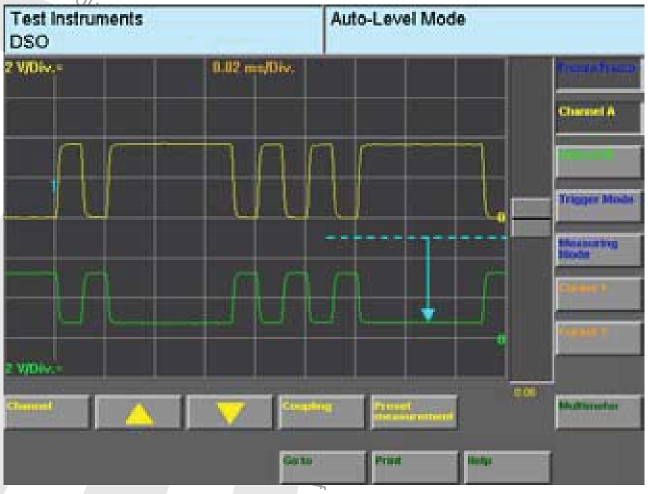
Short Circuit from CAN-Low to Battery Positive *(+)* Voltage with Contact Resistance

This short circuit from CAN-low to positive with contact resistance shifts the recessive voltage in the CAN-low signal path toward positive. As the DSO display shows, the normal CAN-low recessive voltage of roughly 5 volts has risen to approximately 13 volts. The 13-volt figure is determined by the level of transition resistance, and can vary. Smaller resistance levels produce proportionately higher recessive voltages. If there is no transition resistance at the short, the voltage level will coincide with battery voltage.



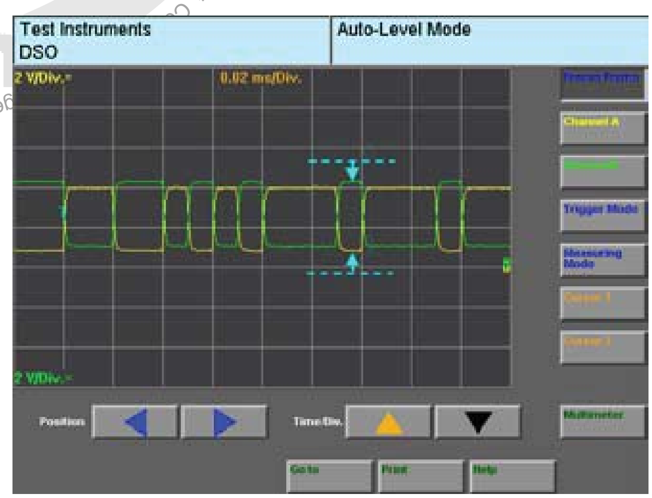
Short Circuit from CAN-Low to Ground with Contact Resistance

With a short circuit from CAN-low to Ground with contact resistance, the recessive voltage on the CAN-low signal path shifts toward 0 volts. The DSO display shows how the normal CAN-low recessive voltage of roughly 5 volts has dropped to approximately 3 volts. This 3-volt figure varies according to the actual level of transition resistance. Lower resistance levels will be accompanied by lower recessive voltage levels. If there is no transition resistance at the short, the voltage level will be 0 volts.



Short Circuit from CAN-High to CAN-Low with Contact Resistance

This short circuit from CAN-high to CAN-low with contact resistance reduces the difference in the recessive voltage levels in the CAN-high and CAN-low lines. Instead of its normal 0 volts, the recessive voltage in the CAN-high signal path is now approximately 1 volt. Meanwhile, the recessive CAN-low voltage is approximately 4 volts instead of the usual 5 volts. The dominant voltages in the CAN-high and CAN-low signal paths are normal.

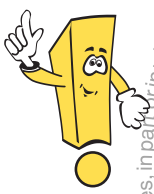


Diagnosis CAN

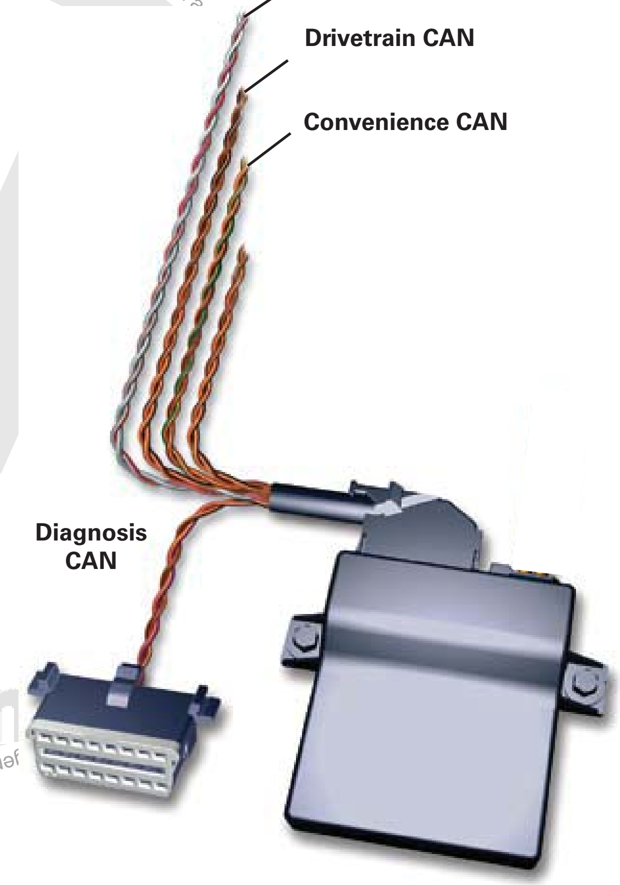
Overview

The Diagnosis CAN is used for data exchange between a VAS Scan Tool and the control modules installed in the vehicle. Diagnosis is performed using a VAS Scan Tool.

Note



K-wires and L-wires are being phased out of production with the exception of emission-related control modules.

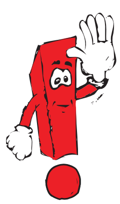


Data Bus On Board Diagnostic Interface J533 *(Gateway)*

The transfer of control module diagnosis data is accomplished by means of the applicable data bus systems to Data Bus On Board Diagnostic Interface J533 *(Gateway)*.

Taking advantage of the rapid data transmission through the Diagnosis CAN and the Gateway function, a Scan Tool is able to show the status of installed components and their fault status.

Important!



Always consult the appropriate Wiring Diagram when diagnosing vehicle symptoms.

The Diagnosis CAN uses two unshielded and twisted wires, each with a diameter of 0.35 mm.

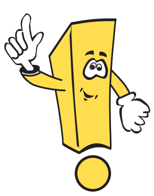
The CAN-low wire is orange/brown and the CAN-high wire is orange/black.

Data transfer occurs at a transfer speed of 500 kilobits per second *(kbits/s)* in the full duplex mode. That means that data can be transmitted in both directions at the same time.

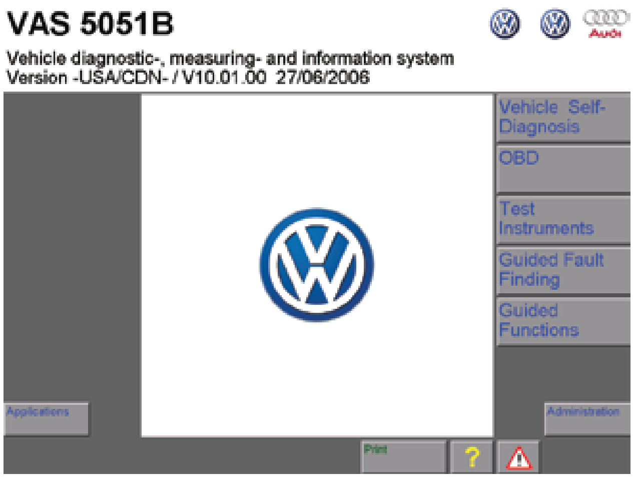
Diagnosis Can Be Done Under the Following Conditions:

Number	Diagnosis	Condition		Remarks
1	Initiation	When ignition is turned ON	Yes	Wake-up of the control module via the Diagnosis CAN is not possible
		When ignition is turned OFF	Yes, but not in sleep mode	
2	Execution	When ignition is turned ON	Yes	
		When ignition is turned OFF	Yes, but no writing procedures *(i. e. coding of the control module)*	
3	End	Cancel by turning ignition OFF	No	

Note



Diagnostic information changes with Base and Brand software level updates. Always be sure to use the latest levels.

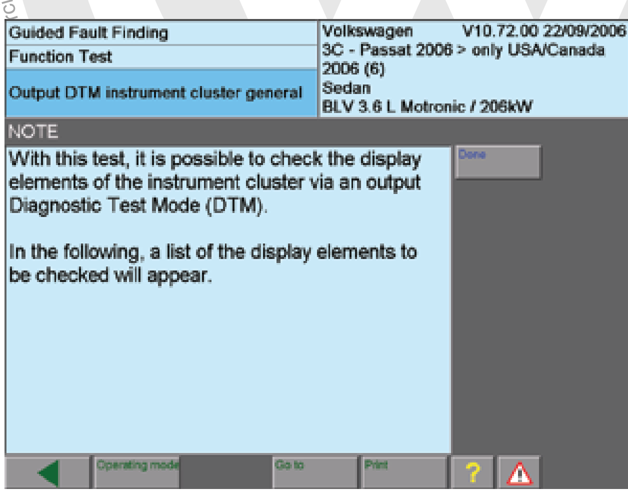


Diagnosis CAN

Extension of Addressing Forms

In addition to directly addressing individual control modules, it is now possible to address them in groups. This allows the DTC memories of several control modules to be read at the same time.

Therefore, the reading of DTC memories can be done much faster.

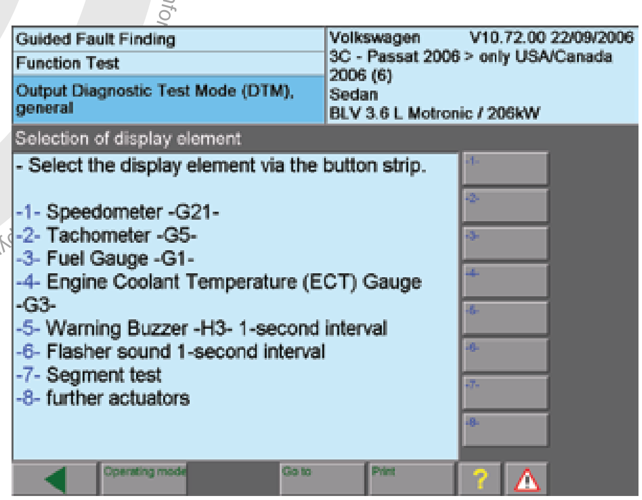


Selective Output Diagnostic Test Mode Test

The selective output diagnostic test mode test allows for direct activation of actuators without staying within a particular sequence.

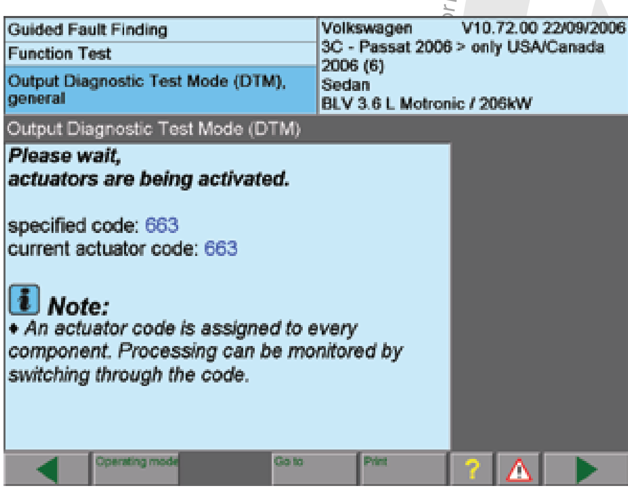
The simultaneous display of measuring value block control modules is also possible when checking switches and sensors.

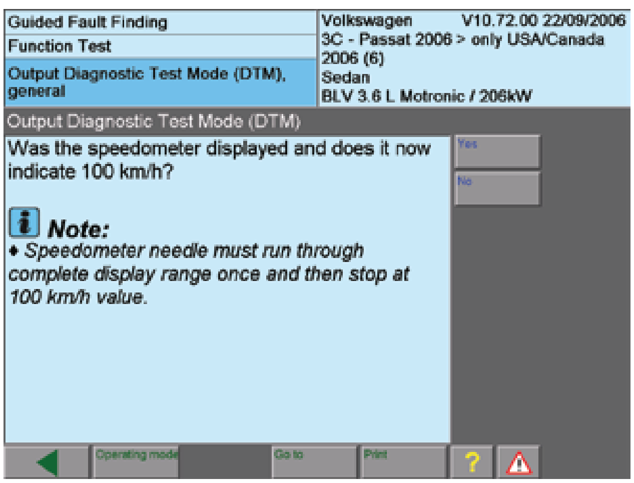
These innovations open new possibilities in guided troubleshooting.



Example:

The illustration below shows the selective output diagnostic test mode test for checking the display elements of the Instrument Cluster.





Pin Assignment at the 16-Pin Data Link Connector *(DLC)*

Pins not listed are not currently in use.

Pin	Wiring
1	Terminal 15
4	Ground
5	Ground
6	High Diagnosis CAN *(CAN-high)*
7	K-Wire
14	Low Diagnosis CAN *(CAN-low)*
15	L-Wire
16	Terminal 30

Other Data Bus Technology

Overview

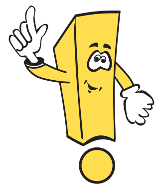
More control modules, divided functions and data exchange have spurred constant development of vehicle data transmission technology.

The following data exchange innovations have been added to familiar Volkswagen CAN-bus systems:

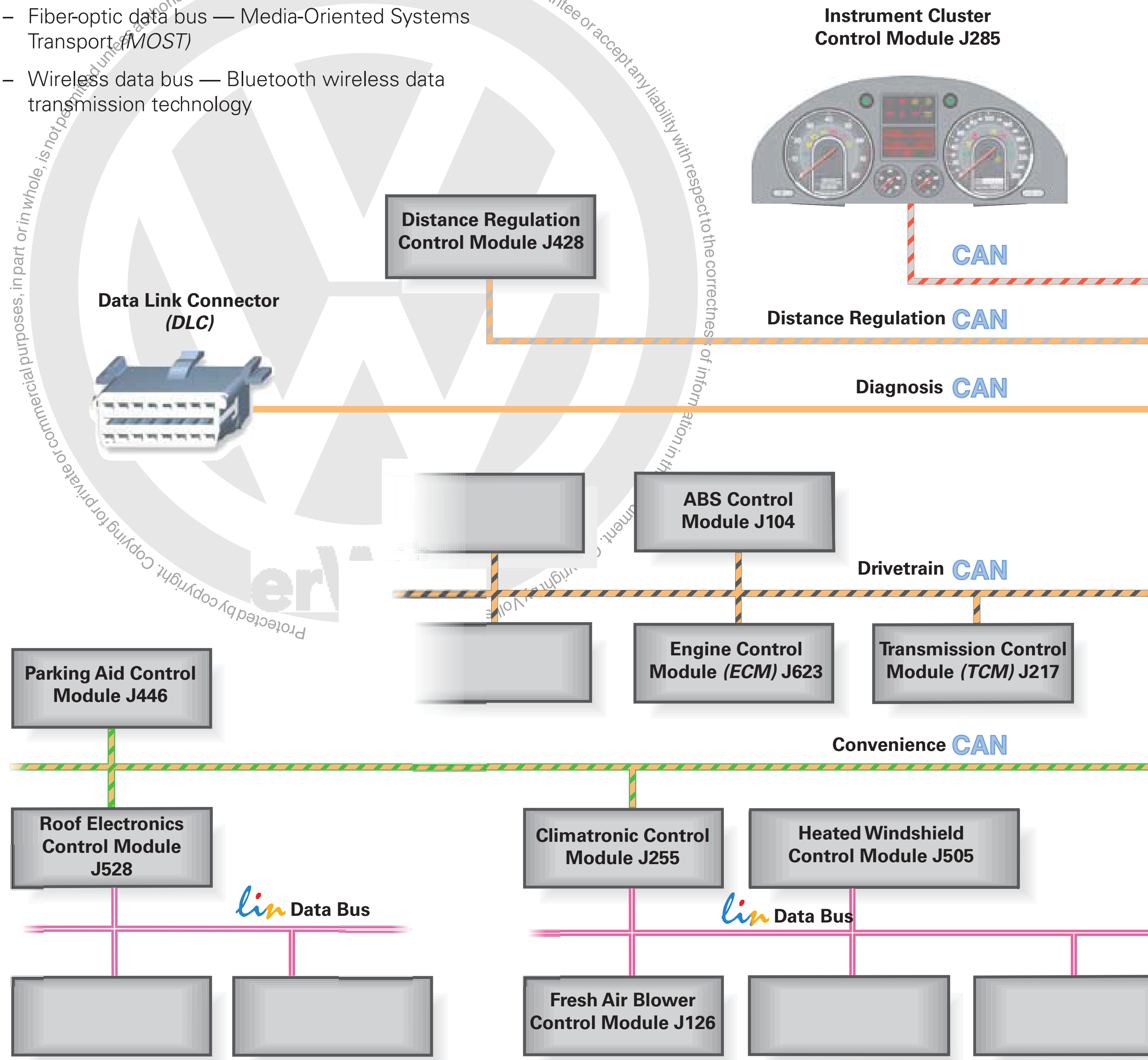
– Single-wire data bus — Local Interconnect Network *(LIN)*

– Fiber-optic data bus — Media-Oriented Systems Transport *(MOST)*

– Wireless data bus — Bluetooth wireless data transmission technology

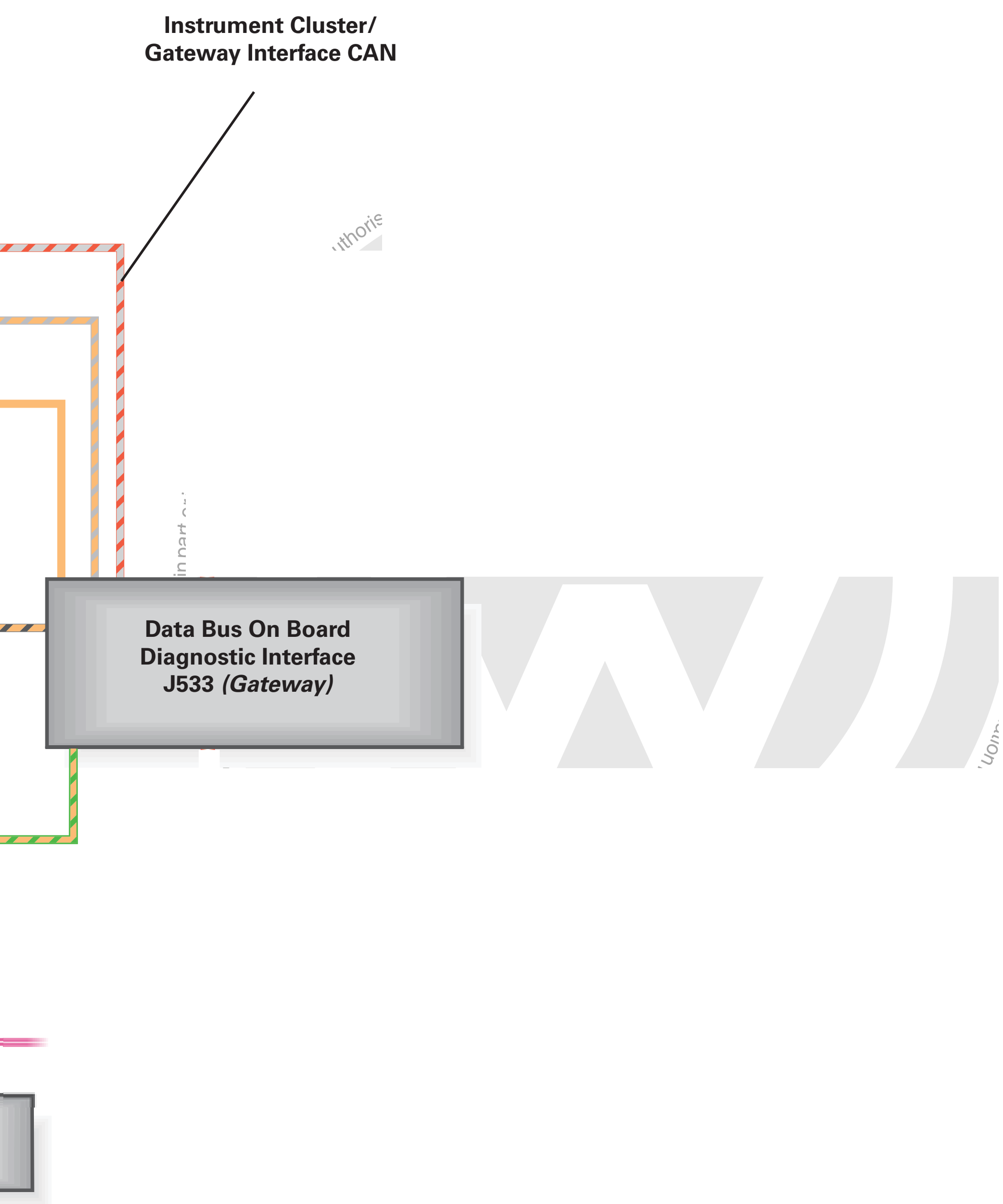


Note Not all components shown here are installed on every vehicle. Some components may not be available for the North American market.



Key

- Drivetrain CAN
- Instrument Panel/Gateway Interface CAN
- Distance Regulation CAN
- Diagnosis CAN
- Convenience CAN
- Local Interconnect Network *(LIN)* Data Bus



LIN Data Bus

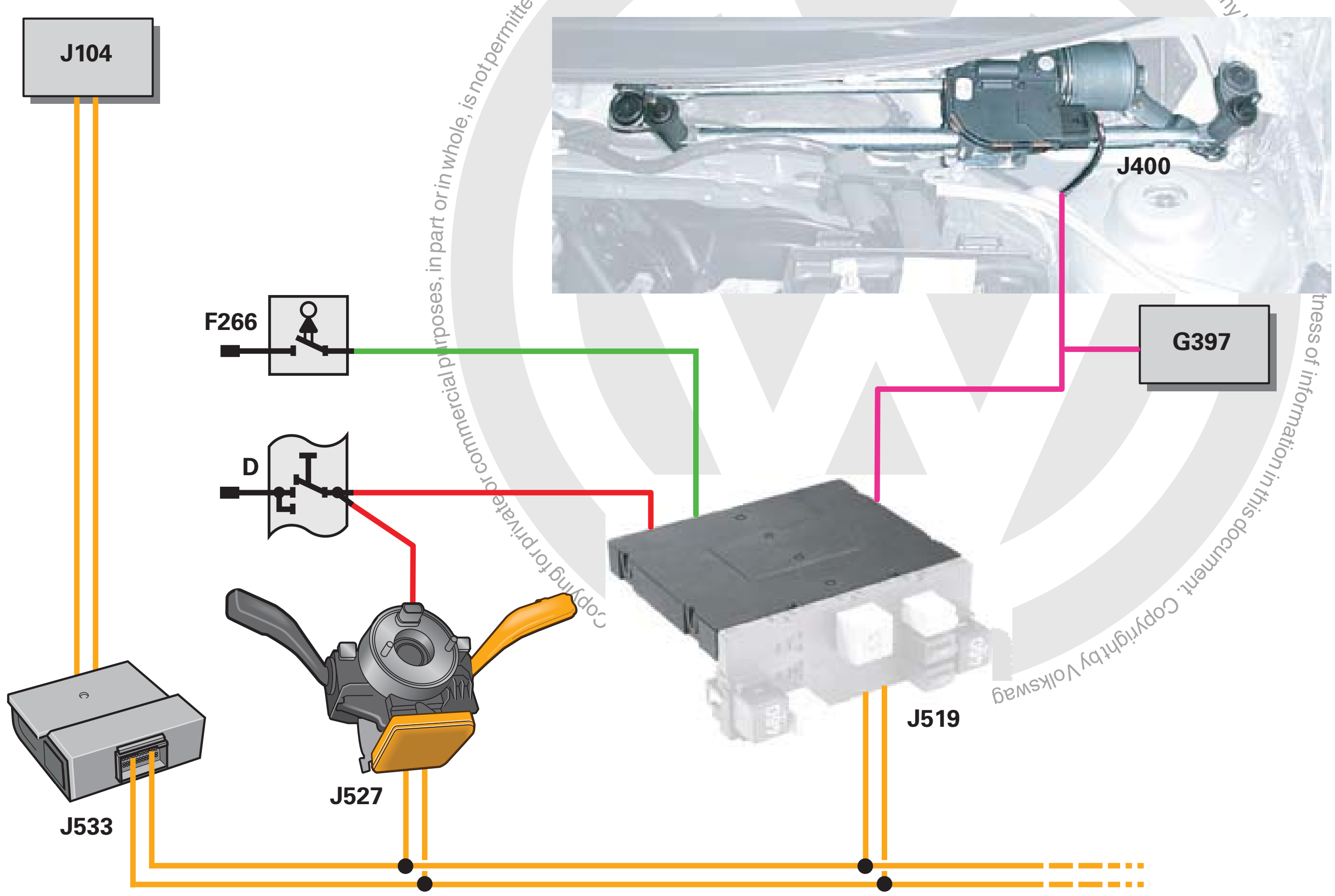
Introduction

All Local Interconnect Network *(LIN)* data bus control modules in an individual network are located within a limited vehicle area, such as the roof. This kind of network is also sometimes called a *local sub-system*.

The data exchange between the individual LIN systems in a vehicle is always controlled by a control module through the CAN-bus.

Each LIN data bus system functions as a single wire bus. The base color of a LIN data bus wire may change depending if it is a Volkswagen bussed component or one provided by a Volkswagen supplier. Some suppliers will designate their own colors for proprietary bus wires. Shielding is not necessary.

Each LIN data bus system allows data exchange between a LIN master control module and up to 16 LIN slave control modules.



LIN Master Control Modules

The control module in the LIN system that is connected to a CAN-bus performs the LIN master control module function.

The LIN master control module controls the data transfer and the data transfer speed. It also sends the message header.

The software contains a cycle to control when and how often a message is sent on the LIN data bus.

The LIN master control module assumes the translation function between the LIN slave control modules of the local LIN data bus system and the associated CAN bus.

The LIN master control module is the only control module in a LIN data bus system that is also connected to a CAN-bus.

The connected LIN slave control modules are diagnosed through the LIN master control module.

Note For more information on message headers, refer to page 108.

LIN Data Bus

LIN Slave Control Modules

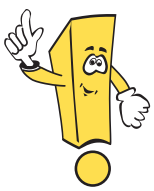
LIN slave control modules can be either individual control modules like Wiper Motor Control Module J400 or sensors like Rain/Light Recognition Sensor G397.

Electronics that evaluate the measured values are integrated into the sensors. Communication of these values is then accomplished on the LIN data bus in the form of a digital signal.

