The Audi CAN Data Bus

Design and Function

Learning + Transformation
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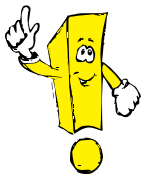
Always check Technical Bulletins and the Audi Worldwide Repair Information System for information that may supersede any information included in this booklet.

Contents

New!



Important/Note!

The Self-Study Program is not a Workshop Manual!

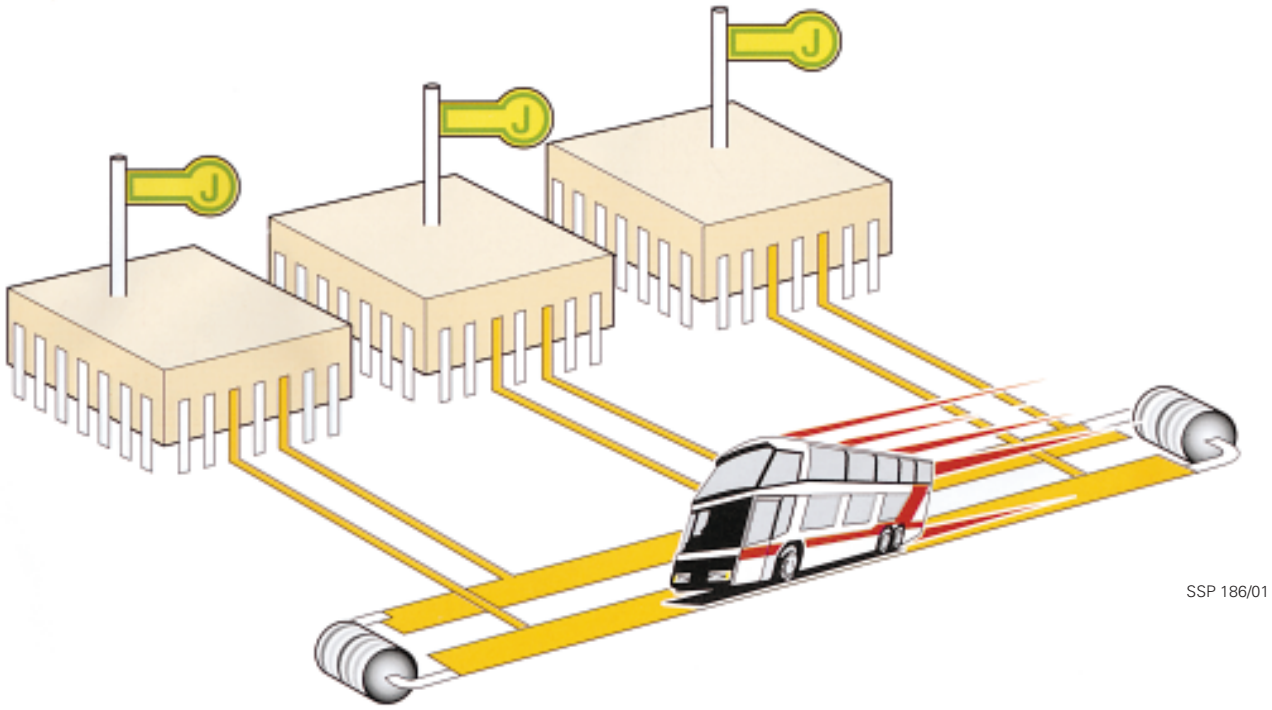
Precise instructions for testing, adjustment and repair can be found in the appropriate Workshop Manual.

Introduction

The requirements relating to driving safety, driving comfort, exhaust emissions and fuel economy are becoming ever more stringent.

This entails more intensive information exchange between control units. A well-engineered solution is necessary to ensure that the electrics/electronics in the vehicle still remain manageable and do not take up too much space.

The **CAN data bus** by Bosch is such a solution. It was developed specially for automobiles and is used by both Volkswagen and Audi. CAN stands for Controller Area Network and means that control modules are networked and interchange data.



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A CAN data bus can be compared to a passenger bus.

While the passenger bus transports a large number of persons, the CAN data bus transports a large volume of information.

In this Self-Study Program we will explain to you the design and function of the **CAN data bus.**

CAN Data Bus

Data Transfer

What are the possible options for data transfer in vehicles at present?