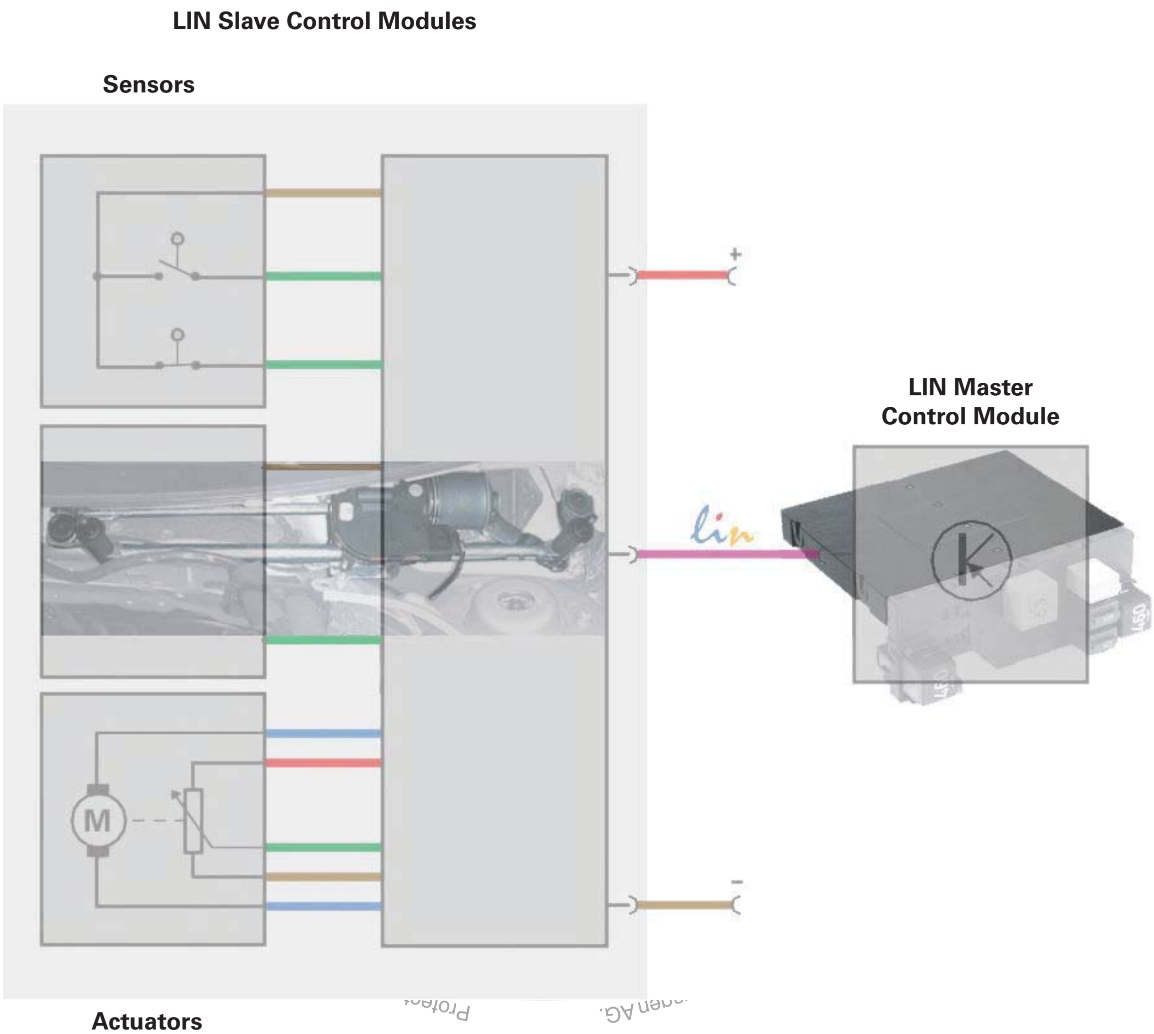
Only one pin is needed for several sensors and actuators at the socket of the LIN master control module.

The LIN actuators are intelligent electro-mechanical subsystems that receive their commands in the form of LIN data signals from the LIN master control module. The actual condition of the actuators can be monitored by the LIN master control module. This allows comparison between actual and specified values.

Note

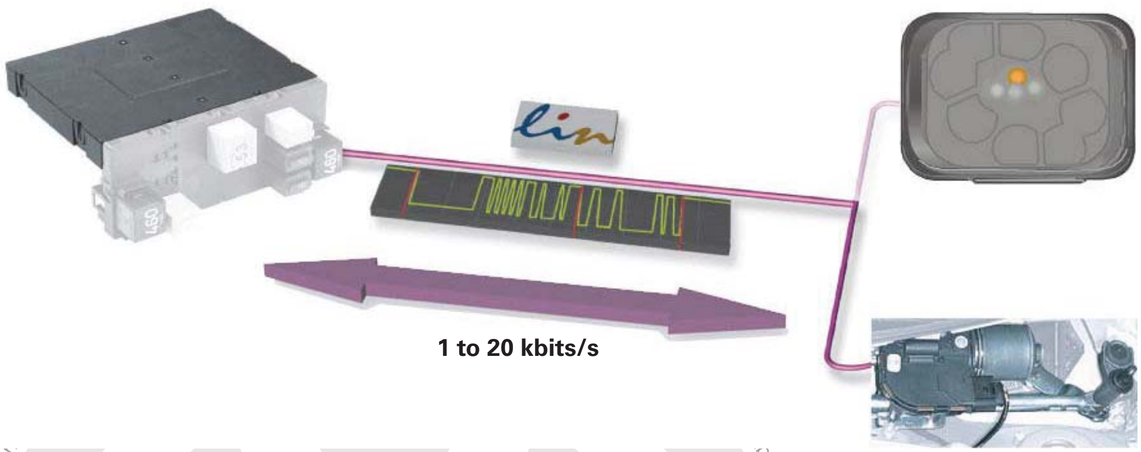


Sensors and actuators only respond when a header is sent by the LIN master control module.



Diagnostic Information

The data transmission rate can be from 1 to 20 kilobits per second (kbits/s). A specific rate is programmed into the software of each LIN control module. This is at most approximately one-fifth of the data transmission rate of the Convenience/ Infotainment CAN.



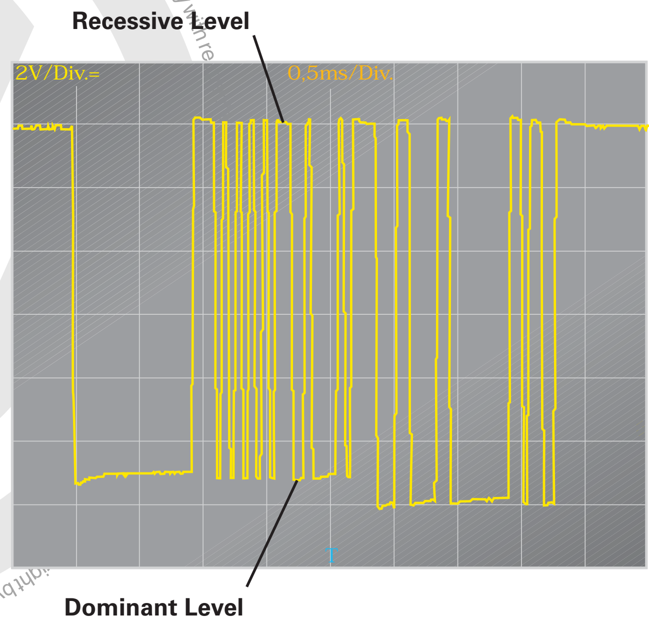
Signal

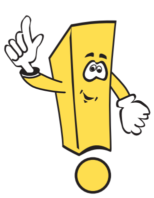
Recessive Level

If no message or a recessive bit is sent on the LIN data bus, the voltage of the data bus wire is close to battery voltage.

Dominant Level

To transmit a dominant bit on the LIN data bus, the data bus wire is switched to ground by a transceiver in the transmitter control module.





Note Because of different designs of transceivers in the control modules, differences in the dominant levels may be visible on the display.

LIN Data Bus

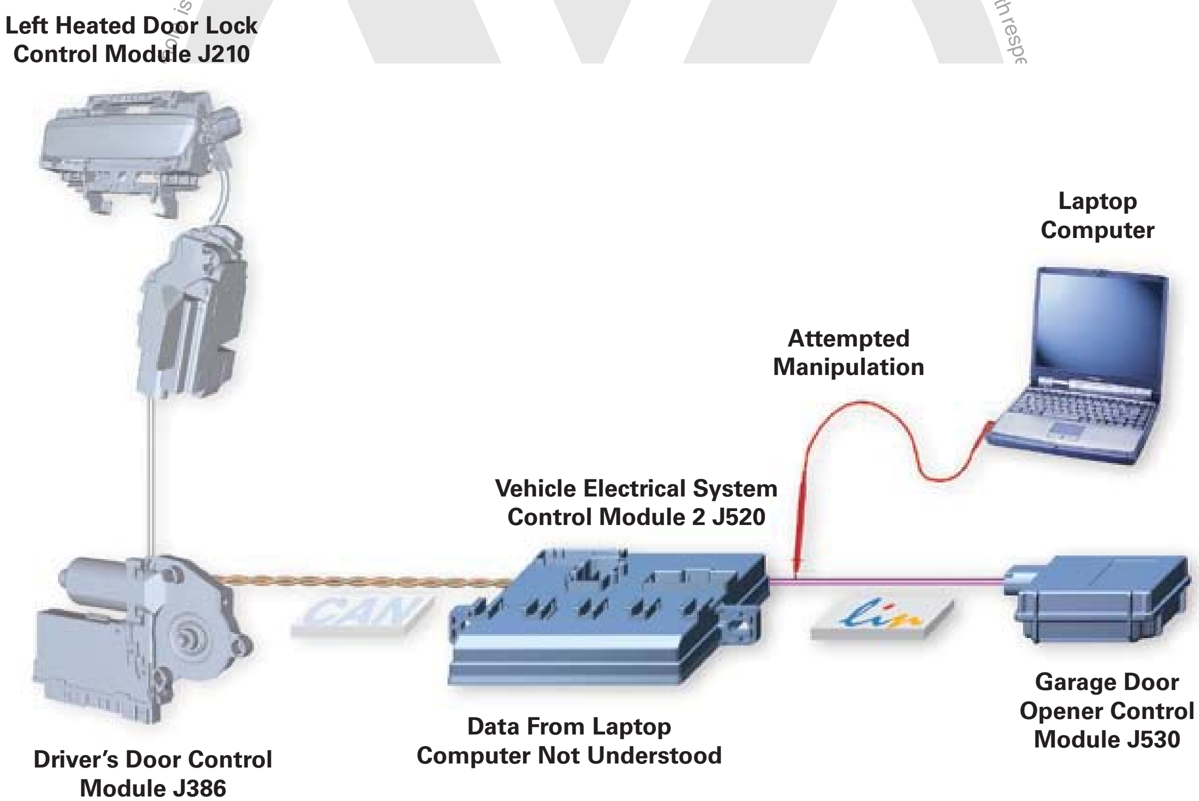
Theft Protection

Data transmission on the LIN data bus only occurs when a LIN master control module sends a header with the applicable identifier.

Manipulation through a LIN wire from outside the vehicle is impossible because of the complete control of all messages by the LIN master control modules. LIN slave control modules can only answer.

For example, doors cannot be opened by tapping into the LIN data bus because of this limitation.

With this arrangement, LIN slave control modules can also be installed on the outside of the vehicle. The Garage Door Opener Control Module J530 can be located in the front bumper for example, without compromising the security of the vehicle or the garage.



Diagnosis

Diagnosis of the LIN data bus system is done through the Address Word for the relevant LIN master control module.

The transfer of diagnostic data from the LIN slave control modules to the LIN master control module occurs on the LIN data bus.

All of the On Board Diagnostic *(OBD)* functions are available for LIN control modules.

Example of Diagnosis Capabilities

Fault Location	Fault Text	Cause of Diagnostic Trouble Code *(DTC)*
LIN Slave Control Module Example: Wiper Motor Control Module	No signal / no communication	Failure of data transmission from the LIN slave control module within a specified time interval that is programmed into the software for the LIN master control module. • Break in wiring or short circuit. • Faulty voltage supply for the LIN slave control module. • Wrong part for LIN slave control module or LIN master control module. • Faulty LIN slave control module.
LIN Slave Control Module Example: Fan Control	Implausible signal	Fault in the check total. Incomplete transmission of the messages. • Electro-magnetic interference affecting the LIN wire. • Capacity and resistance changes of the LIN wire *(such as moisture or contamination at the connector)*. • Software problem *(wrong version)*.

Fiber-Optic Data Bus

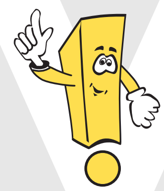
Introduction

In addition to a CAN-bus system, a fiber-optic data bus system was installed for the first time in the Phaeton.

Media Oriented Systems Transport *(MOST)* fiber-optic data bus technology was developed by a group of automobile manufacturers, their suppliers, and software manufacturers. MOST is a unified data bus system that makes rapid data transmission possible.

The MOST standards developed by this cooperative effort have resulted in a network specifically designed to relay media-oriented data. Contrary to what happens on a CAN-bus, the fiber-optic data bus based on the MOST protocol allows address-oriented messages to be sent to a specific recipient.

This technology is used in Volkswagen vehicles for infotainment system data transmission. The infotainment system offers a variety of modern information and entertainment media.



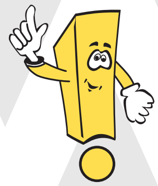
Note Not all components shown here are installed on every vehicle. Some components may not be available for the North American market.

Transmission Rates of Media

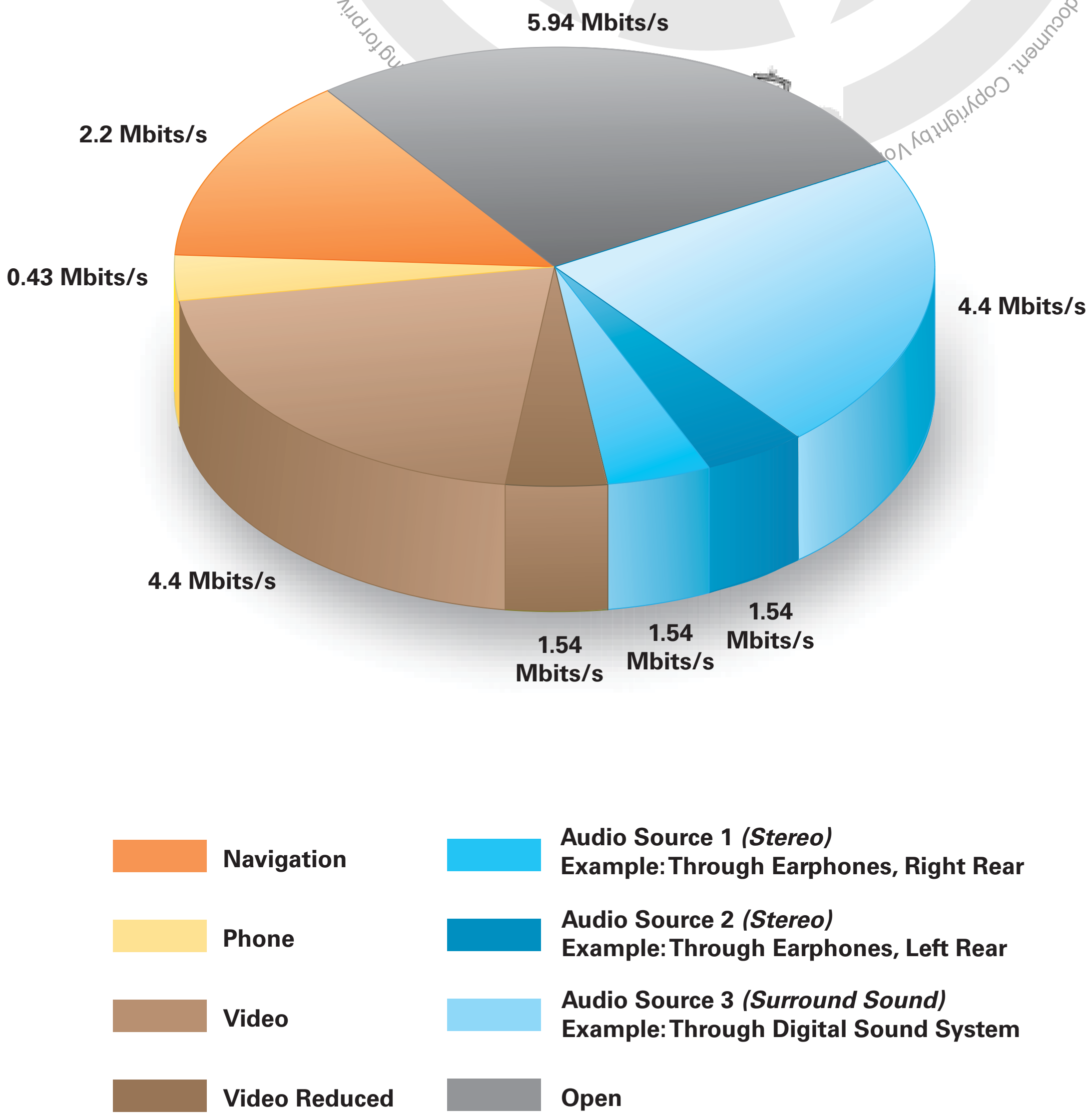
Optical data transfer makes complex infotainment systems possible because CAN-bus systems cannot transfer data fast enough or handle the amount of data that is needed.

Using video and audio applications requires transmission rates of many megabits per second *(Mbits/s)*.

The transmission of a digital TV signal alone requires a transmission speed of about 6 Mbits/s.



Note The MOST fiber-optic data bus allows for transmission rates of 21.2 Mbits/s.



Fiber-Optic Data Bus

Until recently, information such as video and sound could only be transmitted as analog signals. This required additional wiring in vehicle wiring harnesses.

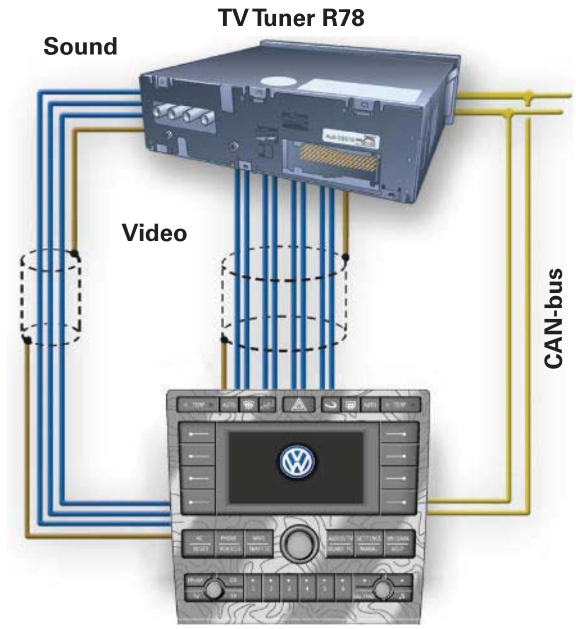
The data transfer rate of a CAN-bus system is restricted to a maximum speed of 1 Mbit/s. This explains why only control signals can be transmitted using the CAN-bus.

Using the MOST fiber-optic data bus, the data exchange between the participating components is digital.

The data transfer using light waves allows for a much higher data transfer rate. It also saves wiring and reduces total vehicle mass.

In comparison with radio waves, light waves have very short wave lengths, they do not produce electro-magnetic interference waves, nor are they affected by them.

Light waves make reliable high-speed data transfer rate possible, with good resistance to interference.



Control Module Design

Fiber-Optic Cable and Connector

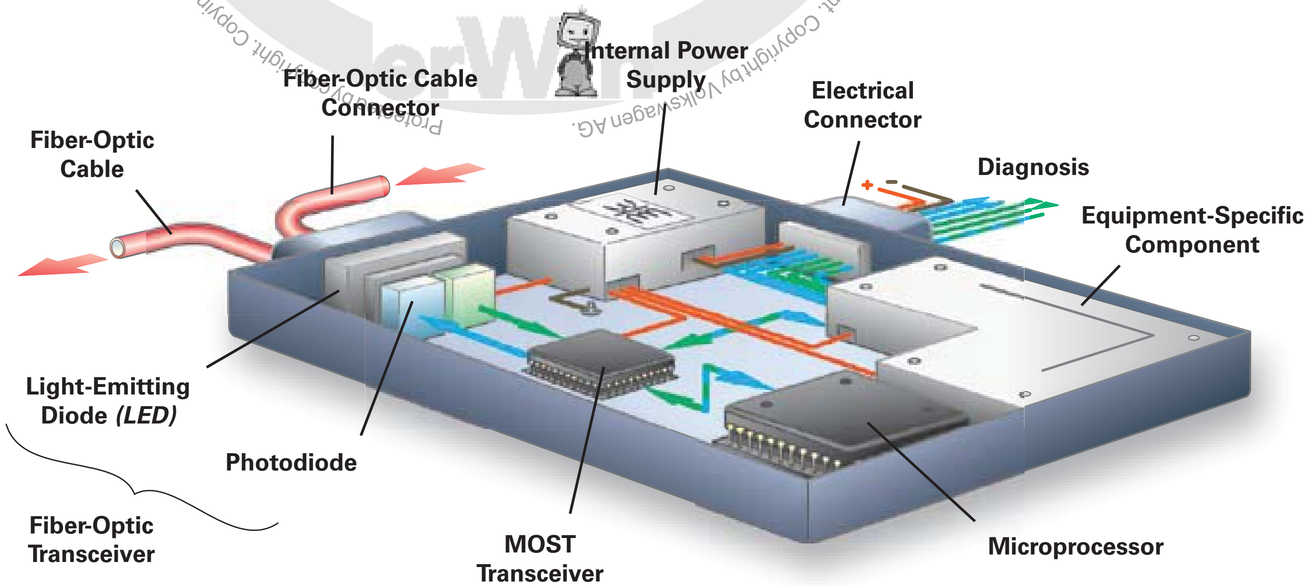
Light signals travel through these connectors to the control module or to the next component on the fiber-optic data bus.

Electrical Connector

The input and output signals to the control module are provided through this connector. It also provides the voltage supply for the ring break diagnosis *(explained starting on page 74)*.

Internal Power Supply

The voltage supplied to the control module through the electrical connector is distributed by the internal power supply to the various control module internal components. The internal power supply can turn OFF these internal components to reduce power consumption when the control module is in the sleep mode.



Fiber-Optic Data Bus

Fiber-Optic Transceiver

The fiber-optic transceiver uses a photodiode to change light signals received through the fiber-optic cable into a voltage that is then transmitted to the MOST transceiver in the control module.

It also uses a Light Emitting Diode *(LED)* to convert voltage signals received from the control module MOST transceiver into light signals so that they can be passed on to the next control module in line on the fiber-optic data bus.

The produced light waves have a wavelength of 650 nanometers *(nm)* and are visible as red light.

The data are transmitted through modulation of the light waves.

This modulated light is transmitted to the next control module through the fiber-optic cable.

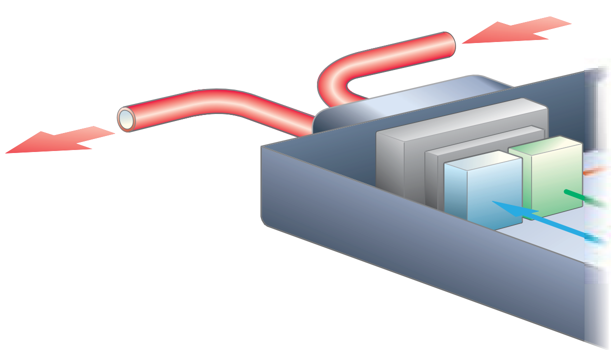
MOST Transceiver

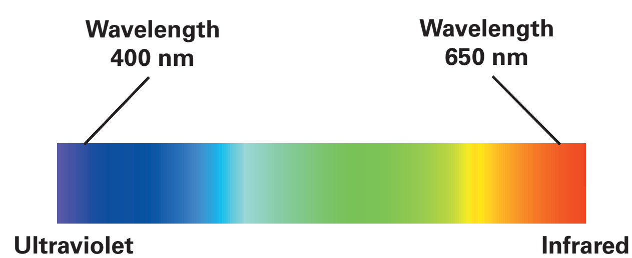
As the name implies, the MOST transceiver consists of both a transmitter and a receiver.

The transmitter sends messages as voltage signals to the fiber-optic transceiver.

The receiver takes the voltage signals from the fiber-optic transceiver and transmits the needed data to the control module microprocessor.

Messages from other control modules that are not needed by this control module are guided through the transceiver without transmitting any data to the microprocessor. These unchanged messages are routed back through the fiber-optic transceiver and transmitted to the next control module.





Microprocessor

A microprocessor is the central processing unit for the control module. It controls all the important functions of the control module.

Equipment-Specific Component

An equipment-specific component controls functions that are unique to the individual control module, such as operating the CD-drive or the radio tuner.

Photodiode

A photodiode converts light waves into voltage signals.

Photodiode Design

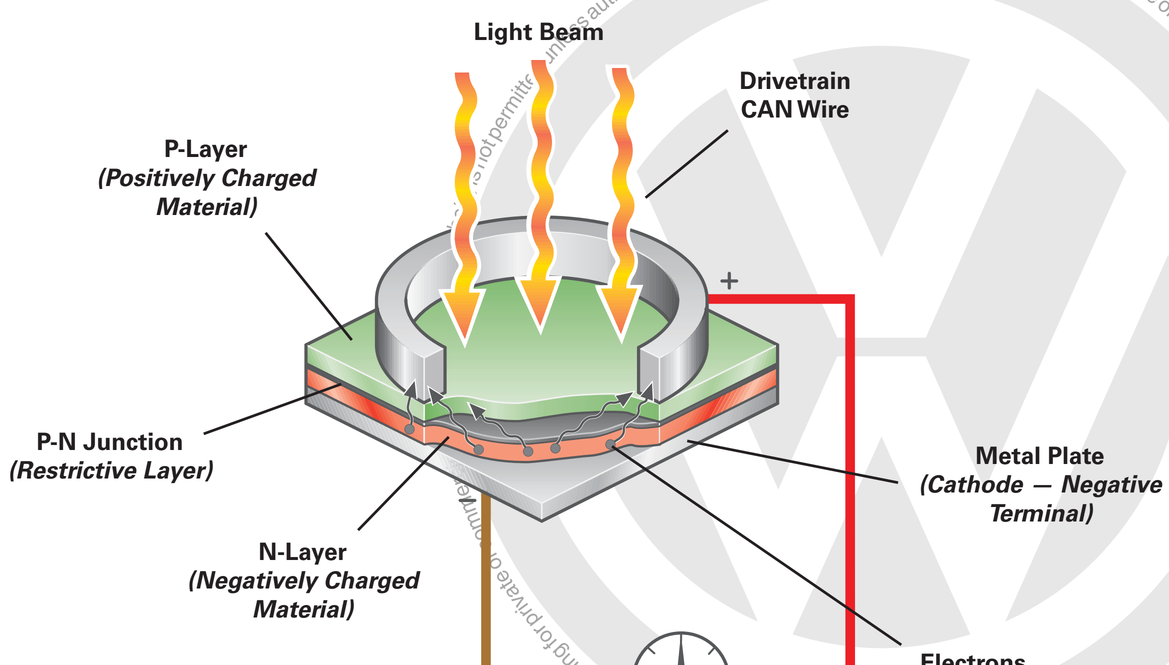
A photodiode has a P-N junction that is affected by light.

Because the P-layer *(positively charged semiconductor material)* is so heavily *doped* with the impurity that gives it its positive charge, the restrictive layer or depletion region at the P-N junction reaches almost into the N-layer *(negatively charged semiconductor material)*.

Note The term *doped* or *doping* refers to the addition of impurities to the semiconductor material to give it an absence or excess of electrons, with the result of a positive or negative charge to the material.

A contact ring on the P-layer provides the anode or positive terminal of the photodiode.

The N-layer is applied to a metallic base plate that acts as the cathode or negative terminal.



Fiber-Optic Data Bus

Photodiode Function

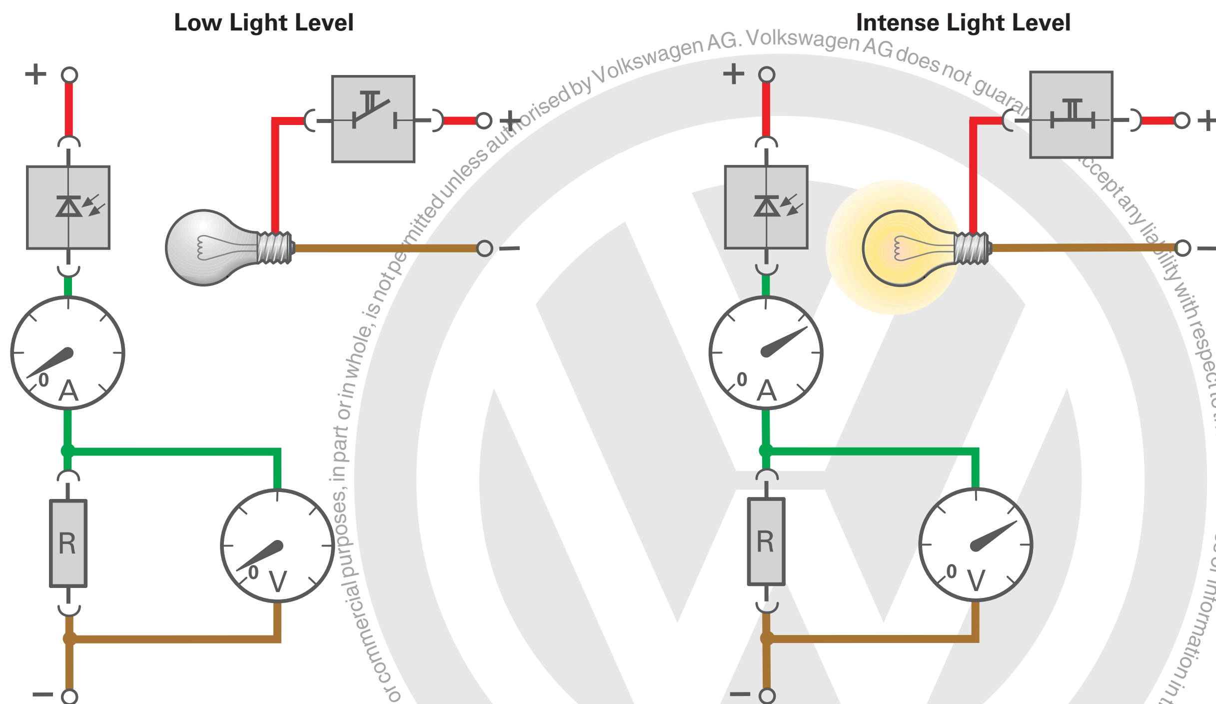
When visible light or infrared rays penetrate the P-N junction, the resulting free energy creates free electrons and holes nearby. These induce a voltage to pass through the P-N junction in direct proportion to the amount of light that is penetrating it.