- **Option No. 1:**

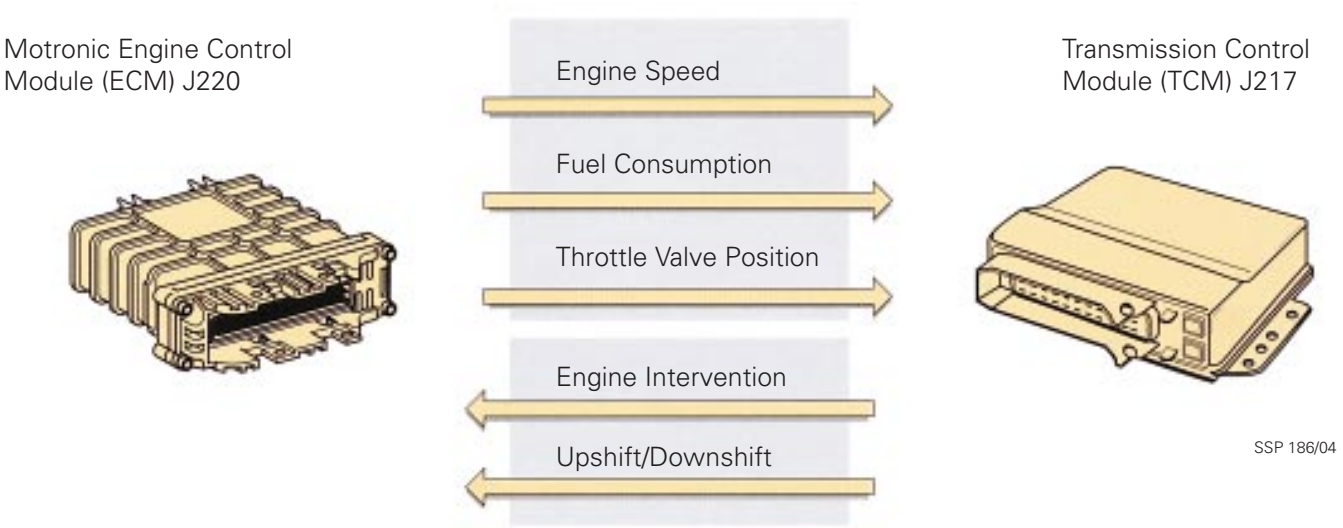
  Each item of information is exchanged over a separate wire.

- **Option No. 2:**

  All information is exchanged between control modules along a maximum of two wires: the CAN data bus.

The figure below shows you option No. 1, where each item of information is transferred along a separate wire.

A total of five wires are required for data transfer in this case.



Conclusion:

A separate wire is required for each item of information.

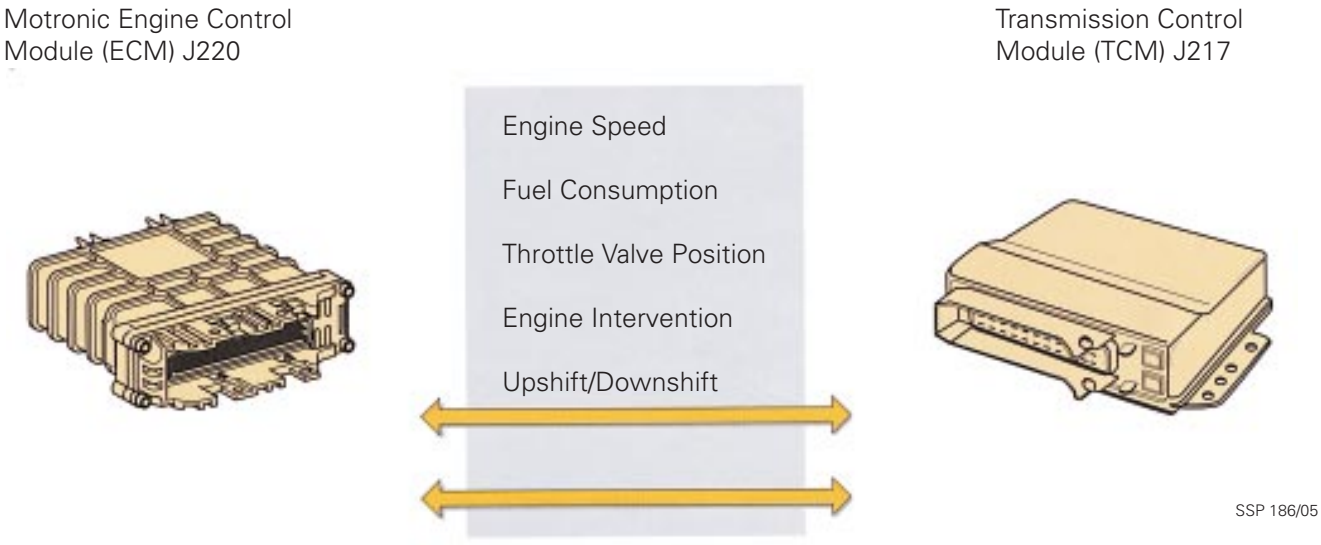
As the volume of additional information increases, so does the number of wires and the number of pins on the control modules.