This means, the more light that reaches the photodiode, the higher the voltage will be that flows through it.

This process is called the *internal photoelectric effect*.

The photodiode is connected in series with a resistor on the negative side in the direction of restriction.

If the voltage through the photodiode increases because more light reaches it, the voltage drop across the resistor will also increase. The resulting changes in voltage effectively translate light signals to voltage signals.



Fiber-Optic Cable

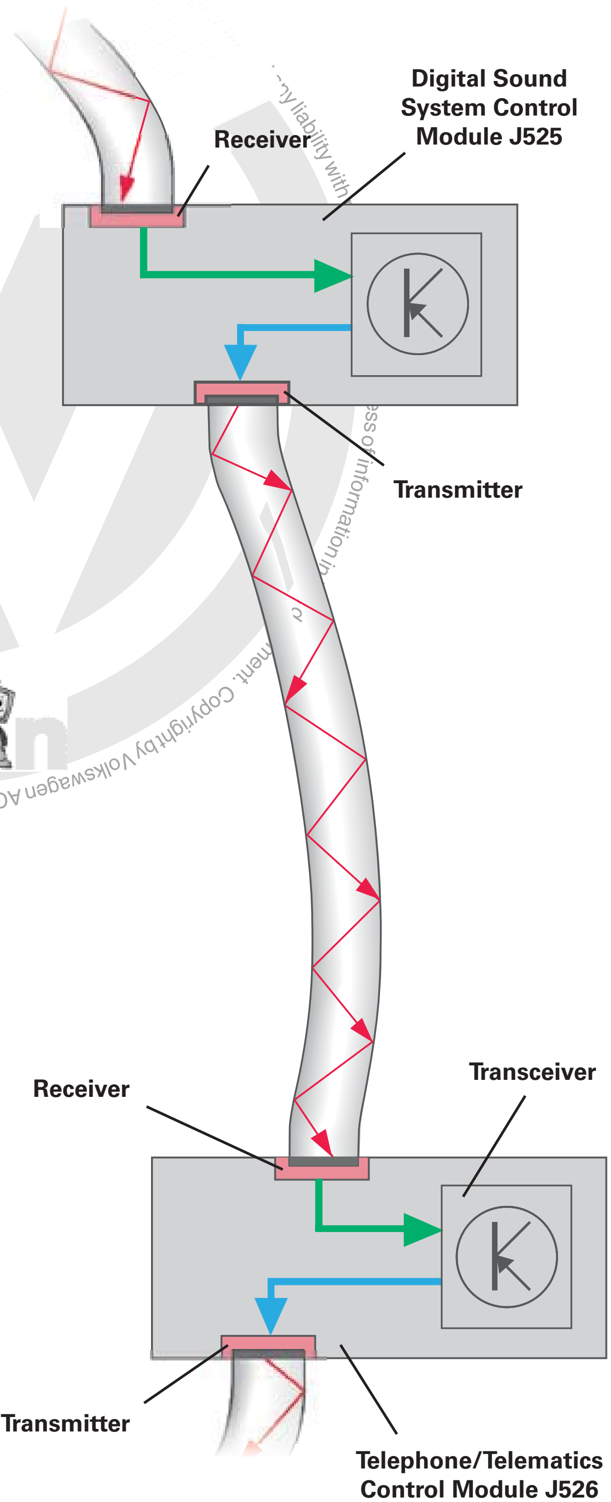
The fiber-optic cable is used to route the light waves produced by the transmitter of one control module to the receiver of another control module.

The following criteria had to be considered during the development of the fiber-optic cable:

- Light waves travel in straight lines and cannot be bent. Light waves must be guided through the bends of the fiber-optic cable.
- The distance between the transmitter and the receiver can be several yards, therefore attenuation can occur.
- Mechanical stress, vibration, or repairs must not damage the fiber-optic cable.
- The function of the fiber-optic cable must be assured during high temperature fluctuations in the vehicle.

For these reasons, the fiber-optic cable must fulfill the following requirements:

- The fiber-optic cable must conduct the light wave with little attenuation
- The light waves must be guided through the bends of the fiber-optic cable
- The fiber-optic cable must be flexible
- The function of the fiber-optic cable must be assured between -40°F and 185°F *(-40°C to 85°C)*



Fiber-Optic Data Bus

Fiber-Optic Cable Design

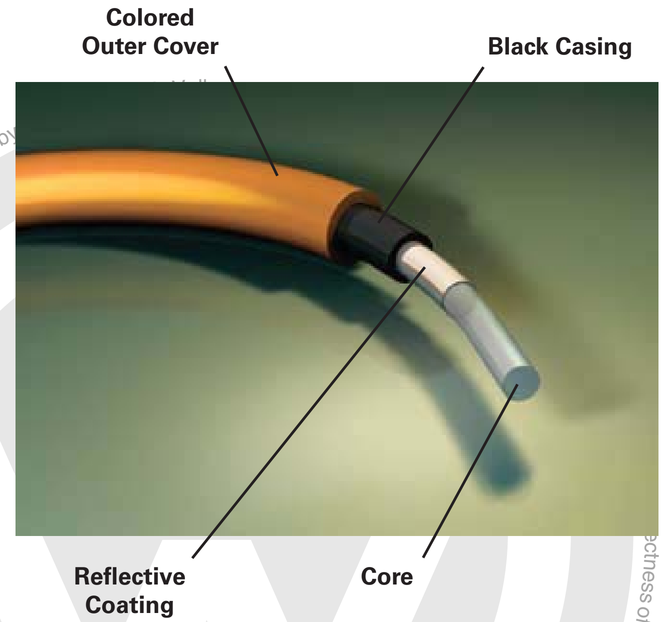
Fiber-optic cable has several layers.

The core is the main part of a fiber-optic cable. It consists of polymethylmethacrylate *(PMMA)*, which is the actual fiber-optic cable. In it, light travels according to the principle of total reflection, with almost no loss.

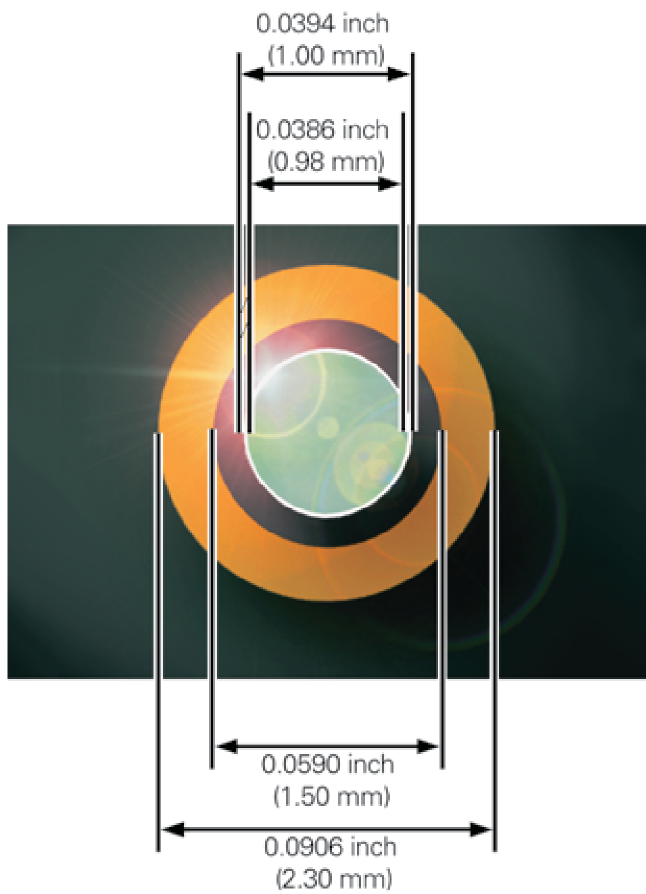
The optically transparent reflective coating around the core is needed for total reflection.

The black casing made from polyamide protects the core from outside light.

The colored outer cover is for identification, protection against outside damage, and insulation against temperature.



Fiber-Optic Cable Diameter

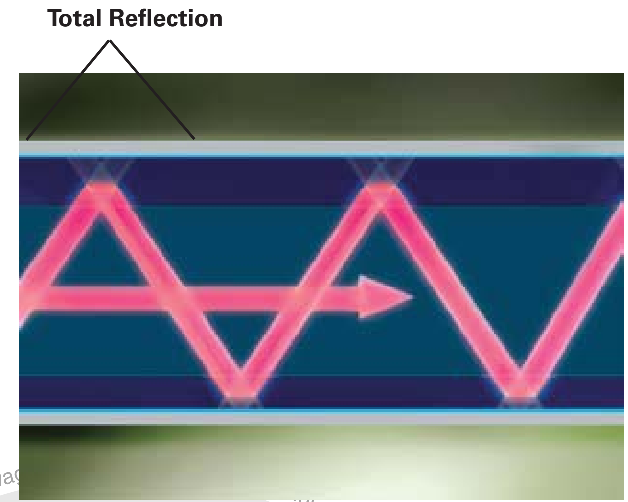


Transmission of Light Waves in Fiber-Optic Cables

Straight Fiber-Optic Cable

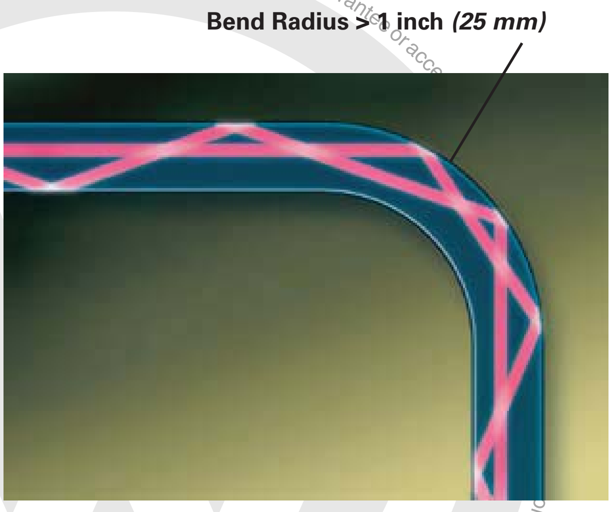
Fiber-optic cable guides part of the light waves in a straight line through the core.

The largest parts of the light waves are guided through the fiber-optic cable in a zigzag line according to the principle of total reflection against the surface of the core.



Bent Fiber-Optic Cable

Light waves are reflected by total reflection at the borderline of the core coating and with that are guided through the bend.



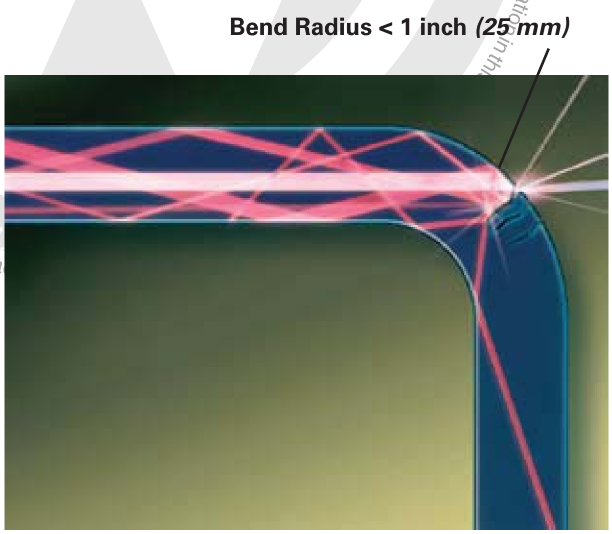
Total Reflection

When a light wave strikes a boundary layer between a dense and an optically thin material at a low angle, the beam will be reflected completely, causing total reflection.

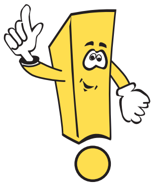
The core in the fiber-optic cable is optically dense material, while the coating is optically thin material. Thus, total reflection occurs on the inside of the core.

This reflection depends on the angle of the light wave as it hits the boundary layer. If this angle is too acute, the light waves will leave the core and higher loss will result.

This condition occurs when the fiber-optic cable is bent too much or is kinked.



Note The bend radius of the fiber-optic cable must not be less than 1 inch *(25 mm)*.



Fiber-Optic Data Bus

Connectors

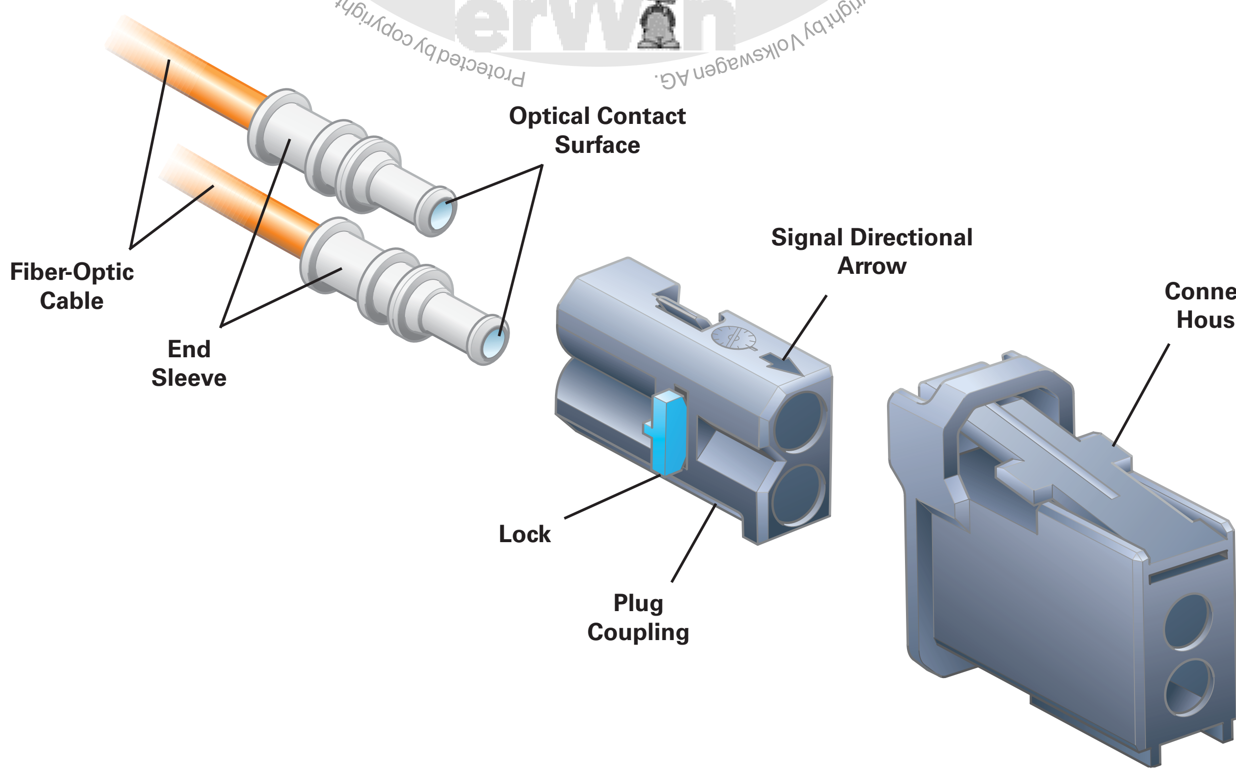
To be able to connect fiber-optic cables to control modules, special optical connectors are used.

There are arrows on the connector plug coupling to indicate signal direction.

The connector housing serves as the connection to the control module.

The transfer of light occurs between the face surface of the core and the transmitter/receiver of the control module.

End sleeves are welded by laser or brass end sleeves are crimped onto the cable ends to enable connection of the fiber-optic cables to the connector plug couplings.



Optical Face Surface

Contamination and scratches on the face surface of the fiber-optic cable increase signal losses *(attenuation)*.

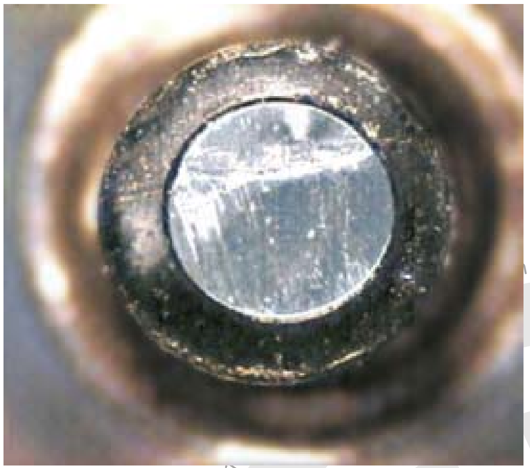
To produce a transfer of light waves with no loss, the face surface must be:

– Smooth

– Perpendicular

– Clean

This condition can only be assured by using a special cutting tool.



Attenuation in the Fiber-Optic Data Bus

A reduction in the amount or intensity of the light waves as they are routed through the fiber-optic cable results in a reduction in signal. This signal loss is referred to as *attenuation*.

To evaluate the efficiency of a fiber-optic cable, the signal loss must be measured.

Attenuation *(A)* is measured in decibels *(dB)*.

A decibel is not an absolute value but a ratio of two values. This is the reason that a decibel is not defined as a physical value. For example, the decibel unit is used to establish acoustic pressure or sound volume.

To measure attenuation, it is calculated from the logarithm of the ratio of the transmitter output versus the receiver output.

Fiber-Optic Data Bus

Formula:

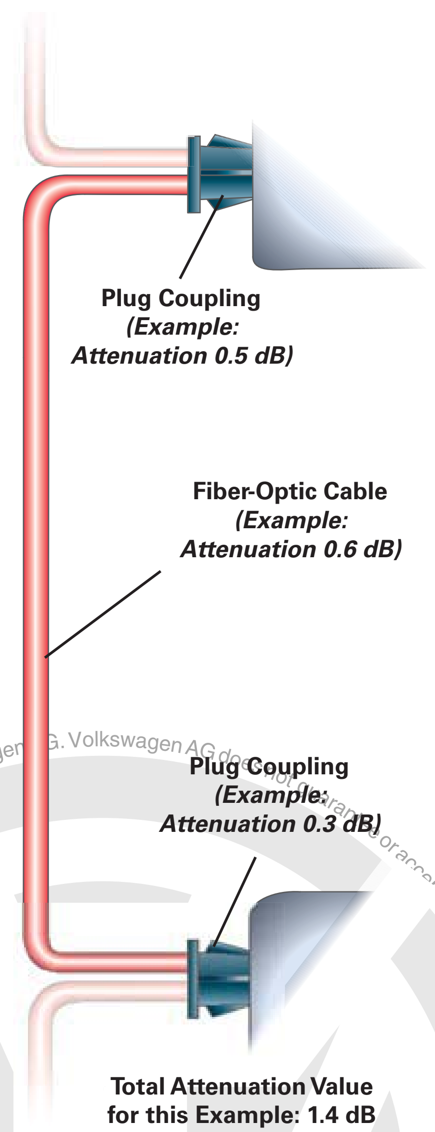
$$\text{Attenuation Value } (A) = 10 \text{ X } \log \frac{\text{Transmitter Output}}{\text{Receiver Output}}$$

Example:

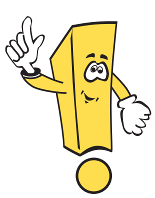
$$10 \text{ X } \log \frac{20\,\text{W}}{10\,\text{W}} = 3\text{ dB}$$

This means that for a fiber-optic cable with an attenuation value of 3 dB, the light signal will be reduced by half.

If several components are involved in the transmission of light signals, the attenuation values can be added to a total attenuation value, similar to the resistance of electrical components that are connected in series.



Note



Since every control module in the MOST fiber-optic data bus always transmits anew, only the total attenuation value between two control modules is of any significance.

Causes for Increased Attenuation in the Fiber-Optic Data Bus

1 Bending radius below the specified limit. If fiber-optic cable was kinked or bent by more than a radius of 1 inch *(25 mm)*, clouding will appear in the core similar to the clouding appearing in sharply bent Plexiglas. In such cases the fiber-optic cable must be replaced.

2 Casing damaged

3 Face scratched

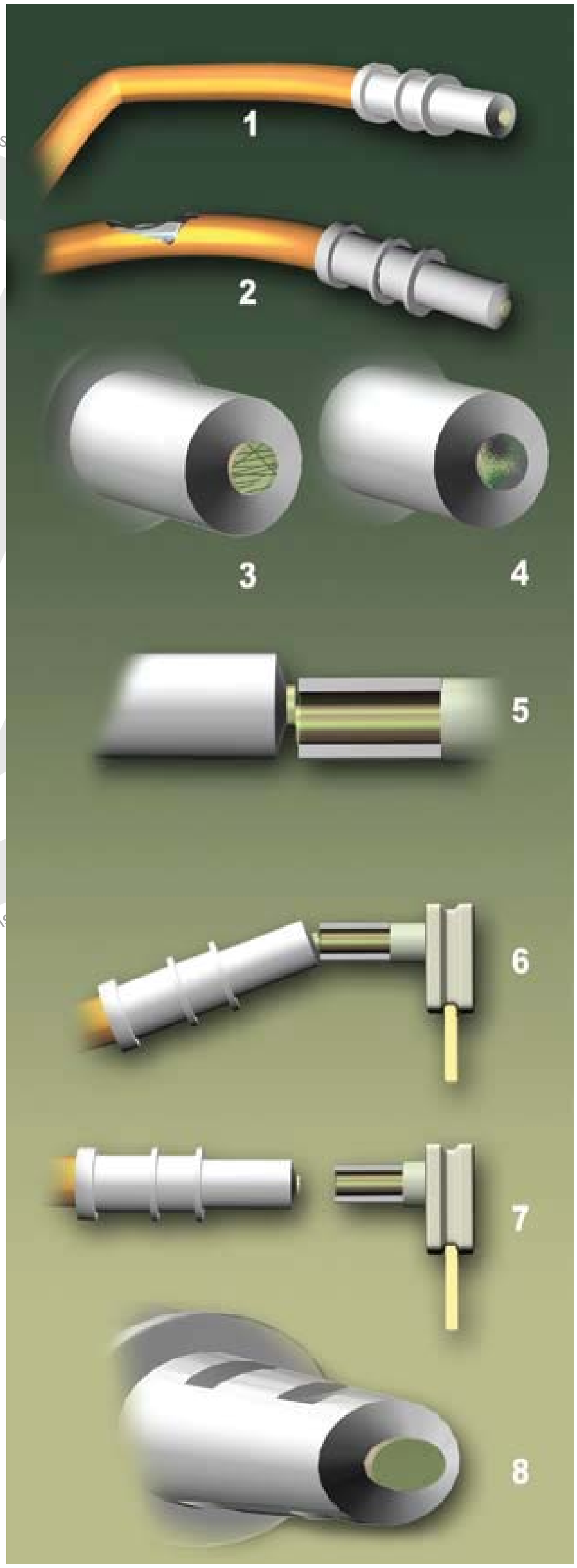
4 Face contaminated

5 Faces offset *(connector housing broken)*

6 Faces positioned on a bias *(angle fault)*

7 Gap between face of fiber-optic cable and contact face of control module *(connector housing broken or not locked)*

8 End sleeve not properly crimped



Fiber-Optic Data Bus

Fiber-Optic Cable Handling

– Do not crush the fiber-optic cable. Avoid damage to the casing such as perforating, cutting, pinching, etc. Do not step on fiber-optic cables or place objects on them.

– Do not kink or bend the fiber-optic cable to a radius of less than 1 inch *(25 mm)*. By installing kink protection *(corrugated pipe)*, a bending radius of more than 1 inch *(25 mm)* is assured during installation.

– Be aware of tie-down and contact points, and use the correct length when routing fiber-optic cables in the vehicle.

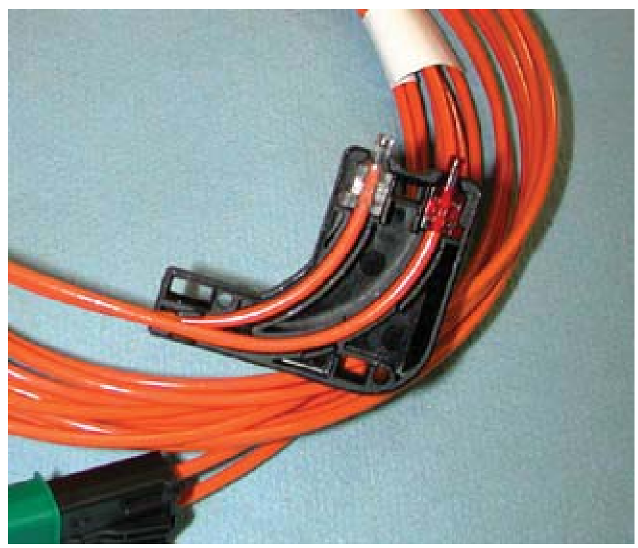
– Prevent contamination of the face surface with liquids, dust, fuels, etc. Do not remove the protective cap from the end of the fiber-optic cable until just before testing or installation. If the protective cap is missing, you may have to replace the fiber-optic cable with another new one that has been properly protected.

– Do not apply thermal treatment or repair methods to fiber-optic cables that involve soldering, heat bonding, or welding.

– Do not employ chemical or mechanical methods to connect fiber-optic cables such as gluing or butt joints.

– Do not twist two fiber-optic cables together or one fiber-optic cable with a copper wire.

Corrugated Pipe for Kink Protection



Note Fiber-optic cables and their components must be handled with extreme care.

Ring Structure of the Fiber-Optic Data Bus

An important feature of the MOST fiber-optic data bus system is its circular arrangement in the form of a ring.

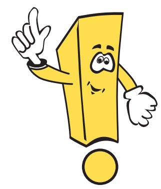
The control modules send data in one direction on a fiber-optic cable to the next control module in the ring.

This procedure is repeated until the data is again received by the control module that sent the data in the first place.

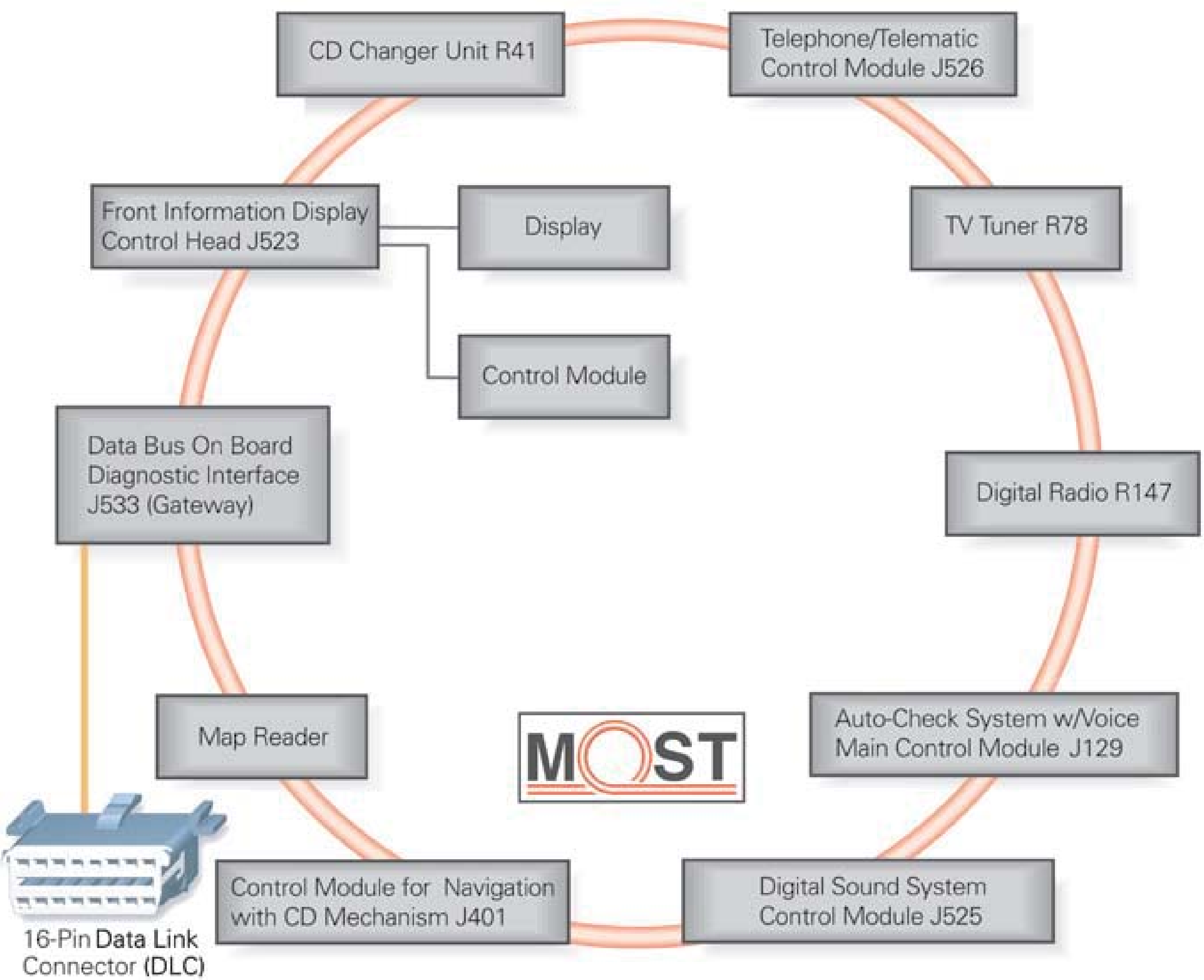
This way the ring closes.