Therefore, this data transfer mode is only suitable for exchanging a limited volume of information.

In contrast to option No. 1, in option No. 2 illustrated below, all information is tranferred along two wires in the CAN data bus.

The same data is transferred along the two bidirectional wires of the CAN data bus.

You will find further information in this Self-Study Program.



Conclusion:

With this data transfer mode, all information is transferred along two wires regardless of the number of participating control modules and the volume of information involved.

Data transfer with the CAN data bus would therefore make sense if a large volume of information is exchanged between control units.

CAN Data Bus

The CAN Data Bus

is a type of data transfer between control modules. It links the individual control modules to form an integrated system.

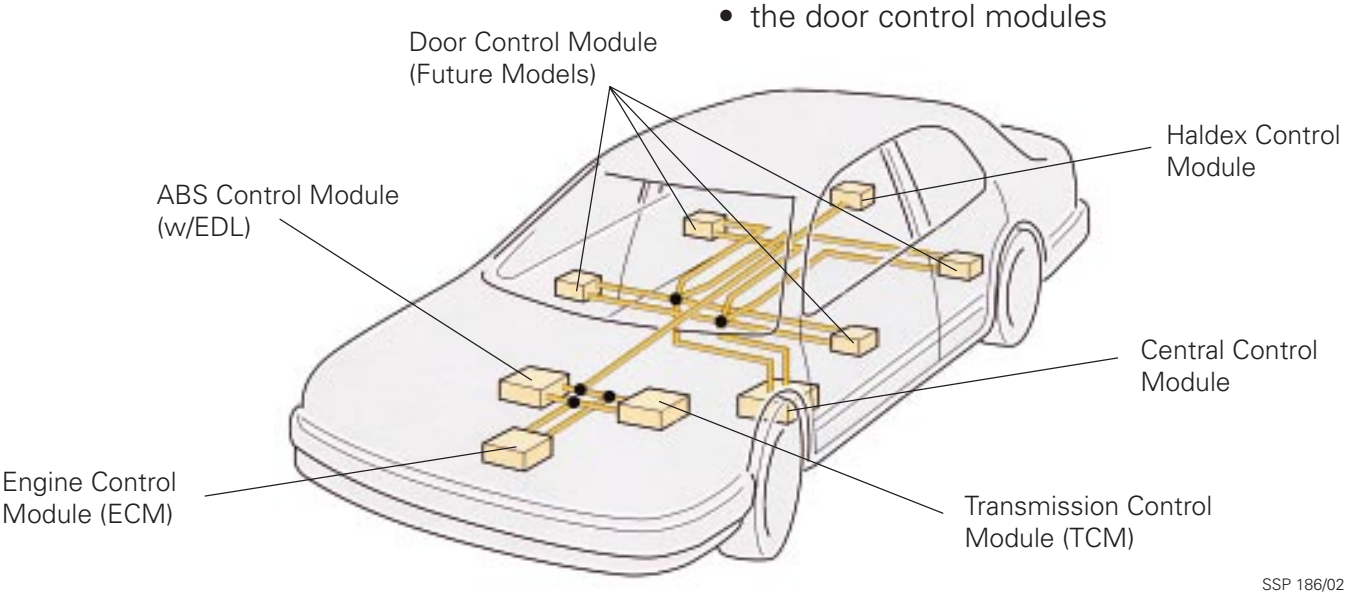
The more information a control module has regarding the state of the overall system, the better it can coordinate the individual functions.

The following components in the drive train form an integrated system:

- the Engine Control Module (ECM)
- the Transmission Control Module (TCM)
- the ABS Control Module (w/EDL)
- Haldex Control Module

The following components can be used in the convenience system to form an integrated system:

- the central control module and
- the door control modules



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Benefits of the Data Bus:

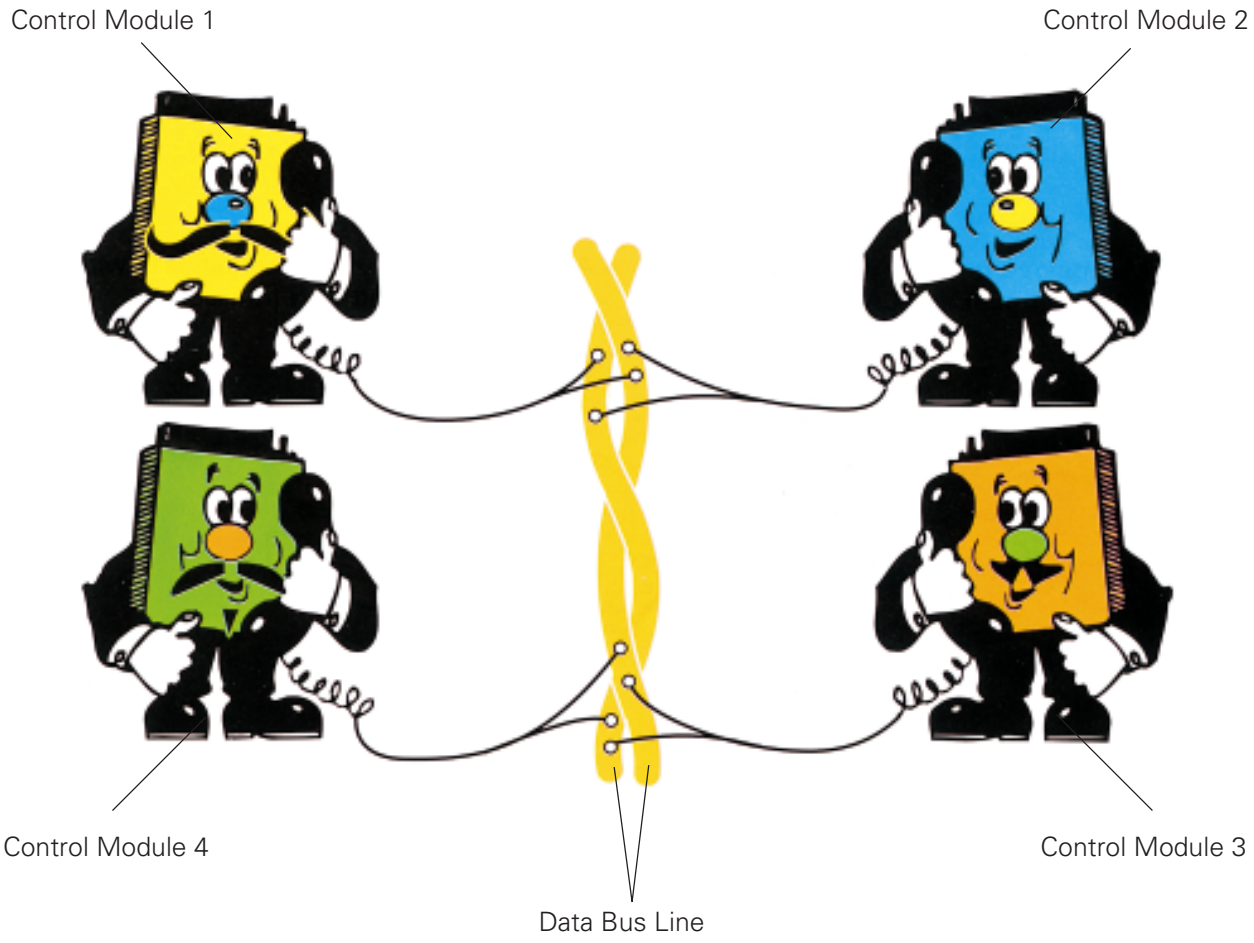
- If the data protocol is extended to include additional information, only software modifications are necessary.
- Low error rate through continuous verification of the transmitted information by the control modules as well as additional safeguards in the data protocols.
- Fewer sensors and signal lines through the multiple use of a sensor signal.
- High-speed data transfer is possible between control units.
- More space available through smaller control modules and smaller control module plugs.
- The CAN data bus conforms to international standards and therefore facilitates data interchange between different makes of control unit.

The Principle of Data Transfer

Data transfer with the CAN data bus functions in much the same way as a telephone conference.

A subscriber (control module) "speaks" data into the line network while the other subscribers "listen in" to this data.

Some subscribers will be interested in this data and will utilize it. The other subscribers will choose to ignore this data.



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CAN Data Bus

What Components Make Up a CAN Data Bus?

The CAN data bus comprises a controller, a transceiver, two data bus terminals and two data bus lines.
Apart from the data bus lines, the components are located in the control modules. The functions of the control modules are the same as before.

They have the following tasks:

The CAN Controller

receives the transfer data from the microcomputer integrated in 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 microcomputer integrated in the control module.