Diagnosis of the MOST fiber-optic data bus system is performed through the Data Bus On Board Diagnostic Interface J533 *(Gateway)* and Diagnosis CAN to the 16-pin Data Link Connector *(DLC)*.

Note



Not all components shown here are installed on every vehicle. Some components may not be available for the North American market.



Fiber-Optic Data Bus

System Manager

The system manager is responsible for the system management in the MOST fiber-optic data bus. The system manager is supported by the diagnosis manager, Data Bus On Board Diagnostic Interface J533 *(Gateway)*.

Front Information Display Control Head Control Module J523 is responsible for the system management function.

The system manager is responsible for:

- Control of system conditions
- Transmitting messages from the MOST fiber-optic data bus
- Control of transmission capacities

MOST System Conditions

Sleep Mode

In sleep mode there is no data exchange on the system. The components are ready but can only be activated by a start impulse from the system manager through the fiber-optic data bus.

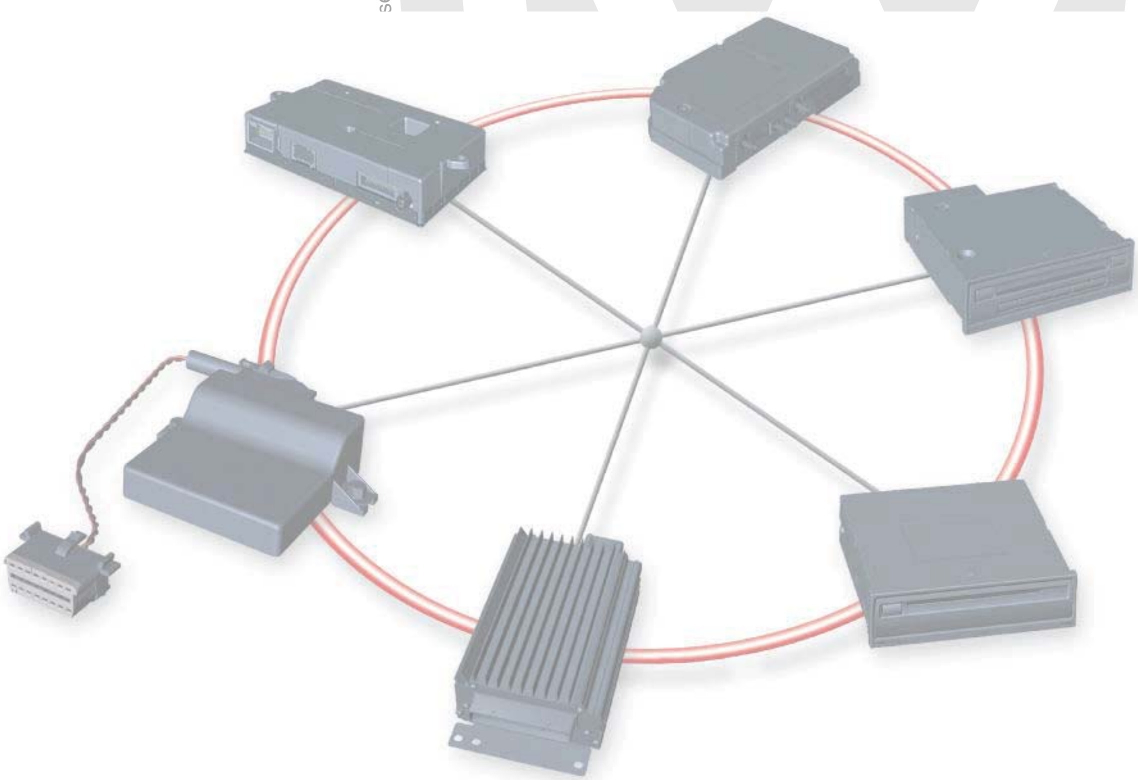
Sleep mode voltage is reduced to a minimum.

Conditions for activating sleep mode:

- All control modules in the system signal their readiness to switch to sleep mode
- There is no request from other bus systems through J533
- Diagnosis is not active

Over-riding the above conditions, the system can be switched to sleep mode by:

- Battery Monitoring Control Module J367 through J533 during discharge of the starter battery
- When transport mode is activated through a VAS Scan Tool



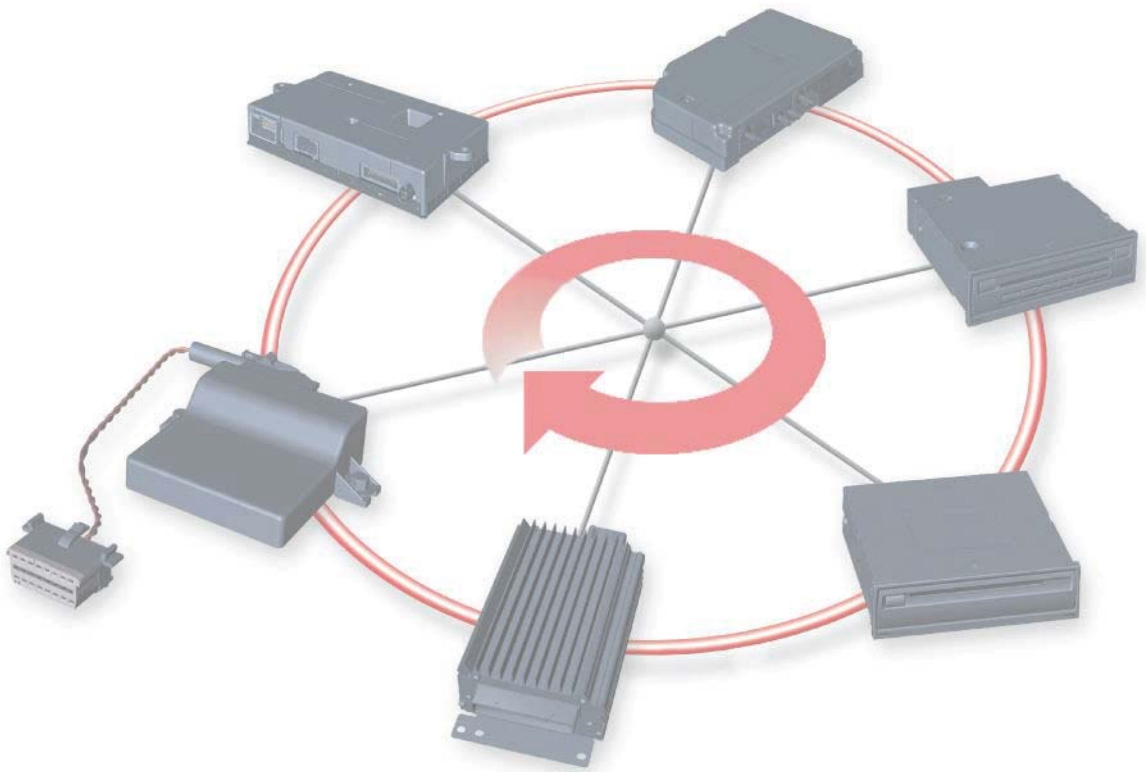
Standby Mode

In standby mode there is no service offered to the operator. It seems as if the system is turned OFF. However, the system is active in the background. All output media *(display, radio amplifier, etc.)* are either inactive or are switched to standby mode.

The system is in standby mode during the after-run period and when the vehicle is being started.

Activation of the standby mode:

- Can be triggered by other data buses through J533 by unlocking and opening the driver's door, or turning the ignition ON
- Can occur through a control module in the MOST fiber-optic data bus, for instance by an incoming phone call



Fiber-Optic Data Bus

Power ON

In power ON mode, all control modules are turned ON. Data exchange occurs on the MOST fiber-optic data bus. All functions are available for the operator.

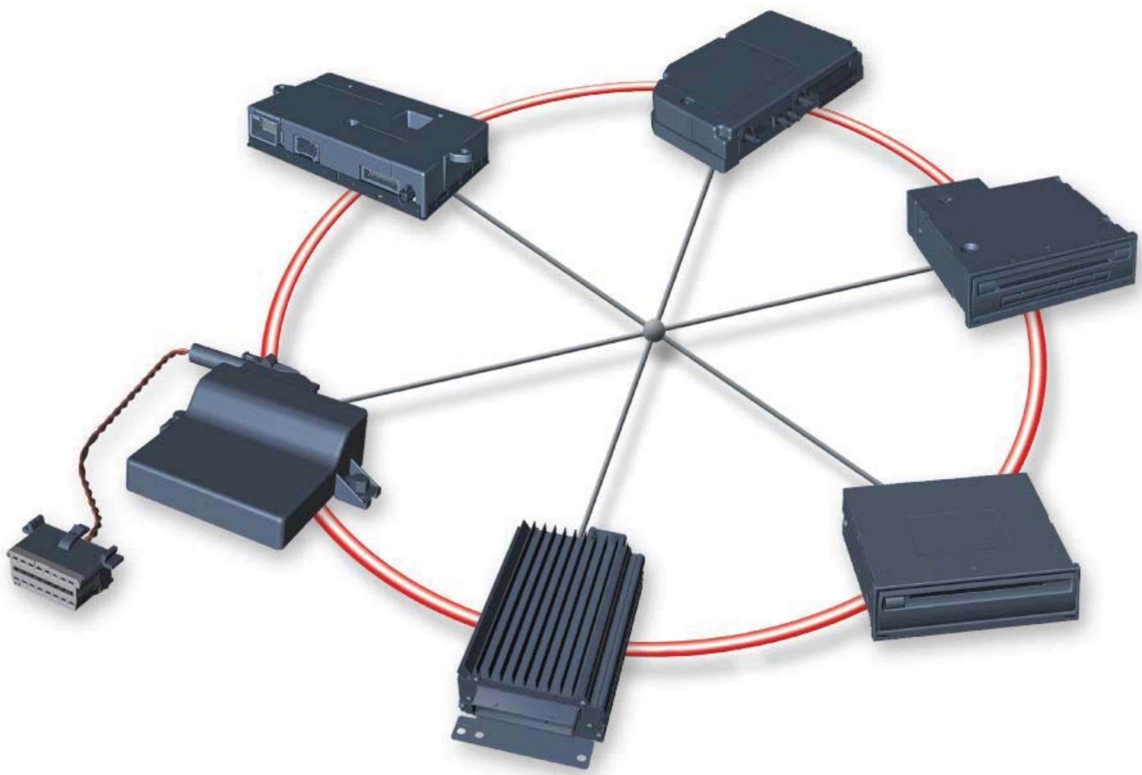
Note For more information about activation conditions, please refer to Self-Study Programs that apply to specific vehicles.

Conditions for activating power ON mode:

– MOST fiber-optic data bus system is in standby mode

– Activation through other data buses via Data Bus On Board Diagnostic Interface J533 *(Gateway)*, for example S-contact, display active

– Activation triggered by a function selection by the operator, such as from Multimedia Control Head E380



MOST Function Flow

System Start *(Wake-Up)*

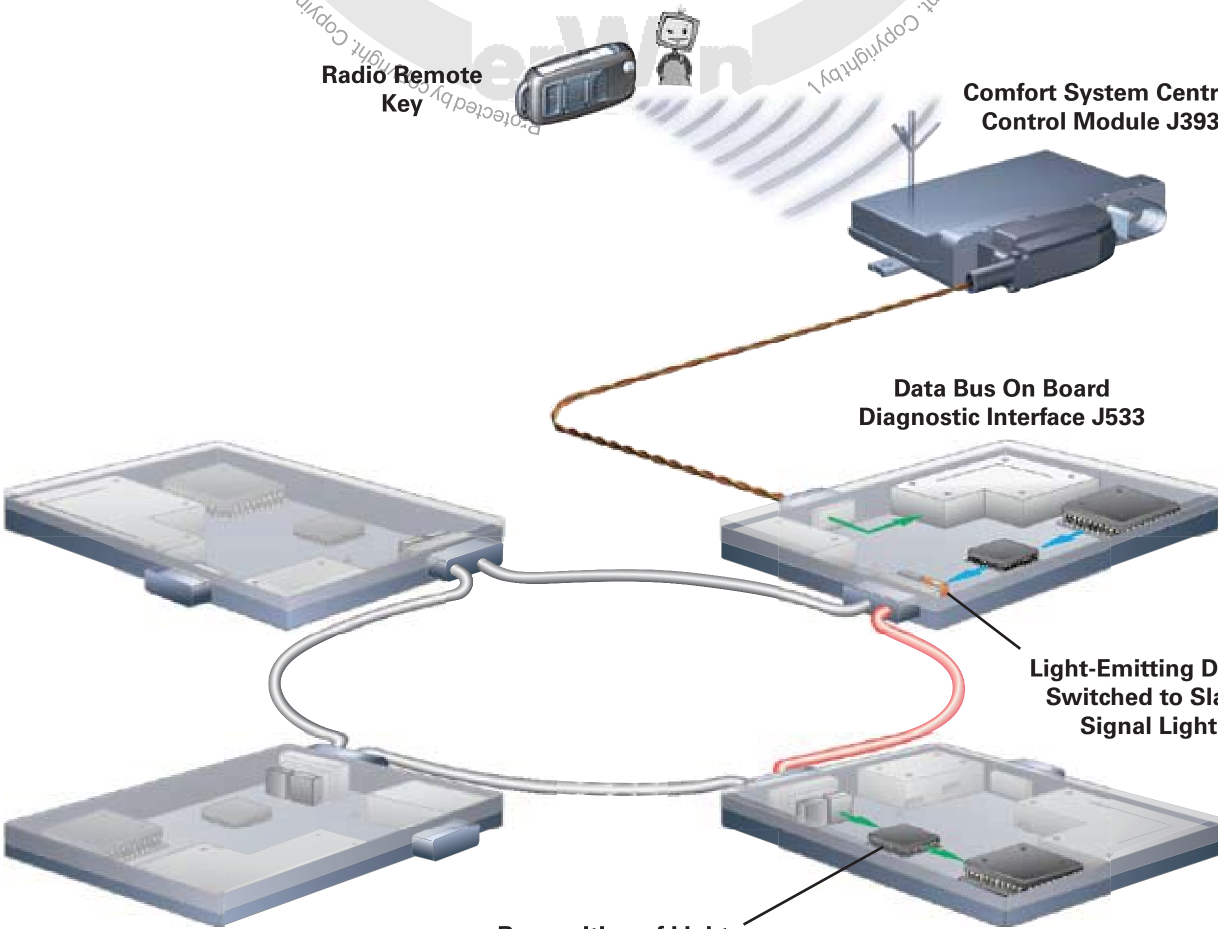
If the MOST fiber-optic data bus is in sleep mode, the system is first switched to standby mode by the wake-up procedure.

If a control module other than the system manager wakes the system, it sends a specifically modulated light signal, the slave light signal, to the next control module.

The next control module in the ring receives the slave light signal by the active photodiode and passes it on.

This process continues until the signal arrives at the system manager.

The system manager recognizes the arrival of the slave light signal as a command to start the system.

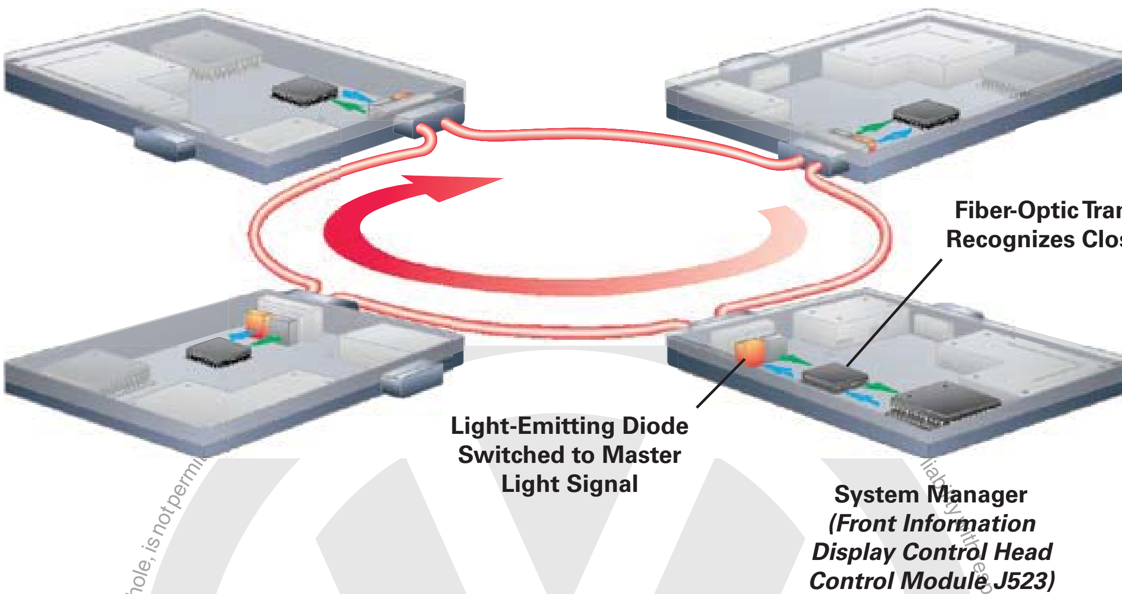


Fiber-Optic Data Bus

In response to this signal, the system manager sends a different specifically modulated light signal, the master light signal, to the next control module in the ring.

This master light signal is transmitted by each control module in turn.

When the system manager receives the master light signal back at its fiber-optic transceiver, it recognizes that the fiber-optic data bus ring has been closed and starts transmitting the message frame.



In the first message frame, the control modules in the MOST fiber-optic data bus are asked to identify themselves.

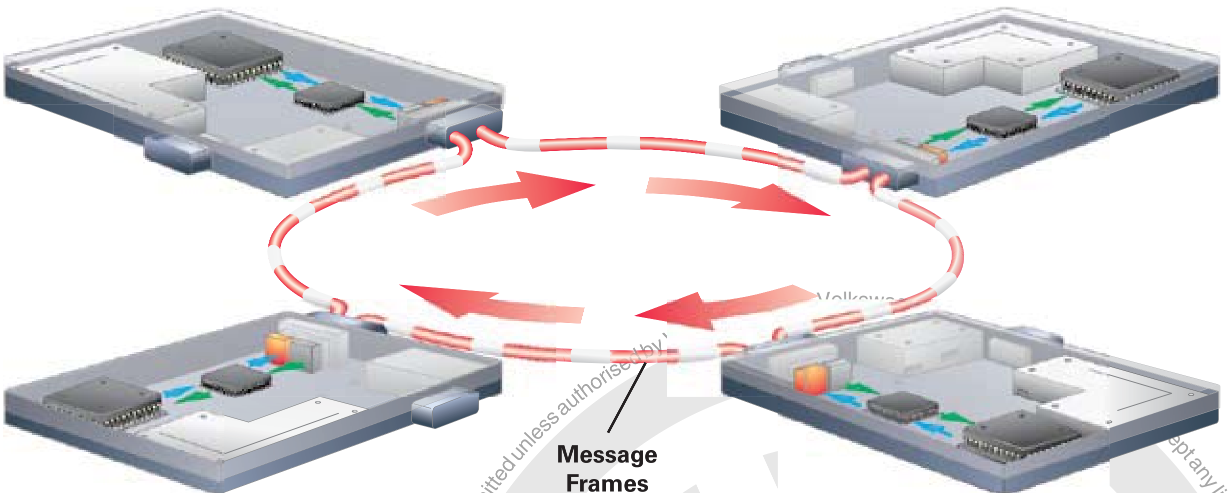
Following the identification cycle, the system manager sends the current sequence *(actual configuration)* to all control modules in the ring.

This makes address-oriented data transmission possible.

The diagnosis manager compares the reported control modules *(actual configuration)* with a stored list of the installed control modules *(specified configuration)*.

If the actual configuration does not match the specified configuration, the diagnosis manager *(Data Bus On Board Diagnostic Interface J533)* stores the applicable Diagnostic Trouble Code *(DTC)*.

At this point the wake-up procedure is concluded and data transmission can begin.



Fiber-Optic Data Bus

Diagnosis

Diagnosis Manager

In addition to the system manager, the MOST fiber-optic data bus has a diagnosis manager.

The diagnosis manager performs a diagnosis of the fiber-optic data bus ring and transmits the diagnosis data of the control modules in the ring to the VAS Scan Tool.

The diagnosis function for the fiber-optic data bus in Volkswagen models is performed by Data Bus On Board Diagnostic Interface J533.

System Failure

If the transmission of data in the fiber-optic data bus is interrupted, it is referred to as a *ring break* because of its ring structure.

Reasons for a ring break can include:

- Interruption of the fiber-optic cable
- Faulty voltage supply of the transmitter or receiver control module
- Faulty transmitter or receiver control module

To localize a ring break, a ring break diagnosis must be performed. The ring break diagnosis is part of the output diagnostic test mode of the diagnosis manager.

Consequences of a ring break are:

- Failure of sound and video reception
- Failure of control and adjustment using Front Information Display Control Head Control Module J523
- Diagnostic Trouble Code *(DTC)* entered into the diagnosis manager is *optical data bus interruption*

Ring Break Diagnosis

Because data transmission in the MOST fiber-optic data bus is not possible in case of a ring break, the diagnosis must be performed using a diagnosis wire.

The diagnosis wire is connected to every control module in the fiber-optic data bus ring from a central connection.

How Ring Break Diagnosis Works

After ring break diagnosis is initiated, the diagnosis manager sends an impulse to the control modules over the diagnosis wire.

In response to this impulse, all of the control modules in the ring use the transmitters in their fiber-optic transceivers to send light signals through the fiber-optic cable.

At the same time all control modules check:

- Their voltage supply and internal electrical functions
- Receipt of the light signals from the previous control module in the ring

Each control module connected to the MOST fiber-optic data bus answers according to timing programmed into the software.

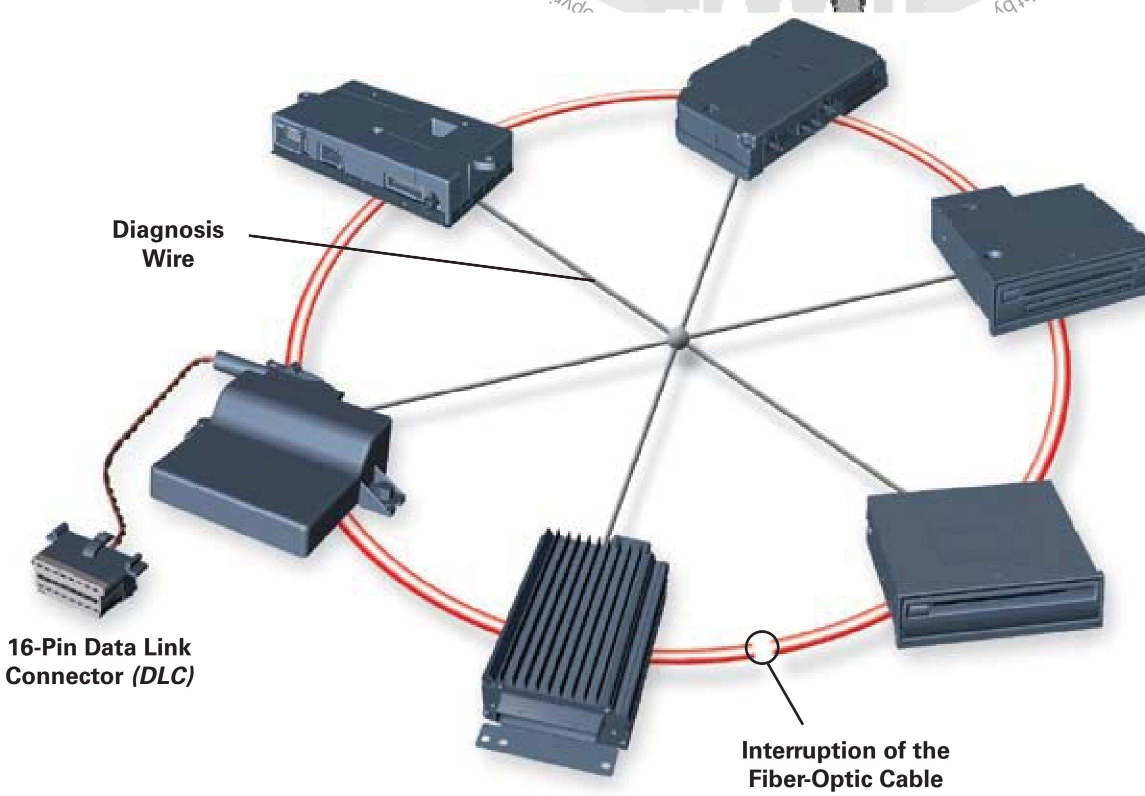
Using the timing between the start of the ring break diagnosis and receipt of the answer, the diagnosis manager recognizes which control module sent the answer.

The control modules connected to the MOST fiber-optic data bus send two messages after the start of the ring break diagnosis:

- "Control module is electrically OK" means that the electrical functions of the control module, such as the voltage supply are OK
- "Control module is optically OK" means that it receives the light signal through its photodiode from the control module that precedes it in the ring

From this information the diagnosis manager can recognize:

- Whether there is an electrical fault in the system *(voltage supply faulty)*
- Between which of the control modules the optical data transmission is interrupted



Fiber-Optic Data Bus

Ring Break Diagnosis with Increased Attenuation

The previously described ring break diagnosis process can only detect an interruption of data flow.

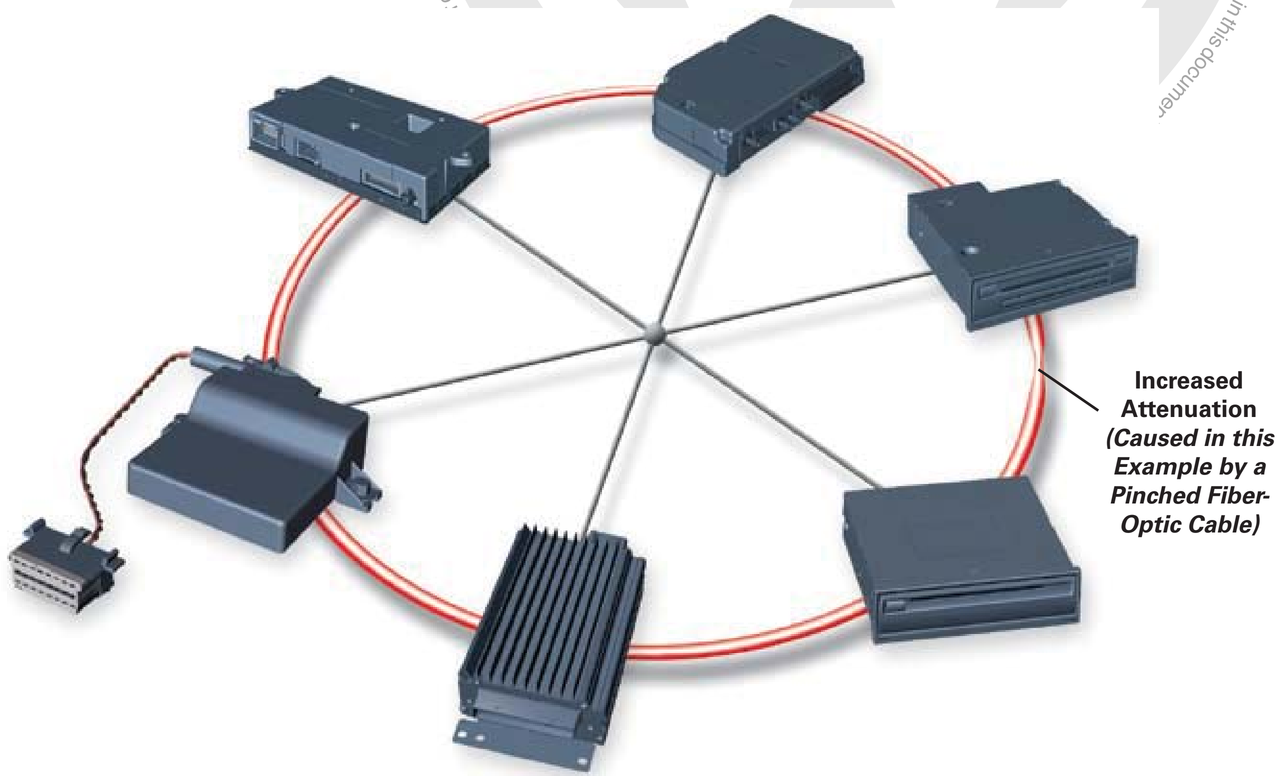
The output diagnostic test mode of the diagnosis manager *(Data Bus On Board Diagnostic Interface J533)* can also perform a ring break diagnosis with reduced light output to recognize a reduction in the amount or intensity of the light waves as they are routed through the fiber-optic cable *(increased attenuation)*.

The process of the ring break diagnosis with reduced output is similar to the one described for interrupted data flow.

However, in this case the control modules switch the LEDs in their fiber-optic transceivers to an attenuation of 3 dB, or to half of their normal light output.

If the fiber-optic cable has an increased attenuation, the light signal is too weak as it reaches the receiver. The receiver then reports "Optics not OK."

From this signal the diagnosis manager recognizes the fault location and produces an appropriate message in the Scan Tool's guided fault finding mode.



Introduction

In the modern business world as well as in private life, mobile communication and information is becoming increasingly important.

A person often uses more than one mobile device such as a mobile telephone, a personal digital assistant, or a laptop computer.

The exchange of information between these mobile devices was possible in the past only through hard-wired electrical connection or wireless infrared connection.

These non-standardized connections took up valuable space and the devices were complicated to operate.

Bluetooth technology takes up less space and reduces the complexity of operating these devices. It enables mobile devices of various manufacturers to be connected through a standardized radio transmission.

Bluetooth

Other applications are planned for the vehicle user:

- Installation of a second phone in the rear passenger compartment
- Connection of laptop computers, smart phones, and notepads to the Internet for transmission of information and entertainment
- Reception and transmission of e-mail using a laptop computer or personal digital assistant
- Transmission of addresses and phone numbers from a laptop or personal digital assistant to the multimedia interface system
- Hands-free operation of mobile phones without additional cable adapters
- Use of Bluetooth technology in other vehicle systems *(remote operation of the auxiliary heater for example)*

What is Bluetooth?

The Swedish company Ericsson promoted the development of a standardized short distance radio transmission system — Bluetooth technology.

In response to this initiative, many companies have joined in the development of this technology. Today the Bluetooth Special Interest Group consists of more than 2000 companies, including telecommunications, data processing, equipment, and vehicle manufacturers.

The name "Bluetooth" comes from the Viking King Harald Blåtand. During the tenth century he united Denmark and Norway and had the nickname "Bluetooth."

Because this transmission system connects diverse information and data processing devices as well as mobile phones, the resulting good communication reflects the philosophy of King Harald. That is the reason it was called Bluetooth.

Design and Function

Bluetooth technology enables wireless connection of various mobile devices from different manufacturers using a standardized radio transmission.

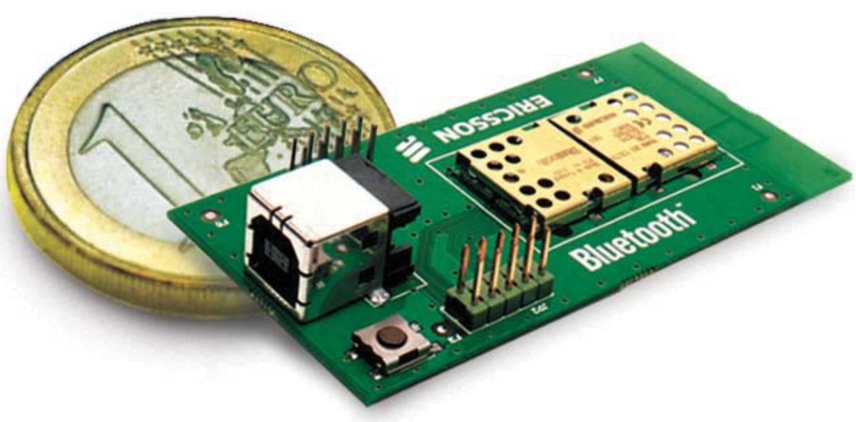
In selected mobile devices, short-range transceivers *(transmitters and receivers)* are either directly installed or integrated using an adapter *(example: PC-card, universal service bus, etc.)*.

Radio transmission occurs in the 2.40 GHz frequency range that is available worldwide. Transmitting on this band does not require a license and is free of charge.

The very short wave length of this frequency makes it possible to integrate the following into the Bluetooth module:

- Antenna *(Bluetooth Antenna R152)*
- Control and encryption
- Entire transmission and receiver technology

The small size of the Bluetooth module allows its installation into electronic devices.



Bluetooth

The Bluetooth data transmission rate is up to 1 megabit per second *(Mbit/s)*. These devices can transmit up to three language channels at the same time.

Bluetooth transmitters normally have a range of about 33 feet *(10 meters)*. In special applications with amplifiers, transmission ranges of up to about 330 feet *(100 meters)* are possible.

The data transmission works with no complicated adjustments.

As soon as two Bluetooth devices meet, they automatically establish a connection. Before that can happen, the devices must be adapted once by entering a Personal Identification Number *(PIN)*.

When the PIN is entered, small transmission cells are formed, called *piconets*, to help with the organization of data.

A piconet offers room for a maximum of eight active Bluetooth devices. Each device can belong to several piconets at the same time.

In each piconet, one device assumes the master function.

- Master establishes the connection
- Other devices synchronize with the master
- Only the device that received a data package from the master may send an answer

To prevent chaos in the construction of a piconet, adjustments can be made to every device to determine whether it will communicate with another device or not.

Each device has an address that is 48 bits long and is unique worldwide. This makes it possible to clearly identify more than 281 trillion devices.

Shared Operating Frequencies

Data transmission in the Bluetooth system is done using radio waves within a frequency range of 2.40 GHz to 2.48 GHz.

This frequency range is used also by other devices:

– Garage door openers
– Microwave ovens
– Medical devices

Interference Reduction Measures

Bluetooth technology employs special measures to reduce interference caused by other devices operating on the same frequencies.

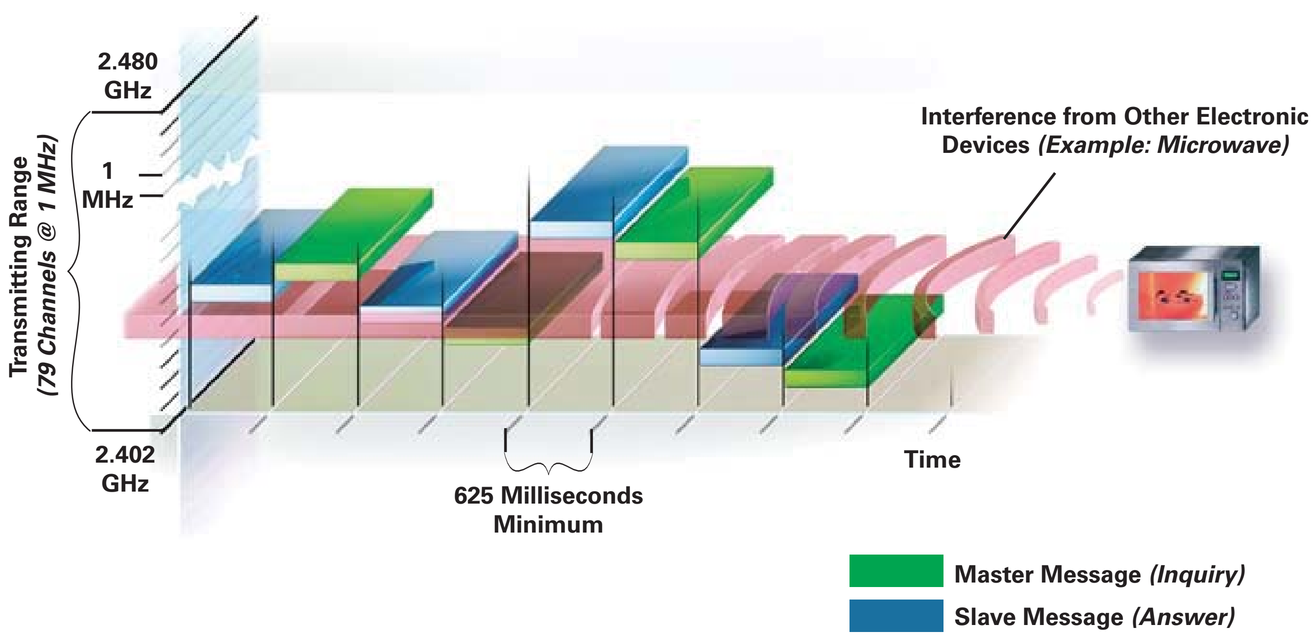
The Bluetooth control module:

– Divides data into short and flexible data packages of about 625 milliseconds in duration
– Checks the completeness of data packages using a check total of 16 bits
– Automatically repeats the transmission of faulty data packages
– Uses robust language coding converted into digital signals

The Bluetooth transmitter module:

– Changes the transmitting and receiving frequencies at random, 1600 times per second *(frequency hopping)*

Function



Bluetooth

Data Security

In the development of Bluetooth technology, the cooperating manufacturers placed great value on the protection of the transmitted data against manipulation and unauthorized access.

The data are encrypted using an encryption key that is 128 bits long.

The receiver is checked for authenticity with a key of 128 bits. The devices use a secret password that is used for participants to recognize each other.

The key is newly created for every connection.

Since the range is limited to about 33 feet *(10 meters)*, a manipulation must occur within this range. This also increases data security.

These same measures also increase security against outside interference and manipulation of the data flow.

By additional use of elaborate encrypting methods, diverse security levels, and network protocols, the equipment manufacturers can increase data security even further.

Diagnosis

The diagnosis of the Bluetooth connection is performed using the Address Word of the master control module.

For example, Telephone/Telematics Control Module J526 is the Bluetooth master for some Volkswagen vehicles. The Bluetooth connection between Cellular Telephone R54 and the Telephone/Telematics Control Module J526 is monitored by Bluetooth Antenna R152.

If an interruption in the connection to Bluetooth Antenna R152 occurs, the Diagnostic Trouble Code *(DTC)* "Bluetooth antenna — no signal / no communication" is stored in DTC memory.

In the measuring value blocks the portable devices that are connected to the master control module can be shown in detail:

– Number of devices

– Device number

– Field strength of the radio connection

In the adaptation of the Bluetooth master, the Bluetooth function can be turned ON or OFF. This may be necessary during air transport of the vehicle or operation of the vehicle in a country that does not allow the use of Bluetooth frequencies.

Appendix A

The following appendices include additional information that, while not strictly necessary for understanding and troubleshooting data bus systems, further details the way CAN-bus systems exchange and process information. These sections provide an opportunity for additional study and a broader understanding of the electronic functions that determine CAN-bus operation.

Please keep in mind that not all components shown may be installed on vehicles for the North American market. They are shown to provide you with an idea of the components that are in use world-wide from the Volkswagen Concern.

Appendix A

Networking Principle

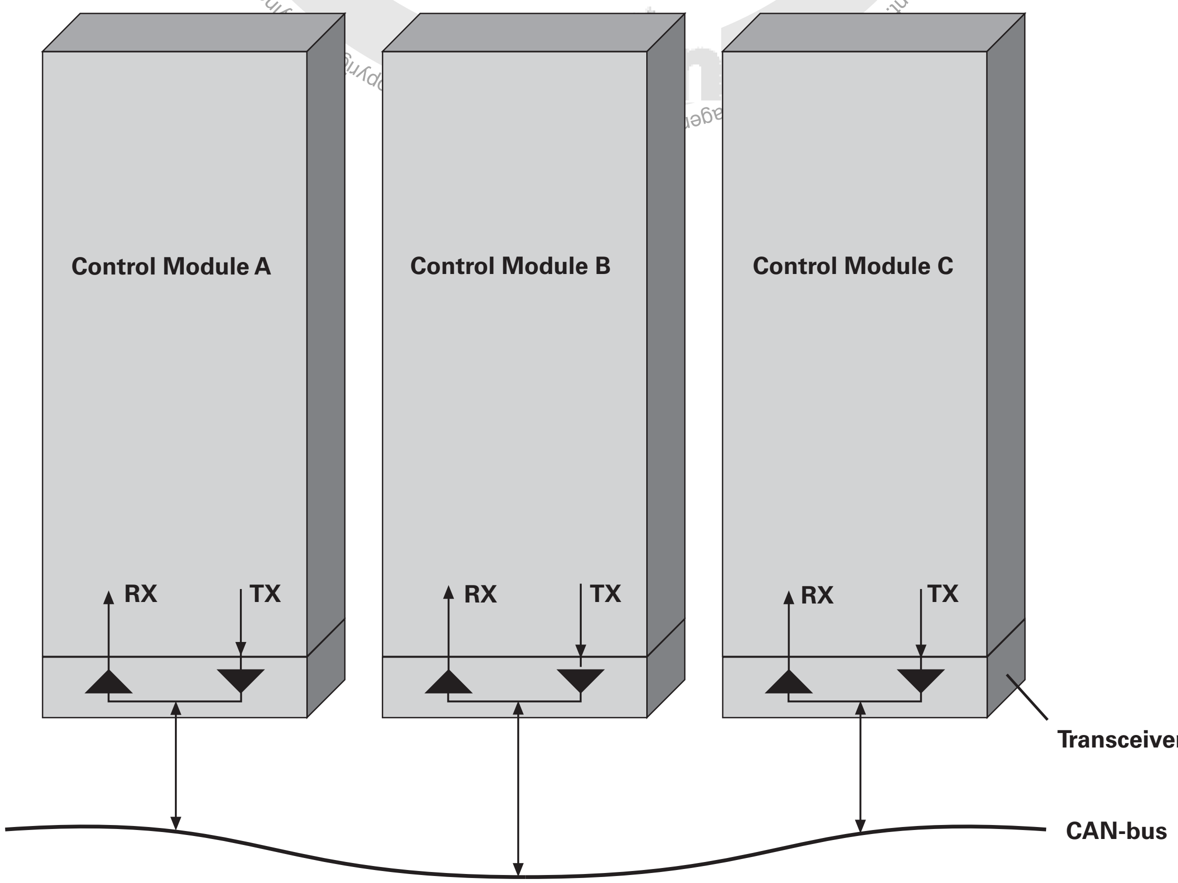
The basic CAN-bus system includes several control modules. They are connected in parallel to the bus line by transceivers. This means that the same conditions apply to all stations. In other words, all the control modules are handled equally, and none has any preference. In this context, this is called *multimaster* architecture.

Information is exchanged serially *(in series)*.

With the exception of the Drivetrain CAN-bus in Volkswagen products, the CAN-bus is designed to be fully functional with a single line. However, in most applications a second wire is provided. The second line is used for signals traveling in reverse order. External interference can be suppressed more effectively by reversing the signals.

Note

To explain the basic principle of data transmission in a simpler way, we will assume a single bus line in the following examples.

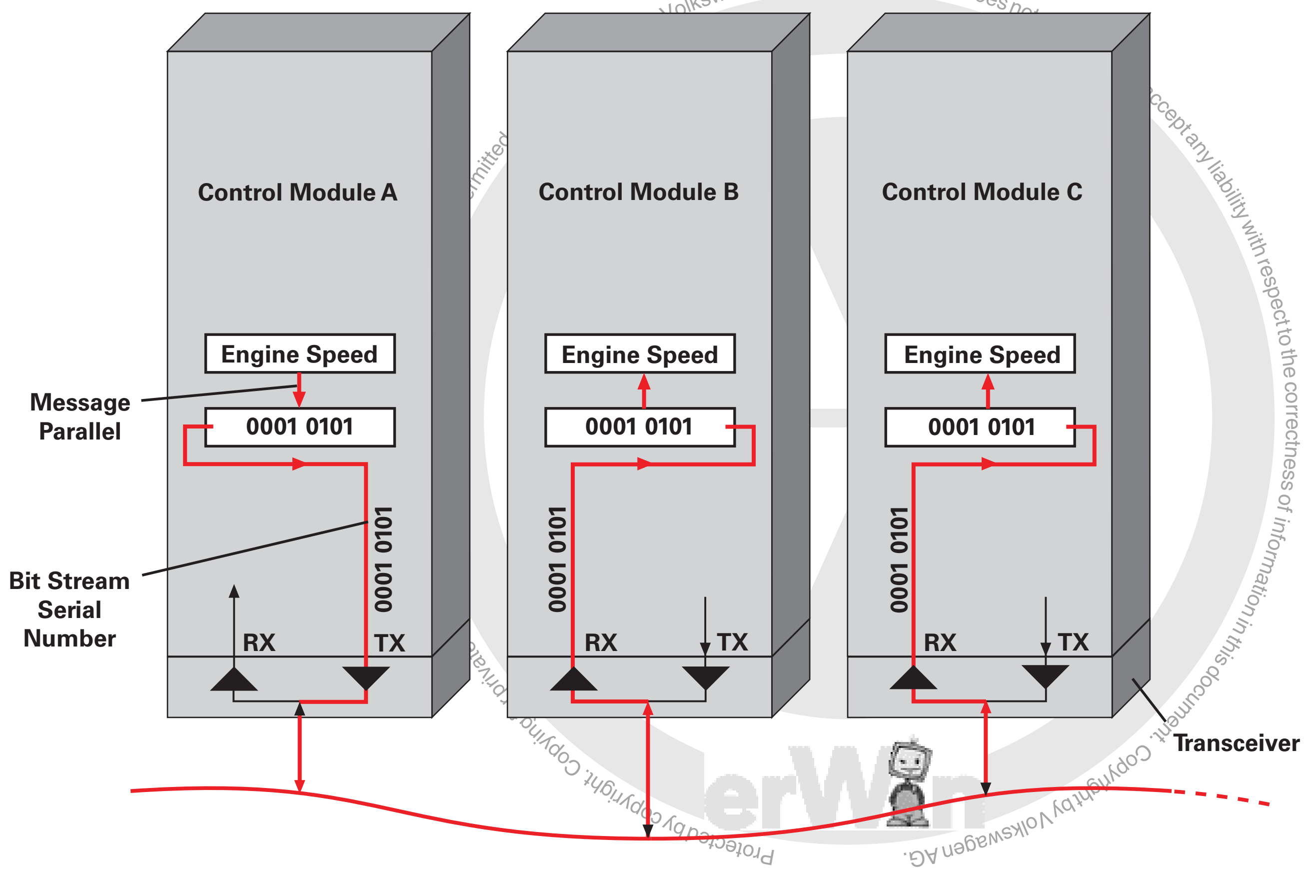


Rx = receive line

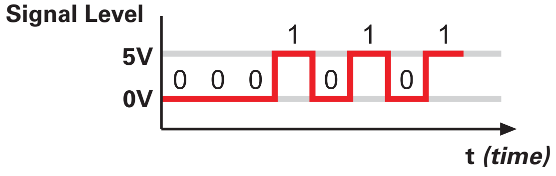
Tx = transmit or send line

Example of Message Exchange on the CAN-bus
(Broadcast Principle)

Electrical Signal Transmissions — One Sends, All Receive



Electrical Signal Transmission in Chronological Sequence



Appendix A

Functional Units

Control Module

The control module receives signals from sensors, processes them, then passes them on to the actuators. The main components of a control module are: a microprocessor with input and output memory, and program memory.

Sensor signals received by the control module, such as engine temperature or engine speed, are interrogated at regular intervals and stored in the input memory in order of occurrence. In the illustration that follows, this principle is represented as a mechanical input selector switch.

The microprocessor links the input values based on program configuration. The results of this process are stored in each output memory and from there they are sent to each of the actuators. In order to process CAN messages, each control module has an additional CAN memory area for received and sent messages.

CAN Controller

The CAN controller controls the data transfer process for CAN messages. It is divided into two sections, the receive section and the send section.

The CAN controller is connected to the control module through the receive mailbox or the send mailbox. It is normally integrated into the chip of the control module microprocessor.

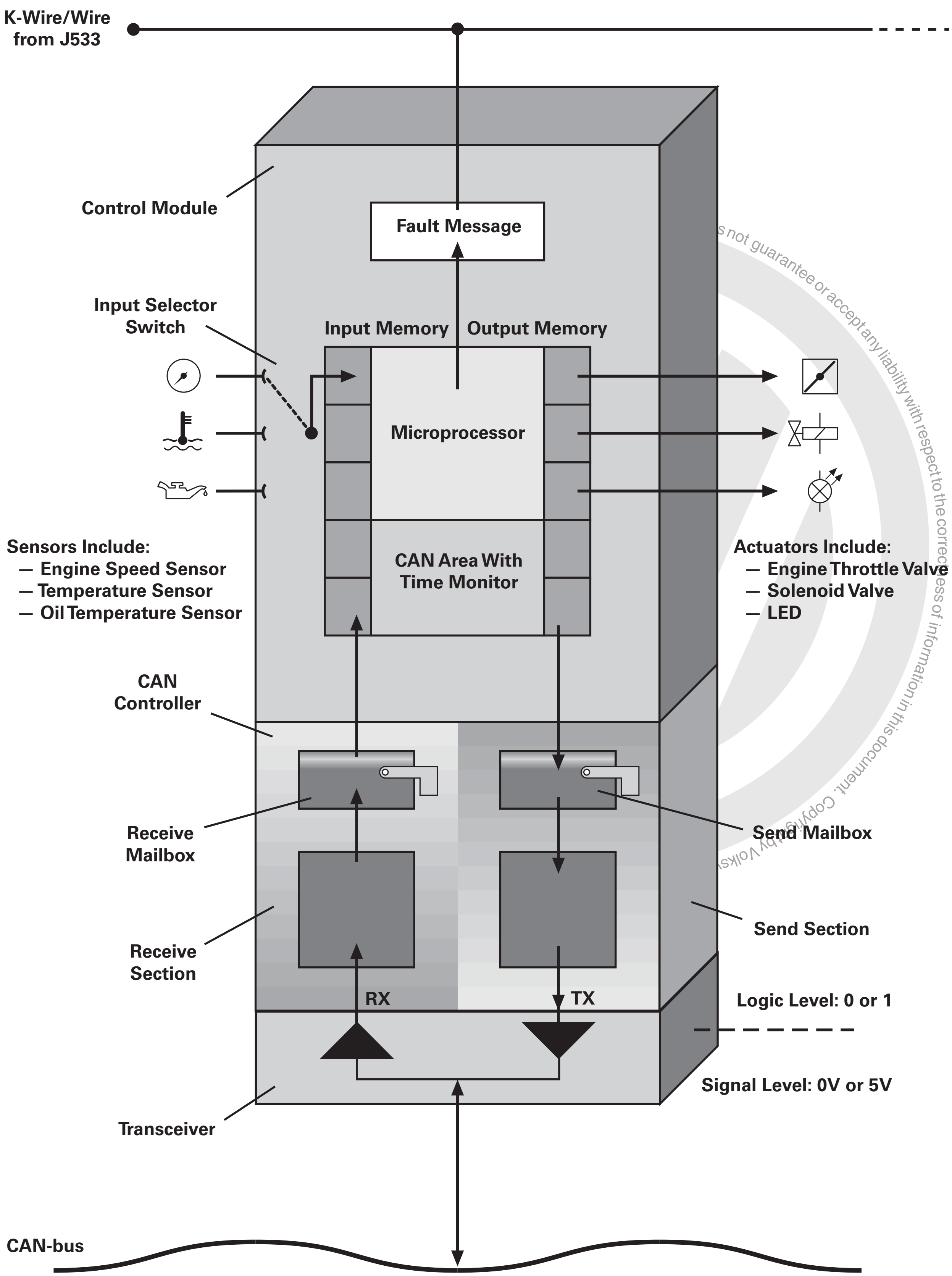
Transceiver

The transceiver is a transmitter and receiver amplifier. It converts the serial bit stream *(logic level)* of the CAN controller into electrical voltage signals *(line level)* and vice versa. The electrical voltage signals are designed for sending over copper wires.

The transceiver is connected to the CAN controller through the TX line *(transmit or send line)* or through the RX line *(receive line)*.

The RX line is directly connected to the CAN-bus and permits continuous monitoring of bus signals.

Functional Units: Control Module, CAN Controller and Transceiver



Appendix A

Special Features of Transceiver

A special feature is the connection of the TX line to the bus. It is normally connected through an open connector.

This results in the possibility of two different states on the bus line.

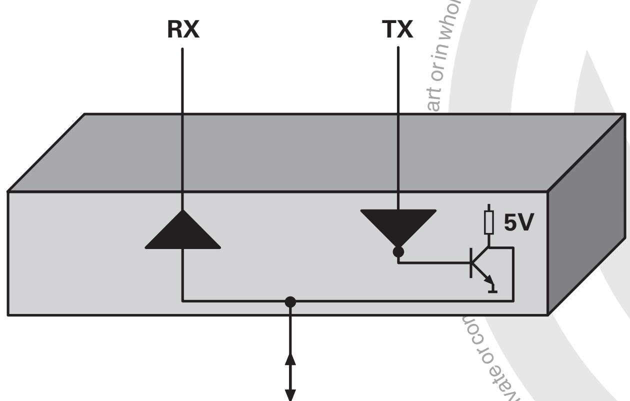
State 1: Inhibited state, transistor inhibited *(switch open)*

Passive: Bus level = 1, high resistance through resistor

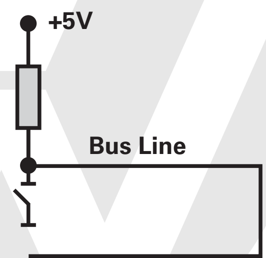
State 0: Switch-through state, transistor switched through *(switch closed)*

Active: Bus level = 1, low resistance without resistor

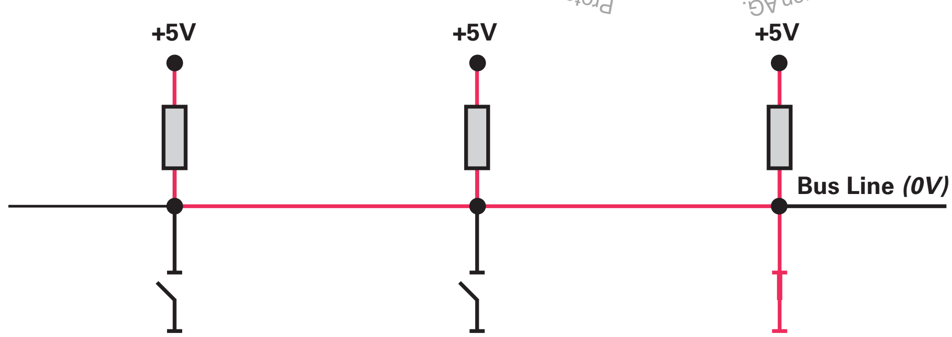
Transceiver with Connection to TX Line



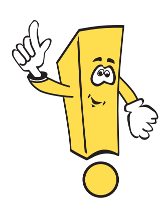
Block Diagram with One Switch



Networking Principle



Note



Switch open means "1" *(passive)*; switch closed means "0" *(active)*.

Three Transceivers Connected to a Common Bus Line *(Transceiver C Active)*

Three transceivers connected to bus line results in the following possible switch positions. The highlighted row shows the previous example *(transceiver C active)*:

Transceiver A	Transceiver B	Transceiver C	Bus Signal
1	1	1	1 *(5V)*
1	1	0	0 *(0V)*
1	0	1	0 *(0V)*
1	0	0	0 *(0V)*
0	1	1	0 *(0V)*
0	1	0	0 *(0V)*
0	0	1	0 *(0V)*
0	0	0	0 *(0V)*

Response:

– If any switch is closed, current flows across the resistor. A voltage of 0V is generated on the bus line.

– If all switches are open, no current flows. No voltage drops across the resistor. A voltage of 5V is generated on the bus line.

In practical terms, this means that if the bus is in state 1 *(passive)*, any other station can overwrite this state with state 0 *(active)*. The passive bus level is called *recessive*; the active bus level is called *dominant*.

This relationship is important in the following situations:

a) For signaling transmission faults *(fault messages about error frames)*

b) Collision detection *(if several stations want to send simultaneously)*

Appendix A

Data Transfer Process

Example

This example describes the complete process for exchanging engine speed information from detection through to display by the tachometer. It explains the chronological sequence of the data transfer process and the interaction between the CAN controllers and the control modules.

First, the engine control module detects the engine speed value. This value is stored in the microprocessor input memory at regular intervals *(cyclically)*. Since the present engine speed value is also required for other control modules, it has to be sent over the CAN-bus.