The CAN Transceiver

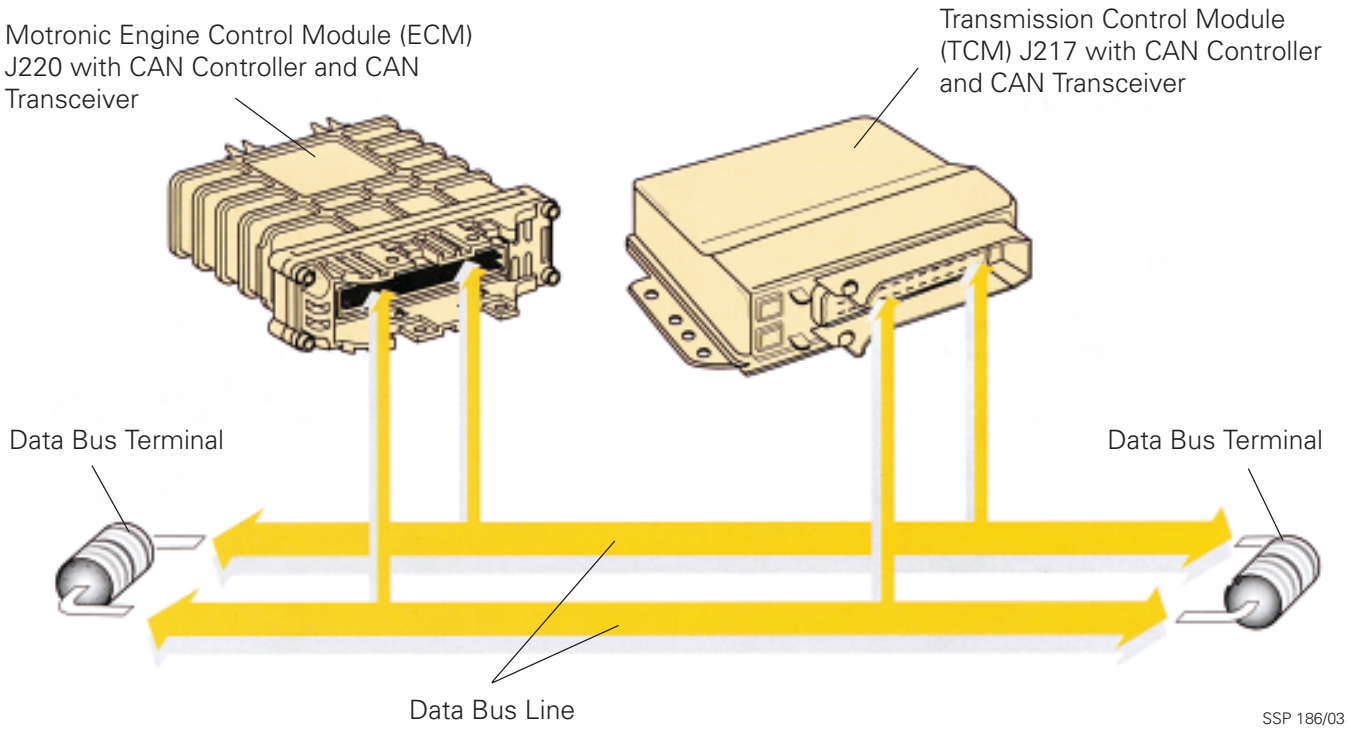
is a transmitter and receiver in one. It converts the data which the CAN controller supplies into electrical signals and sends this data over the data bus lines.
Likewise, it receives data and converts this data for the CAN controller.

The Data Bus Terminal

is a resistor. It prevents data sent from being reflected at the ends and returning as an echo. This would corrupt the data.

The Data Bus Lines

are bidirectional and transfer the data. They are referred to as CAN High and CAN Low.



The data bus does not have a designated receiver. Data is sent over the data bus and is generally received and evaluated by all subscribers.