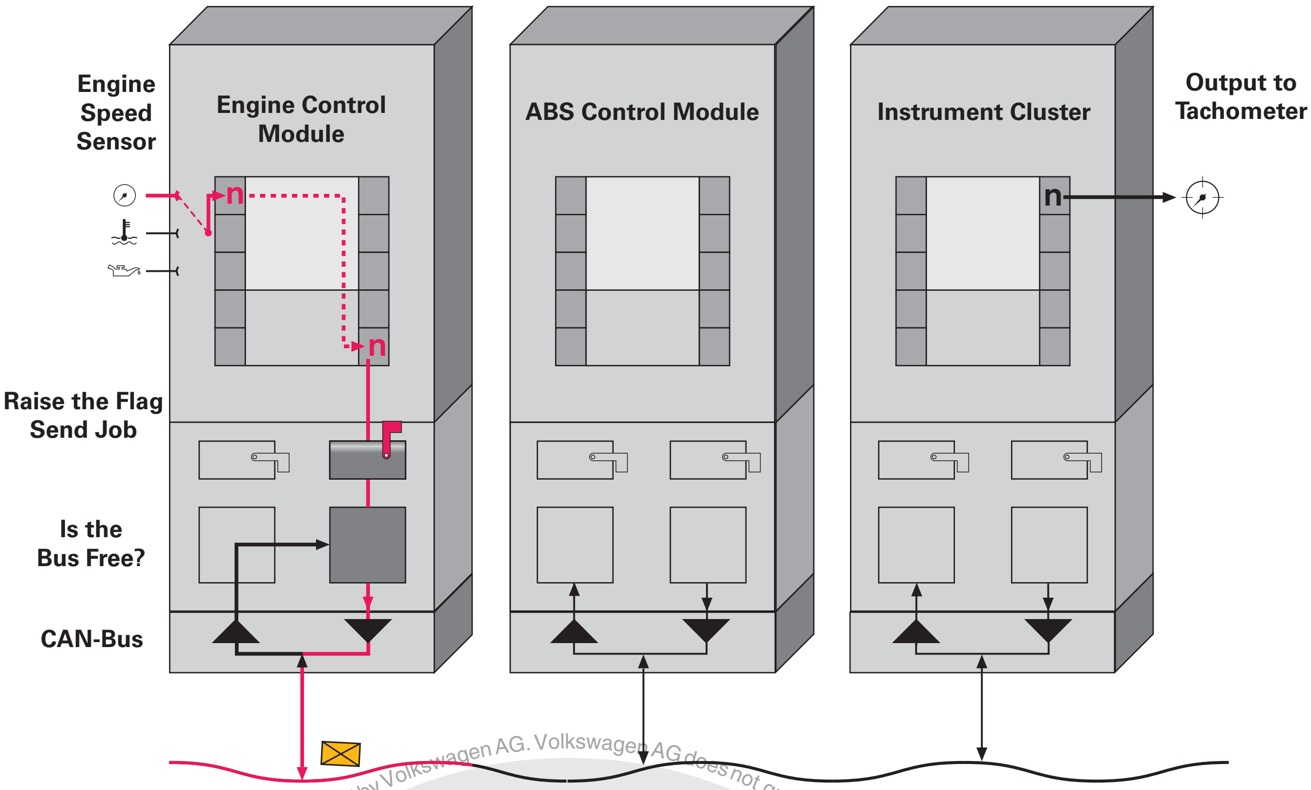
The engine speed value is first copied to the output memory of the engine control module.

From there, the information goes to the send mailbox of the CAN controller. If a current value is located in the send mailbox, it is indicated by the send flag *(the flag is raised)*. Once the message is sent to the CAN controller, the engine control module has completed its part of the process.

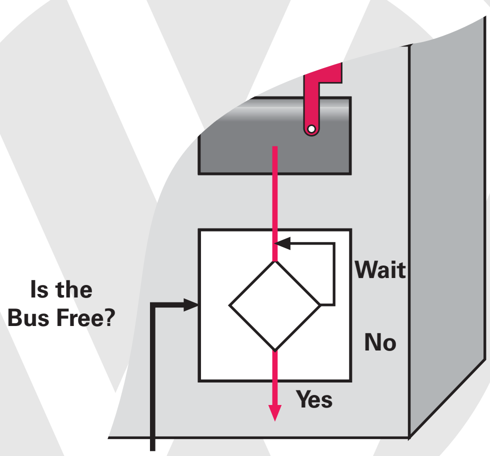
The engine speed value is first converted into a message with a CAN-specific form in accordance with the protocol. The main components of a protocol are shown below.

The CAN controller then checks, through the RX line, whether the bus is active *(whether information is in the process of being exchanged)*. If necessary, it waits until the bus is free *(level 1, passive, for a specific period)*. If the bus is free, the message is sent.

Sending Process



Detail Showing the Interrogation Format for "Is the Bus Free?"



Appendix A

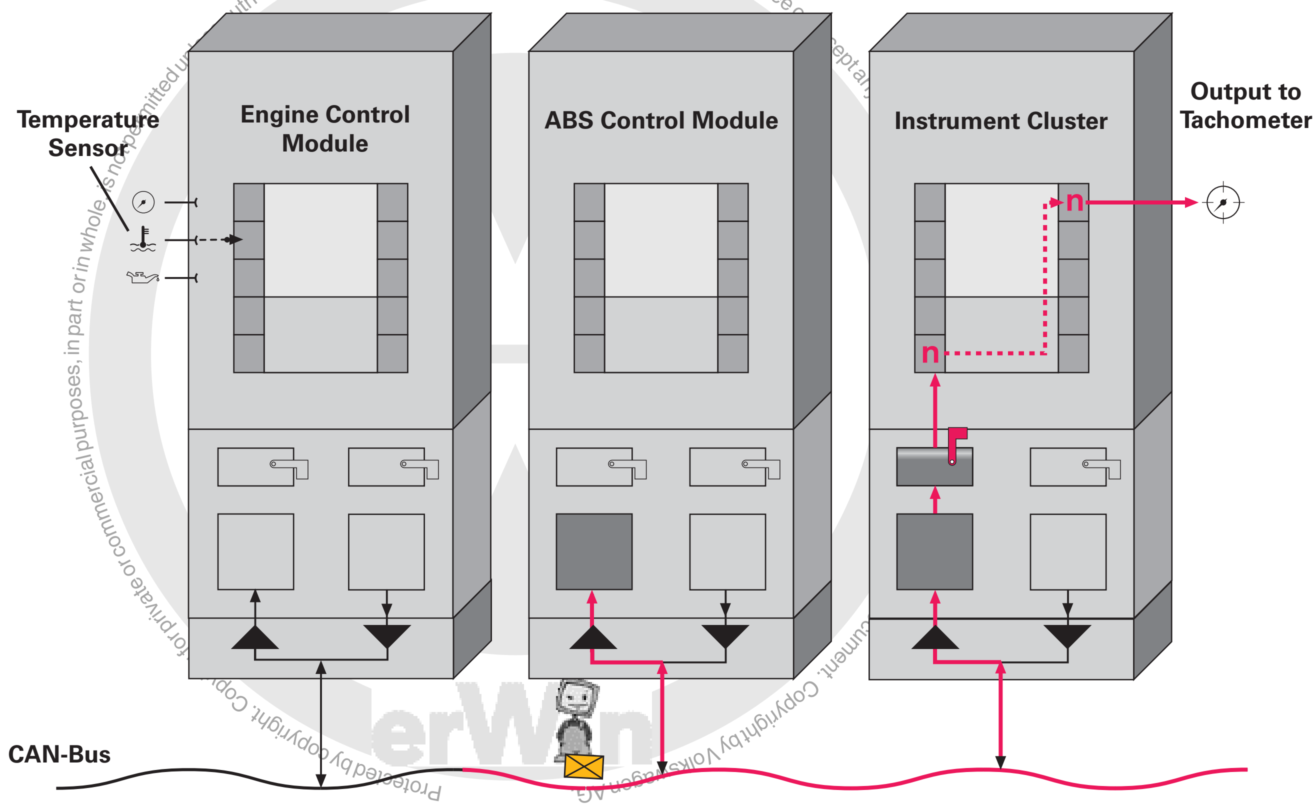
Receiving Process

The receiving process consists of two steps:

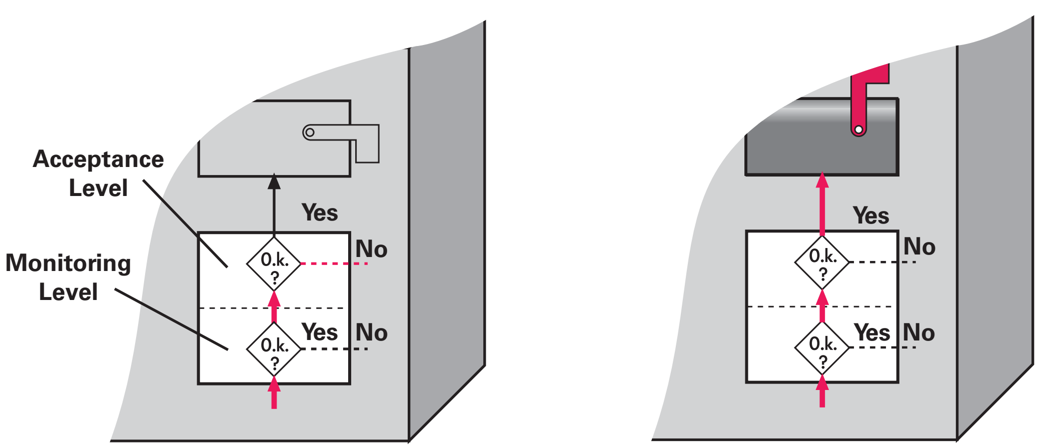
– Step 1 = Check messages for errors
  (at monitoring level)

– Step 2 = Check message for usability
  (at acceptance level)

All connected stations receive the message sent by the engine control module. It travels over the RX lines to the receiving areas of the CAN controllers.



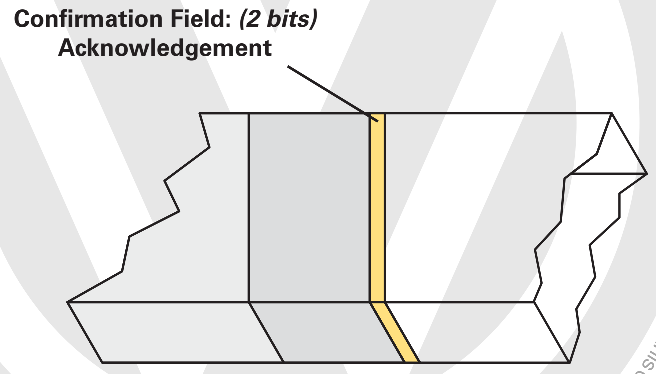
Detail Showing the Receiving Area, with Monitoring and Acceptance Levels



At this point, the CAN controllers have all received the engine message and have checked it for correctness at the associated monitoring level. This helps to detect local faults that may occur in only one control module under certain circumstances. This results in the high data density mentioned before.

All connected stations receive the message sent by the engine control module *(broadcast)*. Using the CRC check value from the Safety field, they can detect whether any errors have occurred in the data transfer. CRC is an acronym for Cyclic Redundancy Check. When a message is sent, a 16-bit check value is generated from all the bits and included in the transfer. The receivers calculate the check value from all the bits received using the same protocol. Then the received check value is compared with the calculated check value.

If no error is found, all the stations send an acknowledgement to the transmitter confirming correct reception.



Finally, the correctly received message goes to the receive sections of the associated CAN controllers.

– There a decision is made as to whether the message is necessary for the function of the related control module

– If not, the message is discarded

– If so, the message is placed in the receive mailbox

When the *receive* flag has been raised, the connected instrument cluster knows that a current message has arrived for processing. The instrument cluster calls the message and copies the value to its input memory.

This concludes the sending and receiving of a message through the CAN controllers.

– After the microprocessor in the instrument cluster processes the engine speed value, the value is sent to the actuator and then to the tachometer

– Data exchange of a message is repeated depending on the cycle time setting *(for example, every 10 ms)*

Appendix A

Simultaneous Sending Attempts by Multiple Control Modules

If several control modules attempt to send messages at the same time, there would be a data collision on the data bus line. To avoid this, the CAN system uses the following strategy:

– Every active control module starts its send process by sending an identifier *(in the Status field)*

– All the control modules monitor data bus traffic by monitoring the bus on their RX *(receive)* line

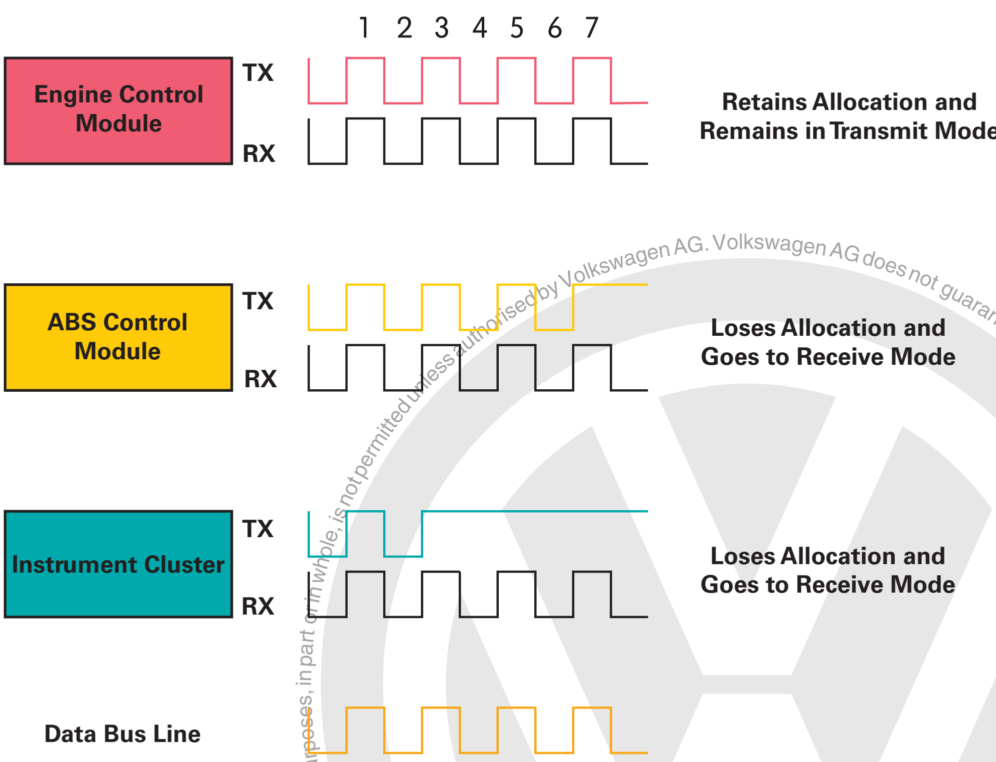
– Every sender compares the state of the TX line bit-by-bit with the state of the RX line to note any differences

The CAN strategy regulates this situation in the following way: the control module whose TX signal was over-written by a zero must withdraw from the bus.

– Message weighting is controlled by the number of leading zeroes in the identifier, to ensure that messages are sent in the order of their priority

– The lower the number in the identifier, the more important the message

– This procedure is called arbitration, from the word arbiter, meaning referee or judge



In the next example, the Steering Angle Sensor has the highest priority when several control modules attempt to send data simultaneously. The Steering Angle Sensor has the smallest number in the Status field *(mainly leading zeroes)*, so the Steering Angle Sensor's message is sent first.

Identifier	**Binary**	**Hex**
Engine_1	0 1 0 _ 1 0 0 0 _ 0 0 0 0	2 8 0
Brake_1	0 1 0 _ 1 0 1 0 _ 0 0 0 0	1 A 0
Inst. Cluster_1	0 1 1 _ 0 0 1 0 _ 0 0 0 0	3 2 0
Steering angle_1	0 0 0 _ 1 1 0 0 _ 0 0 0 0	0 C 2
Transmission_1	1 0 0 _ 0 1 0 0 _ 0 0 0 0	4 4 0

Conclusion When Sending Sensor Values
(Example: Engine Speed)

Due to the high level of transmission protection in the CAN-bus system, errors such as electrical faults or interruptions in the CAN-bus are reliably detected.

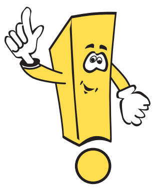
– The engine speed of 1800 rpm is sent correctly, or not sent at all if a fault occurs *(with no display, the tachometer shows "0")*

– For example, if there is an implausible indication of engine speed, the cause may not lie with the data transfer *(CAN-bus)* but with a defective sensor, sensor circuit, or display

Appendix A

CAN Transceiver

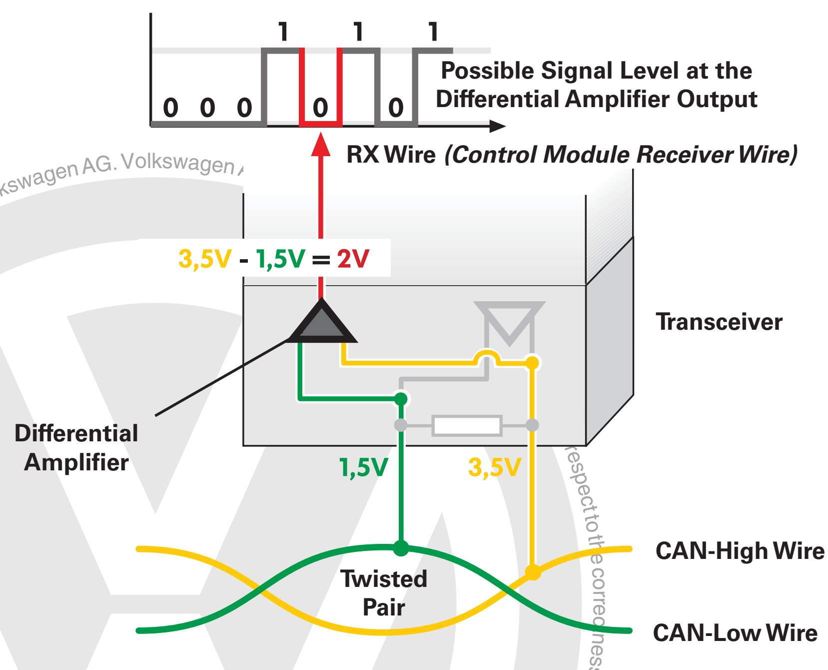
Note The following information describes how the transceiver works, using the Drivetrain CAN as an example.



Each control module is connected to the CAN-bus through a transceiver. Within the transceiver is a receiver or differential amplifier installed on the receiver side. The differential amplifier is responsible for evaluating the input signals from CAN-high and CAN-low *(the voltage difference or differential)* and sending these converted signals to the CAN receiver area of the control module. These converted signals are referred to as output voltage of the differential amplifier.

The differential amplifier determines output voltage by subtracting the voltage of the CAN-low wire *($U_{CAN\ low}$)* from the voltage of the CAN-high wire *($U_{CAN\ high}$)*. In this way, the voltage of the rest state *(2.5 volts on the Drivetrain CAN)* and any other voltage disturbances are removed.

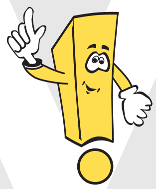
Differential Amplifier of the Drivetrain CAN *(Example)*



Conversion of Signals in the Differential Amplifier

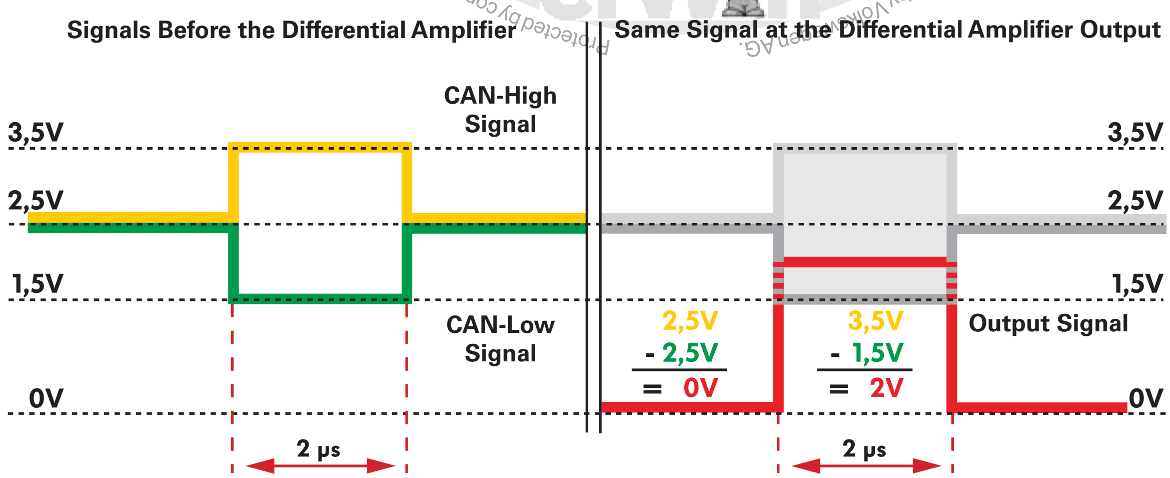
For evaluation in the differential amplifier of the transceiver, the voltage present in the CAN-low wire is deducted from that which is present at the same time in the CAN-high wire.

Note



Unlike the Drivetrain CAN, the Convenience/Infotainment CAN features an intelligent differential amplifier. In order to allow single wire operation, it also evaluates the signals in the CAN-high and CAN-low wire individually.

Evaluation in the Differential Amplifier of the Drivetrain CAN *(Example)*



Appendix A

Filtering Out Disturbances in the Differential Amplifier

Since the data bus wires are routed through the engine compartment, they are subject to different types of electro-magnetic interference. Short circuits to Ground or battery positive *(+)* voltage, overload from the ignition system, and static discharge should be taken into consideration during repair.

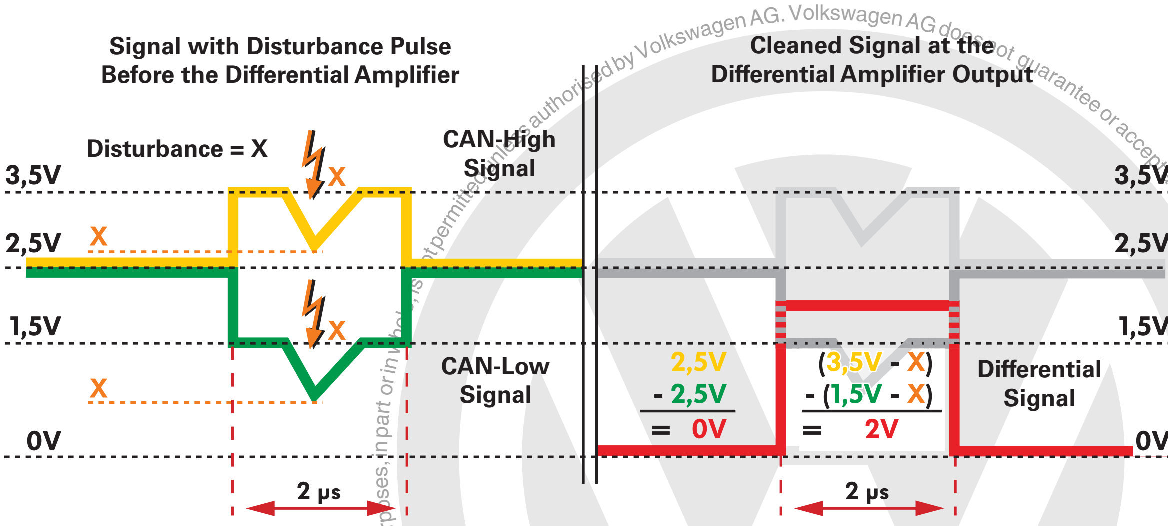
Evaluation of the CAN-high and CAN-low signals in the differential amplifier, using what is known as differential transfer technology, means that the effects of disturbances are practically eliminated.

Another advantage of differential transfer technology is the fact that fluctuations in the on board power supply *(when the engine is started, for example)* do not affect the transfer of data to individual control modules, increasing transfer security.

The effect of this type of transfer can be seen in the illustration below. Due to the twisted pair layout of CAN-high and CAN-low wires, a disturbance *("X")* will always have an equal effect on both wires. Since the CAN-low voltage *(1.5 volts – X)* is deducted from the CAN-high voltage *(3.5 volts – X)* by the differential amplifier, the effect of the disturbance is eliminated during evaluation, and no longer affects the differential signal.

(3.5V – X) – (1.5V – X) = 2V

Filtering Out Disturbances in the Differential Amplifier of the Drivetrain CAN *(Example)*



Signal Levels

Amplification of Control Module Signals in the Transceiver

On the sender side, the transceiver is responsible for amplifying the relatively weak signals of the CAN controller in the control module so that the prescribed signal level is reached in the CAN-bus wires and at the control module outputs.

The control modules connected to the CAN-bus respond much the same way as a load resistor on the CAN wires, due to the electrical component installed there. The load resistance depends on the number of connected control modules and their resistance values.

For example, the engine control module places the Drivetrain CAN under 66 Ohms of load between CAN-high and CAN-low. All other control modules load the bus with 2.6 kOhms each. This means there is a total load of 53–66 Ohm, depending on the number of control modules connected. If terminal 15 *(ignition)* is switched OFF, this resistance can be measured between CAN-high and CAN-low using an ohmmeter.

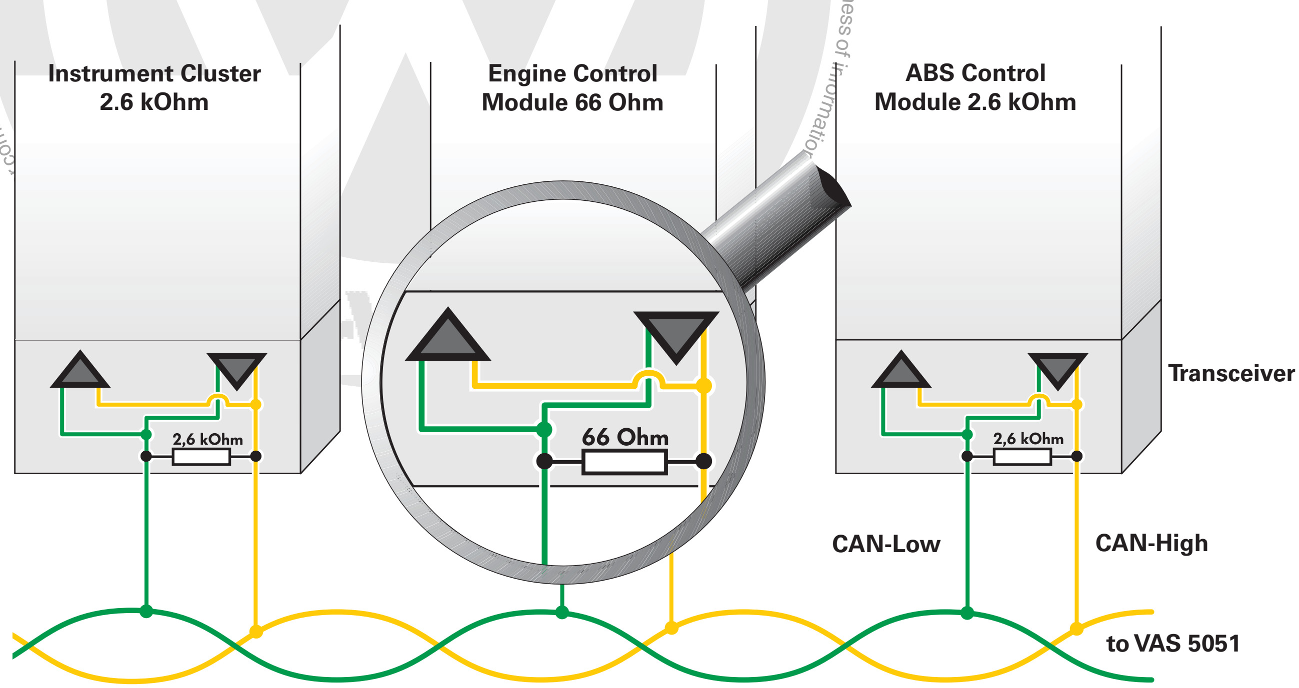
The transceiver sends the CAN signals to both wires of the CAN-bus. In this way, a positive voltage change in the CAN-high wire equates to an equivalent negative voltage change in the CAN-low wire. The voltage change in one CAN wire is at least 1 volt in the Drivetrain CAN, and at least 3.6 volts in the Convenience/Infotainment CAN.

Appendix A

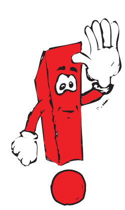
In contrast to the data bus in its basic form, with two matching resistors at both ends of the data bus, Volkswagen uses decentralized matching resistors with a central matching resistor in the engine control module, and high-ohm resistors in the other control modules. The result is stronger reflections, though these do not have negative effects due to the short data bus lengths in the vehicle.

A special feature of the Convenience/Infotainment CAN is that the load resistors in the control modules no longer lie between CAN-high and CAN-low, but between the respective wire and 5 volts or Ground. If the ignition is switched OFF, the load resistors are also switched OFF, which means that these can no longer be measured using an ohmmeter.

Load Resistance in the CAN-High and CAN-Low Wires



Important!



Even for purposes of testing, Drivetrain CAN lines should not be extended by more than 16 ft *(5m)*.

Data Transfer Protection

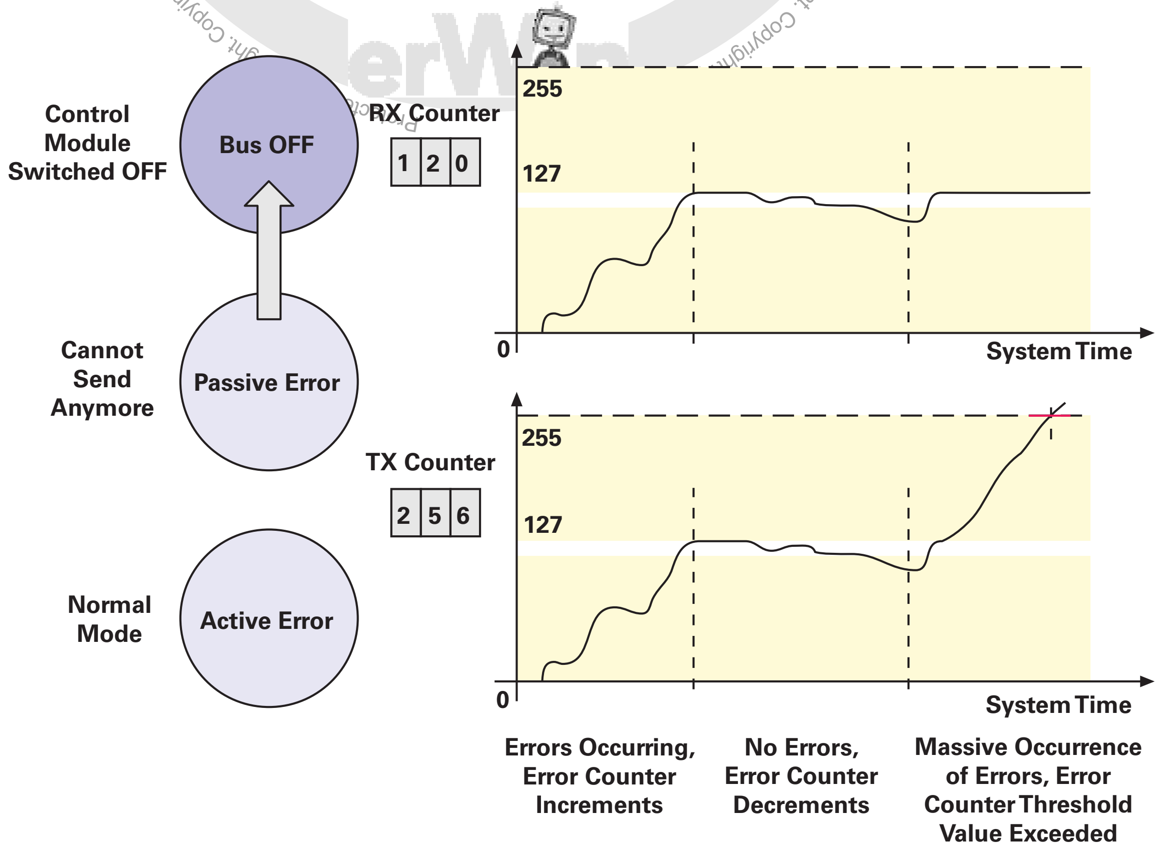
Internal Error Management

To ensure a high level of data protection, the CAN-bus system has an extensive integrated error management system, capable of detecting any data transfer errors with a high degree of certainty so that corrective action can then be taken. The rate of undetected errors, what is known as residual error probability, is less than four errors over the lifespan of the vehicle.

Using the broadcast concept *(one sends, all receive, and evaluate)*, any network user detecting an error immediately notifies all other users by sending an error message. The current message is then rejected by all users.

After the error message, the original data message is automatically sent again. This process is completely normal and may be caused by major voltage fluctuations in the on board power supply *(on engine start or due to strong external interference, for example)*.

The situation is more critical if repeated messages become more frequent due to continuously detected errors. In this case, every station has an integrated error counter that increments detected errors and decrements once the repeat message has been sent.



Appendix A

The internal error counter is responsible for internal error management and these values cannot be read.

If the preset threshold value is exceeded *(equivalent to max. 32 repeated messages)*, the affected control module is informed and is switched OFF by the CAN-bus. After this happens twice *(without any intermediate communication)*, a malfunction is stored in DTC memory.

After a fixed waiting time *(approximately 0.2s)*, the control module attempt to communicate with the bus again.

Message traffic is normally cyclical with prescribed cycle times to ensure that the messages are transferred within good time. If there are delays, it means that at least 10 messages are not received and this triggers the message time-out.

This causes a malfunction to be stored in the DTC memory of the receiving control module. This is the second element of the error management system. The following error messages are available for in-service diagnosis:

1 “Data bus defective”

- Fatal errors were detected in the affected control module
- The control module disconnected at least twice from the bus *(bus OFF)*

2 “Missing messages from ...” or “No communication with ...” the affected control module

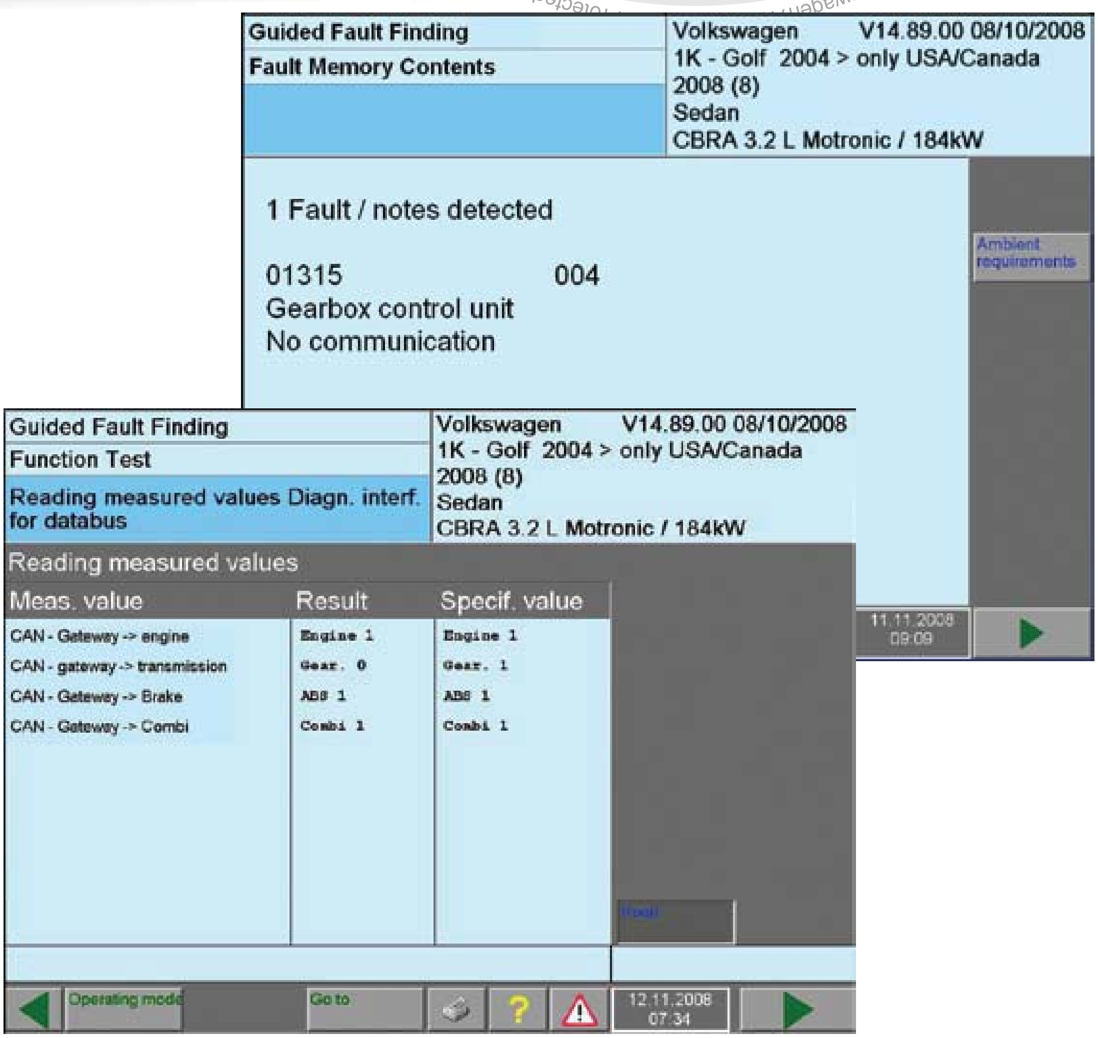
- Messages are not received in good time; time-out monitor responded

Diagnostic Information

Example: Transmission Communication Fault

The transmission data is sent incorrectly, or not sent at all if there is a fault *(value not displayed)*. In this case, the Scan Tool sends notification that there is a malfunction in the CAN-bus system.

If there is an indication of implausible signals, the cause may not lie with the data transfer *(CAN-bus)*, but with a defective sensor, sensor circuit or display.



Appendix A

If there is a malfunction in the CAN-bus system, the VAS Scan Tool indicates a general fault message indicating which component is defective.

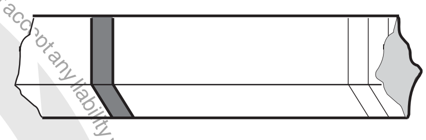
To localize errors, data blocks 125, 126 can be read from the active state gateways of the control modules connected to the CAN-bus *(1 = active, 0 = passive)*.

If necessary, further electrical measurements *(signal testing using the oscilloscope, for example)* may be required.

Appendix B

Data Bit Explanation

The **start field** marks the state of the data protocol. A bit with approximately 5 volts *(depending on system)* is sent over the CAN-high line and a bit with approximately 0 volts is sent over the CAN-low line.

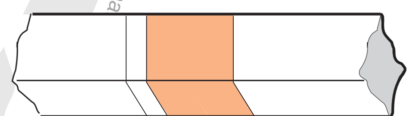


SSP 186/09

The **status field** defines the level of priority of the data protocol. If, for instance, two control modules want to send their data protocol simultaneously, the control module with the higher priority takes precedence.

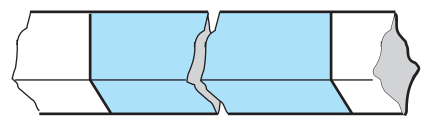
SSP 186/10

The **check field** displays the number of items of information contained in the data field. This field allows any receiver to check whether it has received all of the information transferred to it.



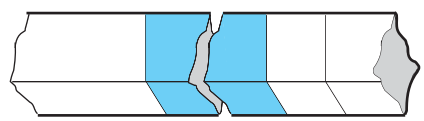
SSP 186/11

In the **data field**, information is transferred to the other control modules.



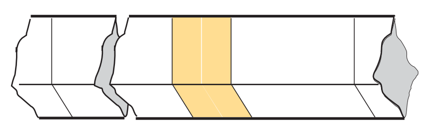
SSP 186/12

The **safety field** detects transfer faults.



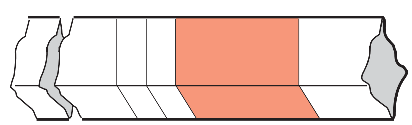
SSP 186/13

In the **confirmation field**, the receivers signal to the transmitter that they have correctly received the data protocol. If an error is detected, the receivers notify the transmitter of this immediately. The transmitter then sends the data protocol again.



SSP 186/14

The **end field** marks the end of the data protocol. This is the last possibility to indicate errors which lead to a repeat transfer.



SSP 186/15

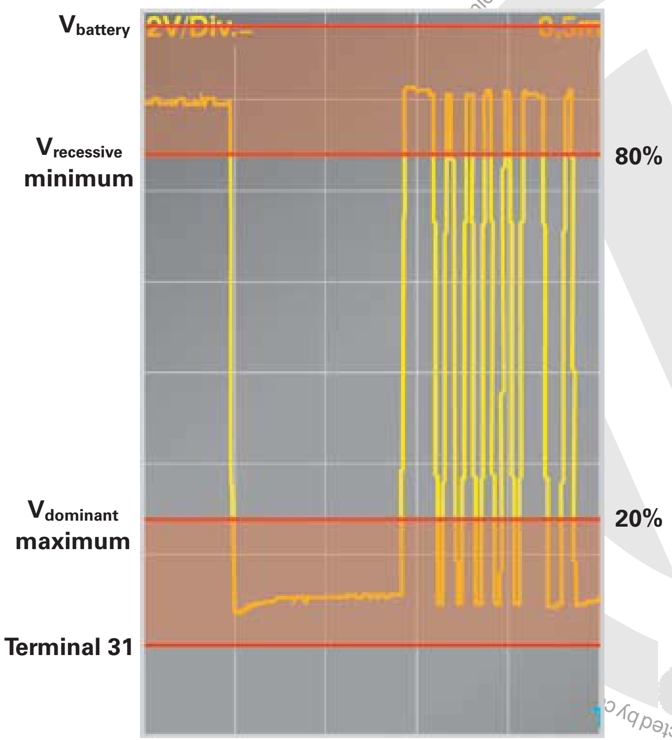
Appendix C

Transmission Reliability

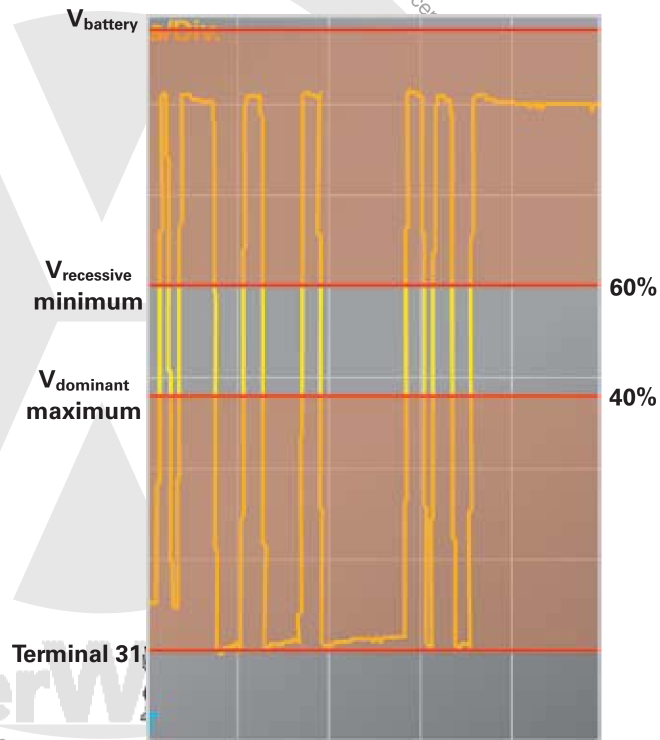
By specifying tolerances for transmitting and receiving within the range of recessive and dominant levels, a stable data transfer is assured.

To be able to receive valid signals in spite of interference radiation, the specified voltage ranges are higher on the receiving side.

Voltage Range for Receiving



Voltage Range for Receiving



Messages

Message with Slave Answer

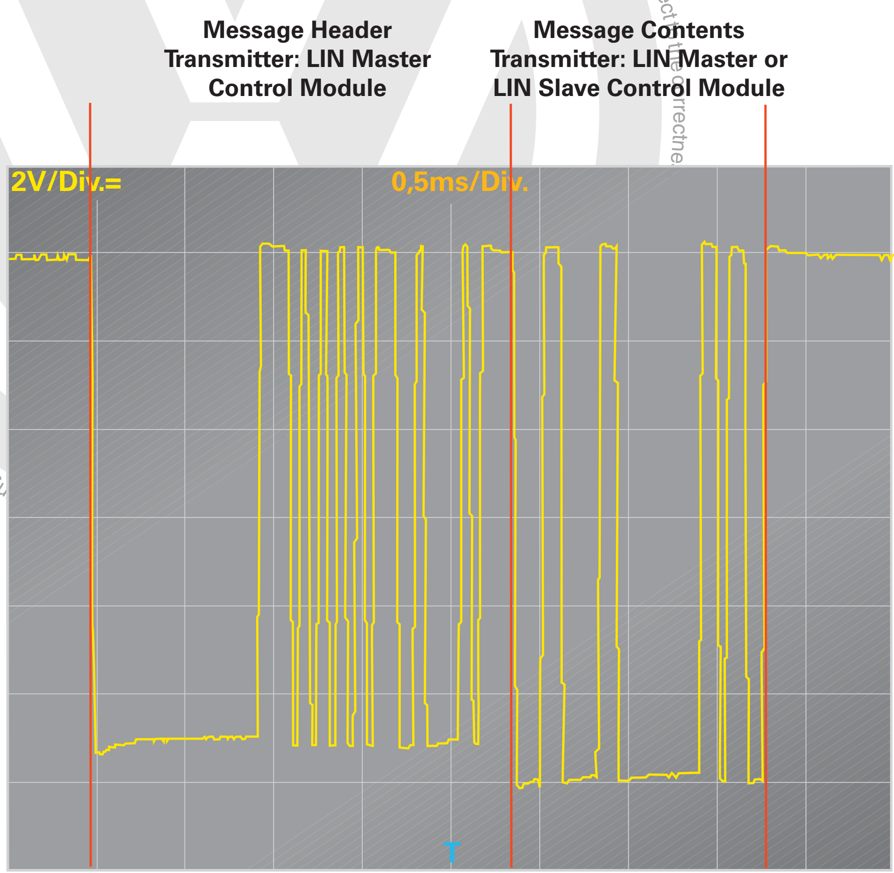
In the message header, the LIN master control module requests information such as switch conditions or measuring values from a LIN slave control module.

The LIN slave control module sends the information back to the LIN master control module in response.

Message with Master Instructions

Using an identifier in the message header, the LIN master control module can also request that the LIN slave control module process the data contained in its response.

The LIN master control module processes the data and sends the response.



Appendix C

Message Header

The LIN master control module transmits the header in cycles. The header can be subdivided into four sections:

– Synchronization break

– Synchronization delimiter

– Synchronization field

– Identifier field

The **synchronization break** *(synch break)* is at least 13 bits long. It is sent with the dominant level.

The length of 13 bits is necessary to clearly inform the LIN slave control modules about the start of a message.

In the succeeding messages, a maximum of 9 dominant bits are transmitted one after the other.

The **synchronization delimiter** *(synch delimiter)* is at least 1 bit long and recessive *(~$V_{battery}$)*.

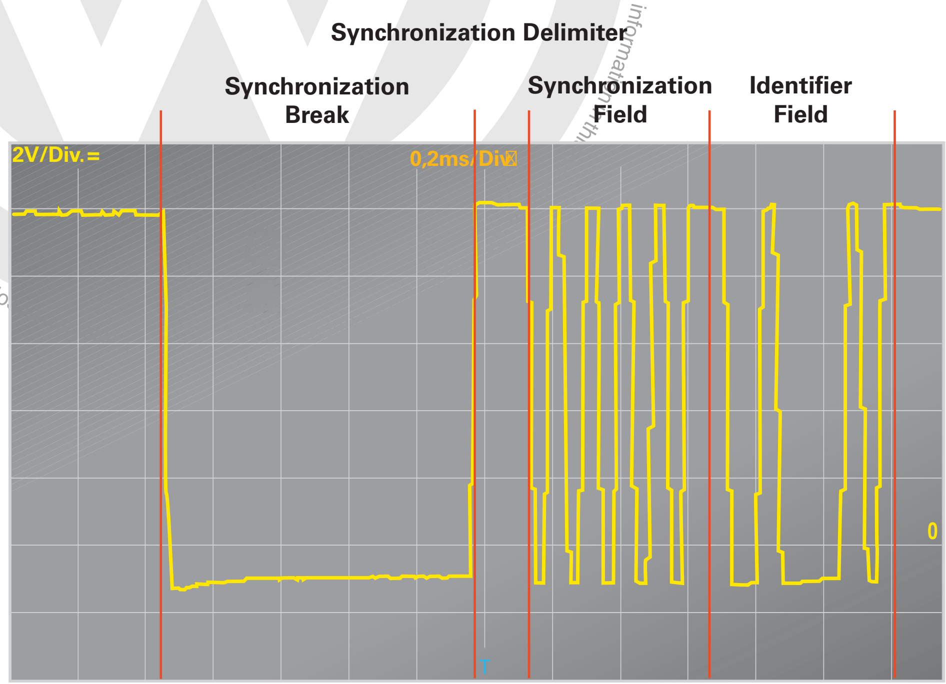
The **synchronization field** *(synch field)* consists of the bit rate 0 1 0 1 0 1 0 1 0 1.

Because of this bit rate, all LIN slave control modules can adapt to or synchronize with the system cycle of the LIN master control module.

The synchronization of all control modules is necessary for an error-free data exchange. Loosing the synchronization would cause the insertion of the bit values into the message at the receiving end. This would lead to errors in the data transfer.

The **identifier field** is 8 bits long. The first 6 bits contain the message identification and the number of data fields of the response. The number of data fields in the response may be between 0 and 8.

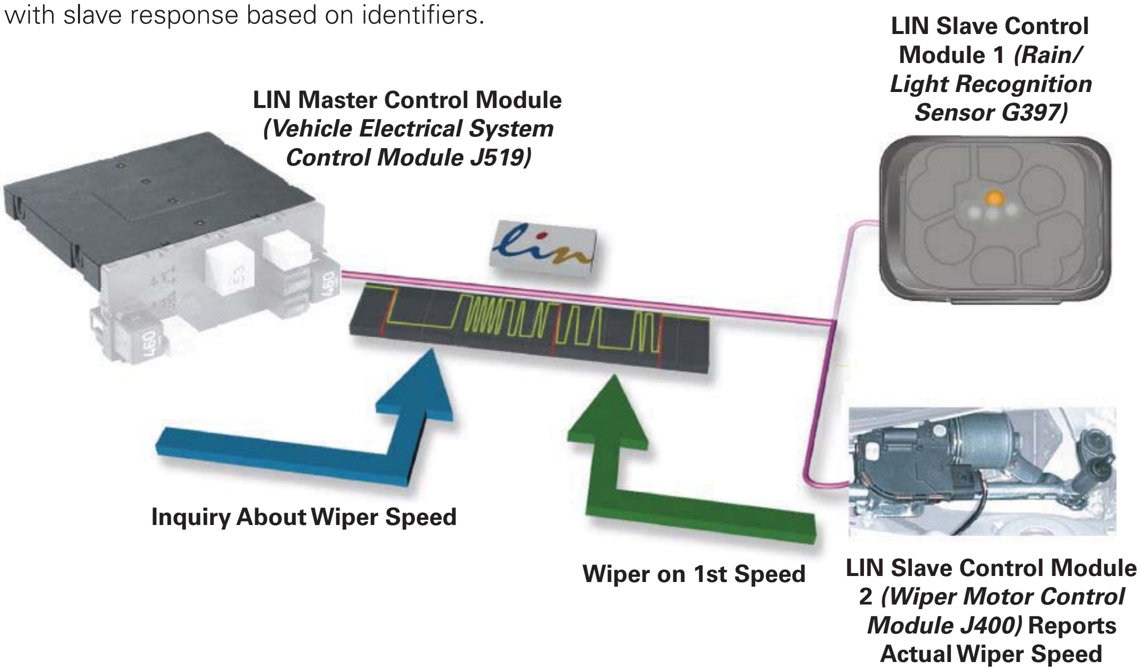
The last 2 bits contain the check-total of the first 6 bits for the identification of transmission errors. The check total is necessary to avoid the assignment of the identifier to a wrong message in case of a transmission error.



Message Contents *(Response)*

The LIN slave control module adds information to a message with slave response based on identifiers.

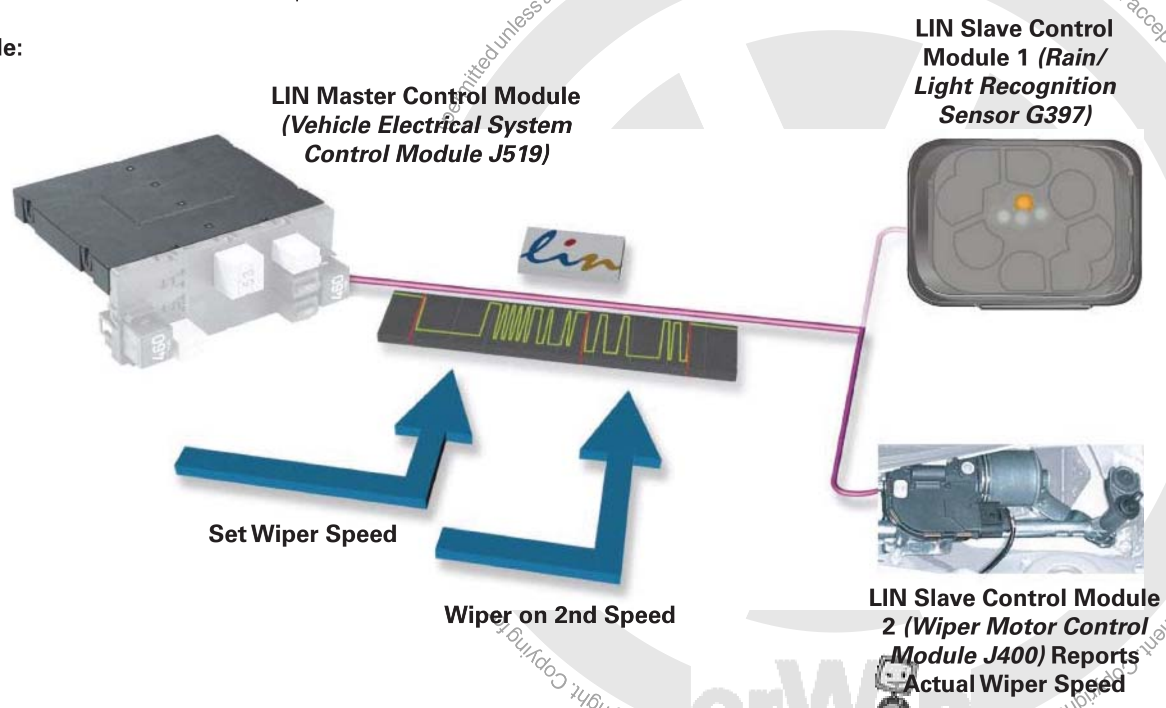
Example:



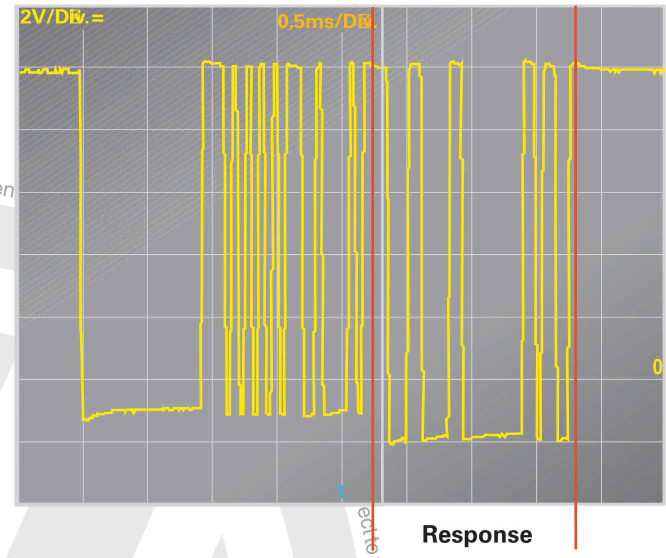
For a data request message from the master, the master control module adds the response.

Depending on the identifier, the applicable LIN slave control modules use the data to perform functions.

Example:



The response consists of one to eight data fields. One data field consists of 10 bits. Each data field consists of one dominant start bit, a data byte that contains the information, and one stop bit. The start and stop bits are used for the after-synchronization to avoid transmission errors.