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

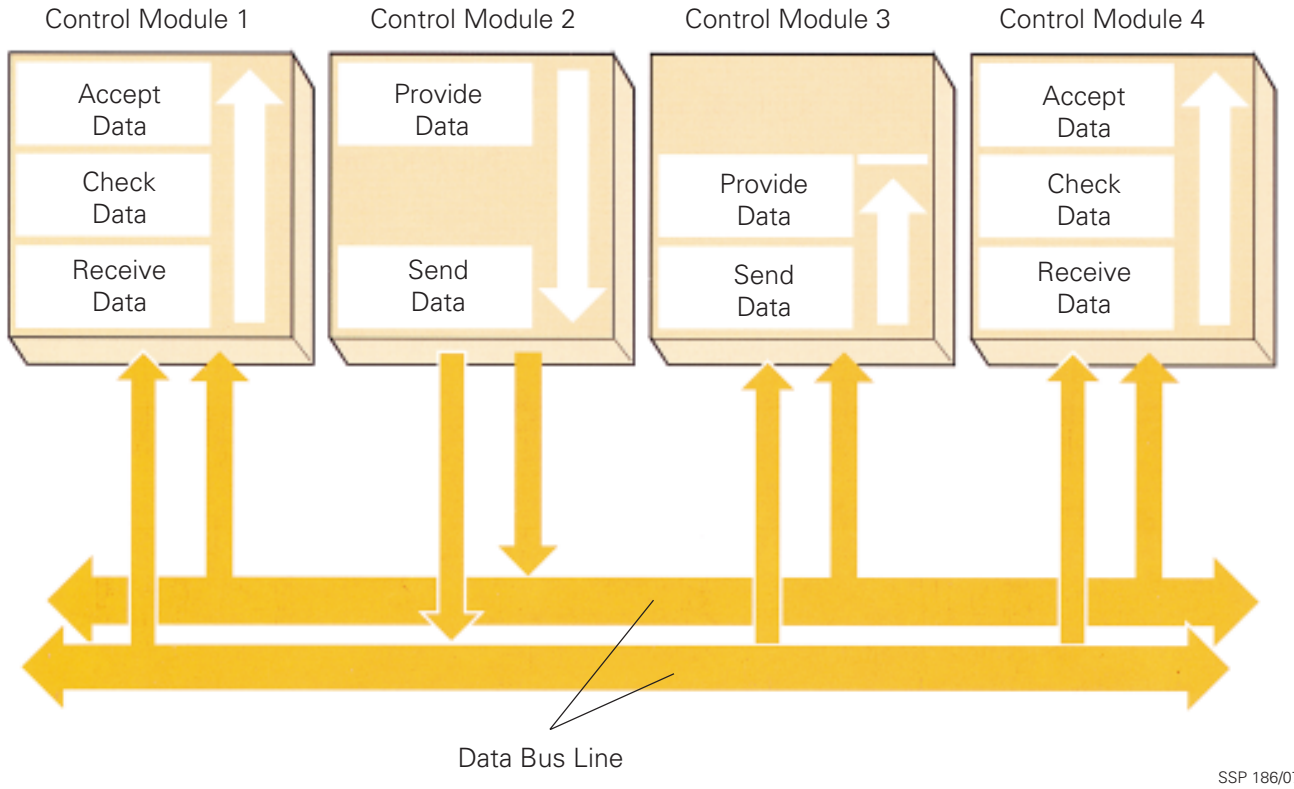
All other control modules networked with the CAN data bus become receivers.

Checking Data

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

Accepting Data

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



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Data Transfer

What Does the CAN Data Bus Transfer?

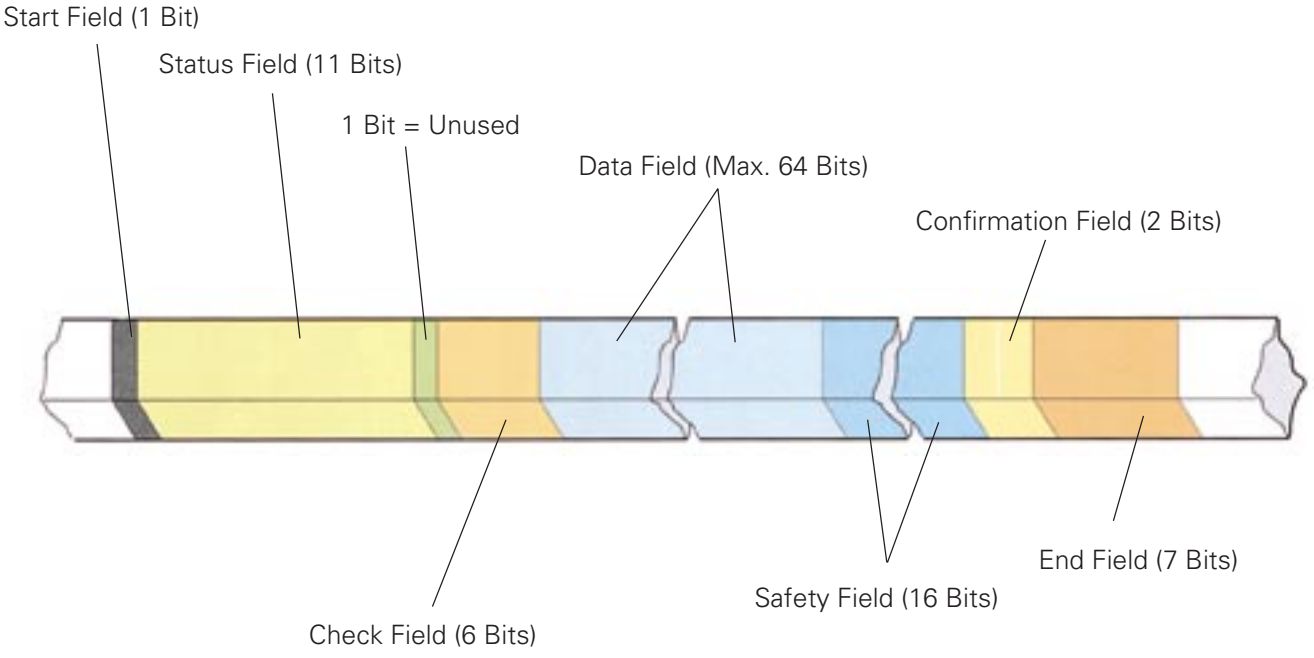
It transfers a data protocol between the control modules at short intervals.
It is subdivided into seven areas.