Sequence of Messages

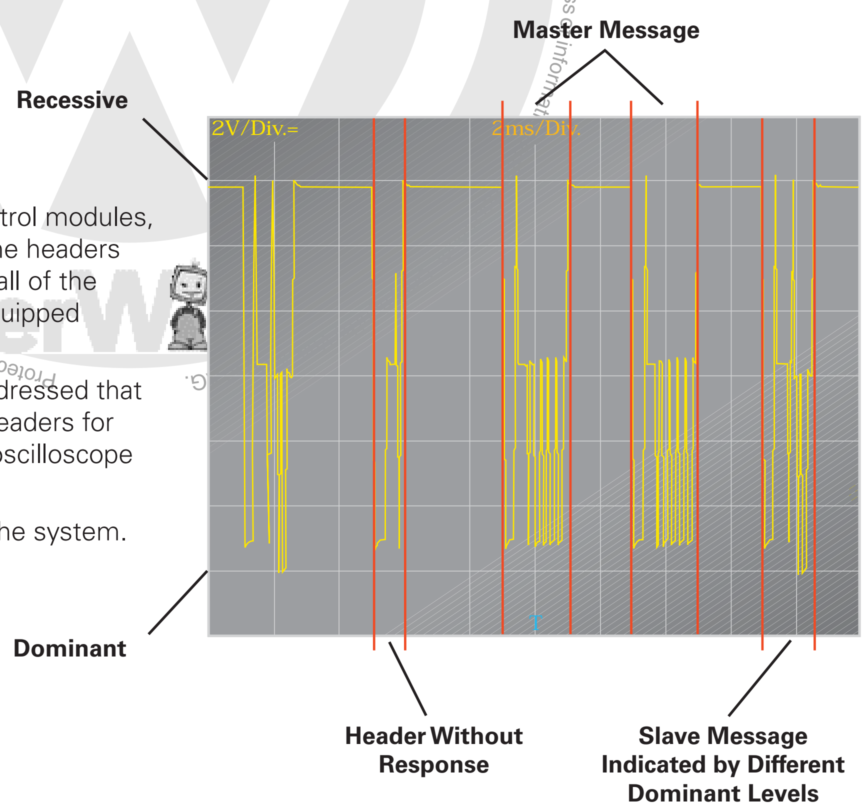
The LIN master control module sends the headers as well as the responses to master messages on the LIN data bus according to a specified sequence and cycle.

Information that is used frequently is sent frequently.

The sequence of the messages can change depending on the prevailing conditions of the LIN master control module.

Example of prevailing conditions:

- Ignition ON or OFF
- Diagnostics active or inactive
- Parking lights ON or OFF



To reduce the variety of LIN master control modules, the LIN master control module sends the headers through the LIN data bus addressed to all of the applicable control modules for a fully equipped vehicle.

Since there may be control modules addressed that are not installed on a specific vehicle, headers for these messages will be shown on the oscilloscope without responses.

This does not affect the functioning of the system.

Message Frames

The system manager *(Front Information Display Control Head Control Module J523)* transmits message frames to the next control module in the fiber-optic data bus ring at a **duty cycle frequency** of 44.1 kHz.

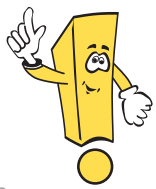
The stability of this duty cycle frequency allows the transmission of *synchronous data* — information such as digital audio and video signals that must always be sent in the same time intervals.

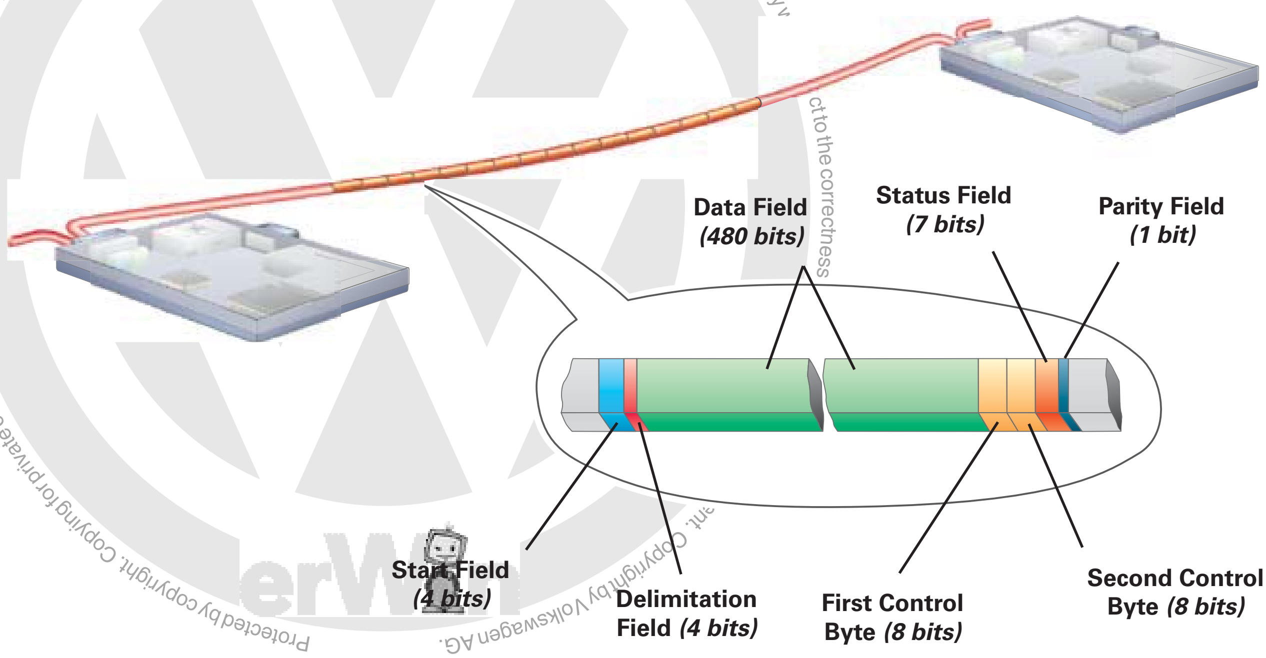
The stable duty cycle frequency of 44.1 kHz corresponds with the transmission frequency of digital audio and video equipment such as CD Changer R41, Video Recorder / DVD Player R129, and Digital Sound System Control Module J525. This allows the integration of such equipment into the MOST fiber-optic data bus system.

Construction of a Message Frame

A message frame is 64 bytes long and subdivided into sections.

Note One byte contains eight bits.





Appendix D

Sections of a Message Frame

The start field, also called the preamble, marks the beginning of a frame. Each frame of a block has its own start field.

A delimitation field is used to clearly separate the start field from the following data fields.

In the data field, the MOST fiber-optic data bus transmits up to 60 bytes of usable data to the control modules.

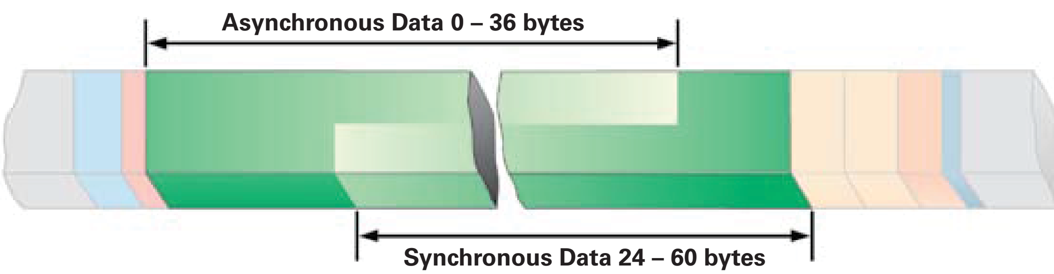
There are two data types in a message frame:

– Sound and video as synchronous data

– Pictures, information for calculation, and text, as asynchronous data

The partition of the data field between the two data types is flexible. The portion of synchronous data in the data field is between 24 and 60 bytes. The transmission of synchronous data has priority over asynchronous data.

Asynchronous data are registered depending on the transmitter and receiver addresses *(identifiers)*, and the available asynchronous portion, in packages of four bytes *(quadlets)* which then sent to the receiver.

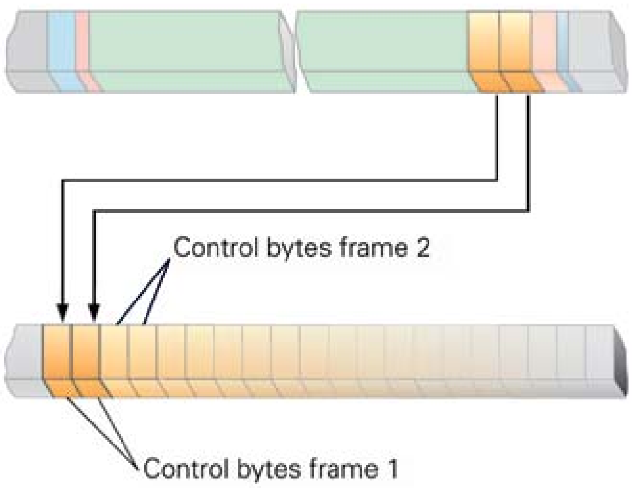


With the two control bytes, the following information is transmitted:

– Transmitter and receiver address *(identifier)*

– Control commands to the receiver *(such as to an amplifier for increasing or decreasing the volume)*

The control bytes of a block are assembled in the control modules to make up a control frame. A block consists of 16 frames. The control frame contains control and diagnostic data for sending the data from one transmitter to a receiver. This is called *address-oriented data transmission*.



Example:

– Transmitter — Front Information Display Control Head Control Module J523

– Receiver — Digital Sound System Control Module J525

– Control Signal — Increase or decrease volume

The status field of a frame contains information for transmission of the frame to the receiver.

The parity field is used to check the frame for a last time for completeness. The contents of this field determine whether a transmission process is going to be repeated.

Appendix D

Transmission of Sound and Video as Synchronous Data

Synchronous data transmission is explained here using a function of the Volkswagen Phaeton audio system as an example: playing a music CD.

The operator selects the desired title *(10 in this example)* on the music CD from the Multimedia Control Head E380 and the Front Information Display Control Head J685.

E380 transmits the control data over a data connection to the system manager *(Front Information Display Control Head Control Module J523)*.

The system manager then adds the continuously sent frames to a message block *(16 frames)* with the control data:

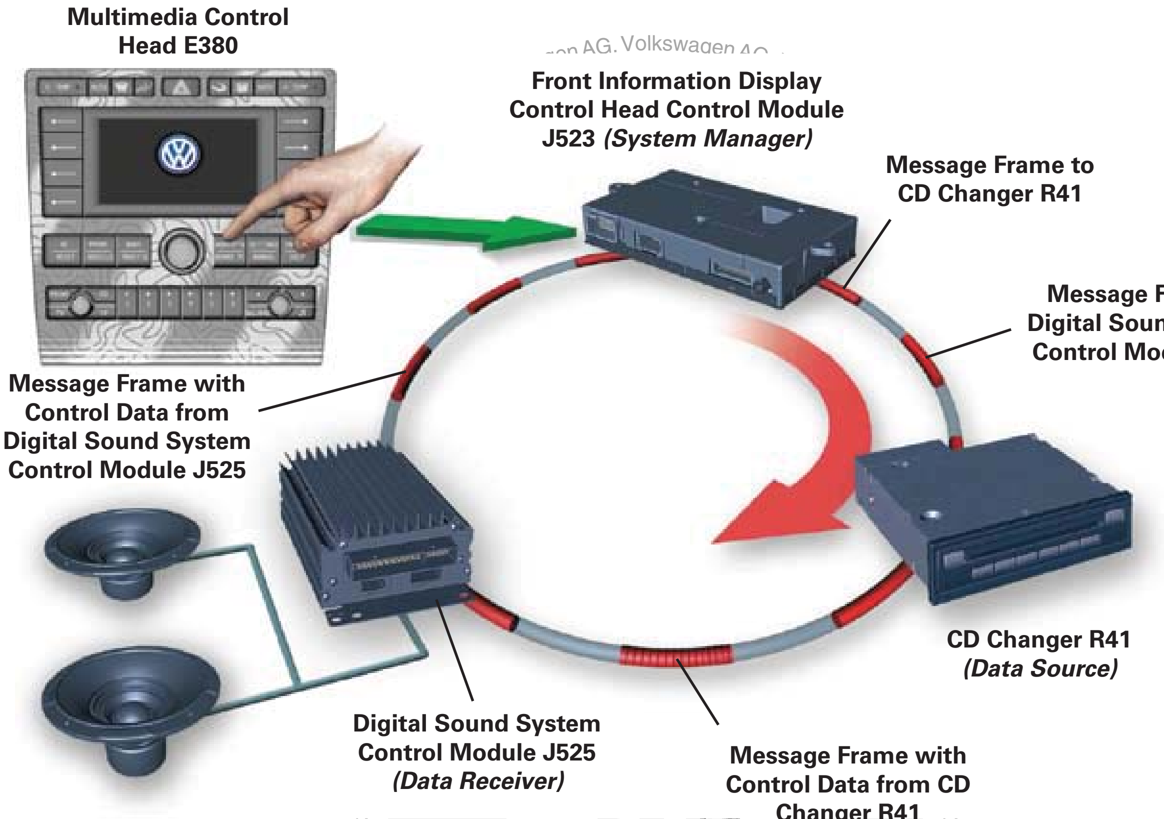
– Transmission address:
  - Front Information Display Control Head Control Module J523, position 1 on the MOST fiber-optic data bus ring
– Receiver address of the data source:
  - CD Changer R41, position on the ring depending on installed options
– Control commands:
  - Play title 10
  - Assign transmission channels

The CD Changer R41 *(the data source)* decides which bytes in the data field are available for the transmission of CD drive data.

Then it adds a block with the following control data:

– Transmission address of the data source:
  - CD Changer R41, position on the ring depending on installed options
– Receiver address of the system manager:
  - Front Information Display Control Head Control Module J523, position 1 on the ring
– Control command:
  - Data transmission music CD on channels 01, 02, 03, 04 *(stereo)*

Selection of Functions



Appendix D

Data Management During Synchronous Transmission

Front Information Display Control Head Control Module J523 commands the Digital Sound System Control Module J525 to play music by using a block with the following control data:

– Transmission address:
  - Front Information Display Control Head Control Module J523, position 1 on the MOST fiber-optic data bus ring

– Receiver address:
  - Digital Sound System Control Module J525, position on the ring depending on installed options

– Control commands:
  - Read data channels 01, 02, 03, 04 and deliver through the loudspeakers
  - Use current sound adjustments, such as volume, fader, balance, base, treble, middle
  - Turn OFF mute

The data of the music CD remain in the data field until the frame reaches CD Changer R41 *(the data source)* again on the ring.

This makes the use of synchronous data possible for each performance device *(sound package, earphone connections)* on the MOST fiber-optic data bus.

As the system manager, J523 assigns which one of the devices will use the applicable control data.

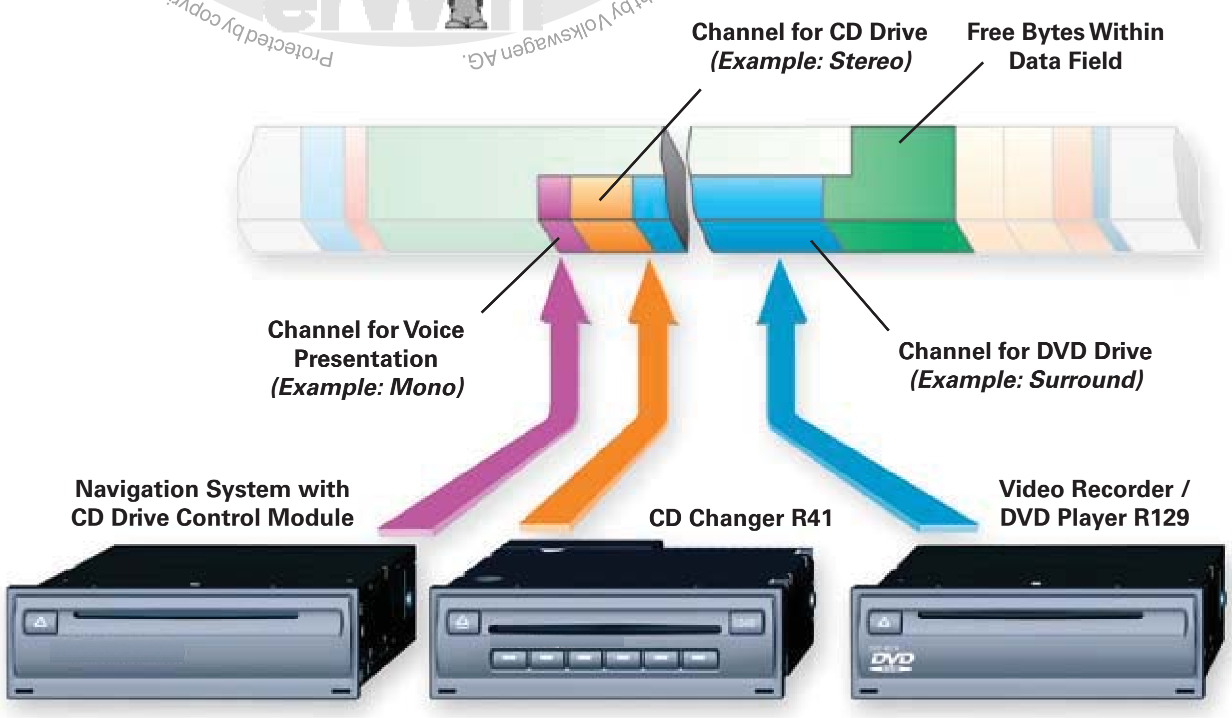
Transmission Channels

The transmission of sound or video requires several bytes in each data field. The data source reserves a number of bytes according to the kind of data. The reserved bytes are called *channels*. Each channel contains one byte of data.

Number of Transmission Channels

Signal	Channels *(Bytes)*
Mono	2
Stereo	4
Surround	12

Reserving these channels makes it possible to simultaneously transmit synchronous data from several data sources.



Transmission of Data for Pictures, Text and Functions as Synchronous Data

The following data are transmitted as asynchronous data:

– Map displays of the navigation system

– Navigation calculations

– Internet web sites

– E-mail

The sources of asynchronous data send them at irregular time intervals.

For this reason, each source saves its asynchronous data in an intermediate memory.

The data source now waits until it receives a message block with the address of the receiver.

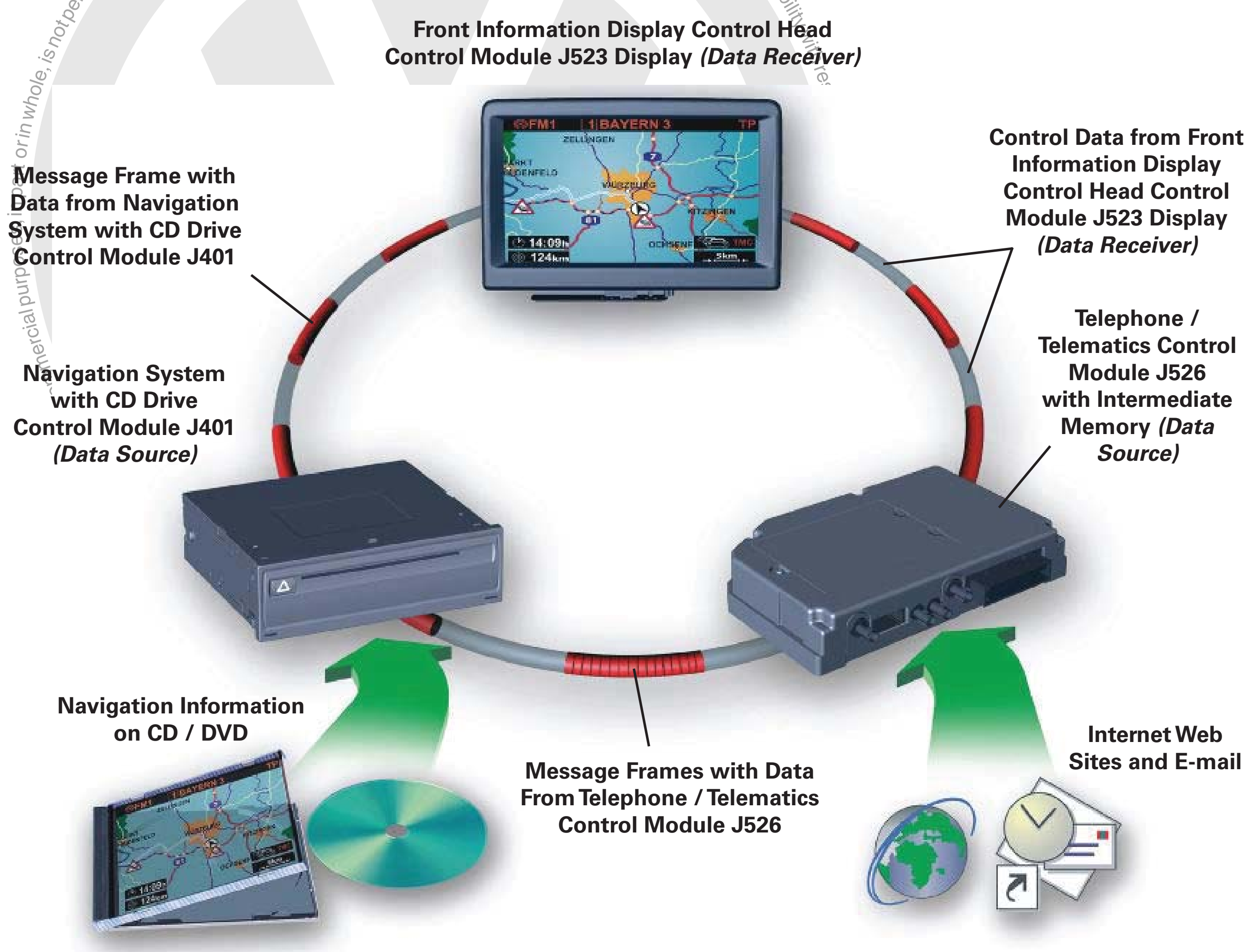
In this message block, the source enters the data in the free bytes in the data fields.

This is done in packages of four bytes each *(quadlets)*.

The receiver reads the data packages in the data fields and uses the information.

The asynchronous data stays in the data fields until the message block again reaches the data source.

The data source selects the data from the data fields and if necessary, replaces them with new data.



Notes

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Knowledge Assessment

An on-line Knowledge Assessment *(exam)* is available for this Self-Study Program.

The Knowledge Assessment may or may not be required for Certification.

You can find this Knowledge Assessment at:

www.vwwebsource.com

For Assistance, please call:

Volkswagen Academy

Certification Program Headquarters

1 – 877 – VW – CERT – 5

(1 – 877 – 892 – 3785)

(8:00 a.m. to 8:00 p.m. EST)

Or, E-Mail:

vwlms@convergent.com

872803

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Cautions & Warnings

Please read these WARNINGS and CAUTIONS before proceeding with maintenance and repair work. You must answer that you have read and you understand these WARNINGS and CAUTIONS before you will be allowed to view this information.

- If you lack the skills, tools and equipment, or a suitable workshop for any procedure described in this manual, we suggest you leave such repairs to an authorized Volkswagen retailer or other qualified shop. We especially urge you to consult an authorized Volkswagen retailer before beginning repairs on any vehicle that may still be covered wholly or in part by any of the extensive warranties issued by Volkswagen.

- Disconnect the battery negative terminal (ground strap) whenever you work on the fuel system or the electrical system. Do not smoke or work near heaters or other fire hazards. Keep an approved fire extinguisher handy.

- Volkswagen is constantly improving its vehicles and sometimes these changes, both in parts and specifications, are made applicable to earlier models. Therefore, part numbers listed in this manual are for reference only. Always check with your authorized Volkswagen retailer parts department for the latest information.

- Any time the battery has been disconnected on an automatic transmission vehicle, it will be necessary to reestablish Transmission Control Module (TCM) basic settings using the VAG 1551 Scan Tool (ST).

- Never work under a lifted vehicle unless it is solidly supported on stands designed for the purpose. Do not support a vehicle on cinder blocks, hollow tiles or other props that may crumble under continuous load. Never work under a vehicle that is supported solely by a jack. Never work under the vehicle while the engine is running.

- For vehicles equipped with an anti-theft radio, be sure of the correct radio activation code before disconnecting the battery or removing the radio. If the wrong code is entered when the power is restored, the radio may lock up and become inoperable, even if the correct code is used in a later attempt.

- If you are going to work under a vehicle on the ground, make sure that the ground is level. Block the wheels to keep the vehicle from rolling. Disconnect the battery negative terminal (ground strap) to prevent others from starting the vehicle while you are under it.

- Do not attempt to work on your vehicle if you do not feel well. You increase the danger of injury to yourself and others if you are tired, upset or have taken medicine or any other substances that may impair you or keep you from being fully alert.

- Never run the engine unless the work area is well ventilated. Carbon monoxide (CO) kills.

- Always observe good workshop practices. Wear goggles when you operate machine tools or work with acid. Wear goggles, gloves and other protective clothing whenever the job requires working with harmful substances.

- Tie long hair behind your head. Do not wear a necktie, a scarf, loose clothing, or a necklace when you work near machine tools or running engines. If your hair, clothing, or jewelry were to get caught in the machinery, severe injury could result.

- Do not re-use any fasteners that are worn or deformed in normal use. Some fasteners are designed to be used only once and are unreliable and may fail if used a second time. This includes, but is not limited to, nuts, bolts, washers, circlips and cotter pins. Always follow the recommendations in this manual - replace these fasteners with new parts where indicated, and any other time it is deemed necessary by inspection.

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Cautions & Warnings

- Illuminate the work area adequately but safely. Use a portable safety light for working inside or under the vehicle. Make sure the bulb is enclosed by a wire cage. The hot filament of an accidentally broken bulb can ignite spilled fuel or oil.

- Friction materials such as brake pads and clutch discs may contain asbestos fibers. Do not create dust by grinding, sanding, or by cleaning with compressed air. Avoid breathing asbestos fibers and asbestos dust. Breathing asbestos can cause serious diseases such as asbestosis or cancer, and may result in death.

- Finger rings should be removed so that they cannot cause electrical shorts, get caught in running machinery, or be crushed by heavy parts.

- Before starting a job, make certain that you have all the necessary tools and parts on hand. Read all the instructions thoroughly; do not attempt shortcuts. Use tools that are appropriate to the work and use only replacement parts meeting Volkswagen specifications. Makeshift tools, parts and procedures will not make good repairs.

- Catch draining fuel, oil or brake fluid in suitable containers. Do not use empty food or beverage containers that might mislead someone into drinking from them. Store flammable fluids away from fire hazards. Wipe up spills at once, but do not store the oily rags, which can ignite and burn spontaneously.

- Use pneumatic and electric tools only to loosen threaded parts and fasteners. Never use these tools to tighten fasteners, especially on light alloy parts. Always use a torque wrench to tighten fasteners to the tightening torque listed.

- Keep sparks, lighted matches, and open flame away from the top of the battery. If escaping hydrogen gas is ignited, it will ignite gas trapped in the cells and cause the battery to explode.

- Be mindful of the environment and ecology. Before you drain the crankcase, find out the proper way to dispose of the oil. Do not pour oil onto the ground, down a drain, or into a stream, pond, or lake. Consult local ordinances that govern the disposal of wastes.

- The air-conditioning (A/C) system is filled with a chemical refrigerant that is hazardous. The A/C system should be serviced only by trained automotive service technicians using approved refrigerant recovery/recycling equipment, trained in related safety precautions, and familiar with regulations governing the discharging and disposal of automotive chemical refrigerants.

- Before doing any electrical welding on vehicles equipped with anti-lock brakes (ABS), disconnect the battery negative terminal (ground strap) and the ABS control module connector.

- Do not expose any part of the A/C system to high temperatures such as open flame. Excessive heat will increase system pressure and may cause the system to burst.

- When boost-charging the battery, first remove the fuses for the Engine Control Module (ECM), the Transmission Control Module (TCM), the ABS control module, and the trip computer. In cases where one or more of these components is not separately fused, disconnect the control module connector(s).

- Some of the vehicles covered by this manual are equipped with a supplemental restraint system (SRS), that automatically deploys an airbag in the event of a frontal impact. The airbag is operated by an explosive device. Handled improperly or without adequate safeguards, it can be accidentally activated and cause serious personal injury. To guard against personal injury or airbag system failure, only trained Volkswagen Service technicians should test, disassemble or service the airbag system.

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Cautions & Warnings

- Do not quick-charge the battery (for boost starting) for longer than one minute, and do not exceed 16.5 volts at the battery with the boosting cables attached. Wait at least one minute before boosting the battery a second time.
- Never use a test light to conduct electrical tests of the airbag system. The system must only be tested by trained Volkswagen Service technicians using the VAG 1551 Scan Tool (ST) or an approved equivalent. The airbag unit must never be electrically tested while it is not installed in the vehicle.
- Some aerosol tire inflators are highly flammable. Be extremely cautious when repairing a tire that may have been inflated using an aerosol tire inflator. Keep sparks, open flame or other sources of ignition away from the tire repair area. Inflate and deflate the tire at least four times before breaking the bead from the rim. Completely remove the tire from the rim before attempting any repair.
- When driving or riding in an airbag-equipped vehicle, never hold test equipment in your hands or lap while the vehicle is in motion. Objects between you and the airbag can increase the risk of injury in an accident.

I have read and I understand these Cautions and Warnings.

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Version 1.0