The Data Protocol:

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

The diagram below shows the format of a data protocol. This format is identical on both data bus lines.
For simplicity's sake, only one data bus line will be shown in this Self-Study Program.

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", i.e. "yes" or "no".



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The Seven Areas:

The **start field**
marks the start of the data protocol. A bit with approximately 2.5 or 5.0 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.

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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.

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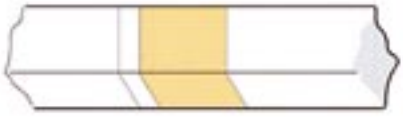
The **check field**
displays the number of items of information contained in the data field. This field allows any receiver to check whether it has received all the information transferred to it.



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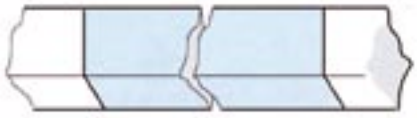
In the **data field**,
information is transferred to the other control modules.



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The **safety field**
detects transfer faults.

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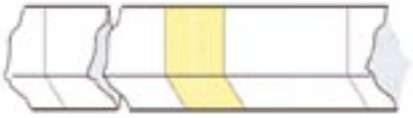
In the **confirmation field**,
the receivers signal to the transmitter that they have correctly received the data protocol. If an error is detected, the receivers notify the transmitter of this immediately. The transmitter then sends the data protocol again.



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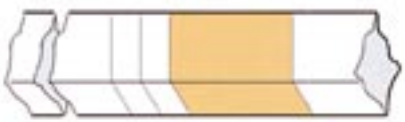
The **end field**
marks the end of the data protocol. This is the last possibility to indicate errors which lead to a repeat transfer.



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Function

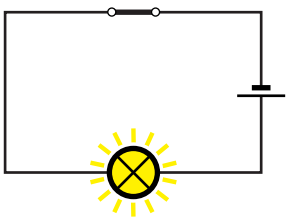
How is a Data Protocol Produced?

The data protocol comprises a string of several bits. Each bit can only have status or value "**0**" or "**1**".

Here is a simple example to explain how a status with the value "0" or "1" is generated:

The light switch
switches a light on or off. This means that the light switch can have two different states.

Status of the light switch with the value "1"
- Switch closed
- Lamp on



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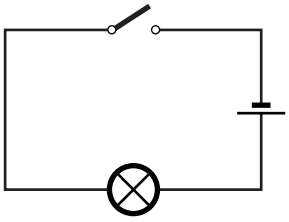
Status of the light switch with the value "0"
- Switch open
- Lamp is not on



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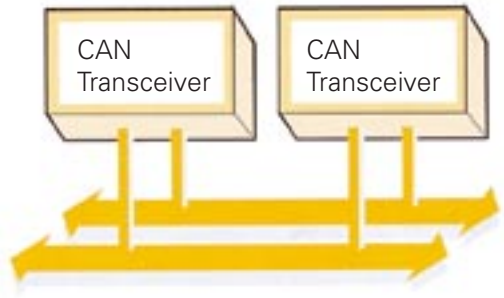
In principle, the CAN data bus functions in exactly the same way.

The transceiver
can also generate two different bit states.



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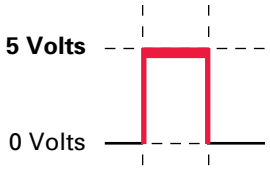
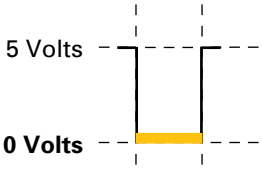
Status of bit with the value "1"
- Transceiver open, switches to 2.5 Volts in the drive train system (convenience system: approximately 5.0 Volts)
- Voltage applied to data bus line: approximately 2.5 Volts in the drive train system (convenience system: approximately 5.0 Volts)



Status of the bit with the value "0"
- Transceiver closed, switches to ground
- Voltage applied to data bus line: approximately **0 Volts**

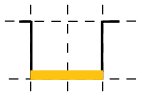
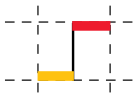
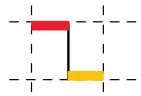
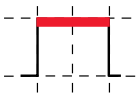


The table below shows you how information can be transferred with two consecutive bits.

With two bits, there are four possible variations.
One item of information can be assigned to each variation and is binding for all control modules.

Example:

If bits 1 and 2 are transmitted with 0 Volts, this indicates that the electric windows are in motion and that the coolant temperature is 10°C.

Possible Variation	2nd Bit	1st Bit	Graphic	Electric Window Status Information	Information on Coolant Temperature
One	0 Volts	0 Volts		in motion	10°C
Two	0 Volts	5 Volts		not moving	20°C
Three	5 Volts	0 Volts		within range	30°C
Four	5 Volts	5 Volts		upper stop recognition	40°C

The table below shows you how the number of items of information increases with each additional bit.

Bit Variants Containing 1 Bit	Possible Information	Bit Variants Containing 2 Bits	Possible Information	Bit Variants Containing 3 Bits	Possible Information
0 Volts	10°C	0 Volts, 0 Volts	10°C	0 Volts, 0 Volts, 0 Volts	10°C
5 Volts	20°C	0 Volts, 5 Volts	20°C	0 Volts, 0 Volts, 5 Volts	20°C
		5 Volts, 0 Volts	30°C	0 Volts, 5 Volts, 0 Volts	30°C
		5 Volts, 5 Volts	40°C	0 Volts, 5 Volts, 5 Volts	40°C
				5 Volts, 0 Volts, 0 Volts	50°C
				5 Volts, 0 Volts, 5 Volts	60°C
				5 Volts, 5 Volts, 0 Volts	70°C
				5 Volts, 5 Volts, 5 Volts	80°C

The higher the number of bits, the more items of information can be transferred.

The number of possible items of information doubles with each additional bit.

CAN Data Bus Allocation

If more than one control module wants to send its data protocol simultaneously, the system must decide which control module comes first.
The data protocol with the highest priority is sent first. For safety reasons, the data protocol supplied by the ABS Control Module (w/EDL) is more important than the data protocol supplied by the Transmission Control Module (TCM).

How are allocations made?

Each bit has a value, and this value is assigned a weighting. There are two possibilities: high weighting or low weighting.

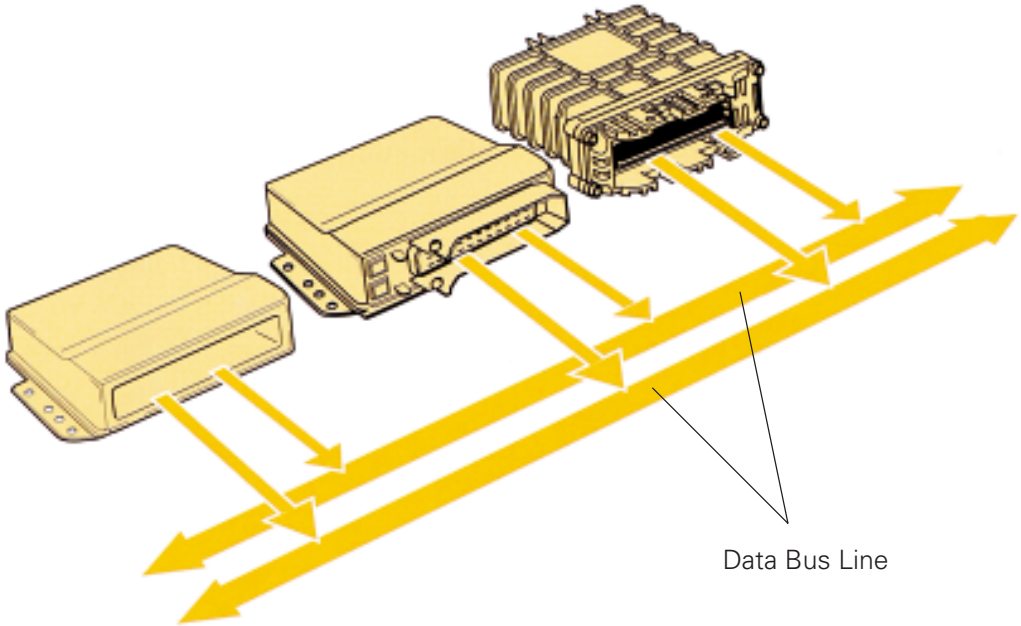
Bit With	Value	Weighting
0 Volts	0	High Weighting
5 Volts	1	Low Weighting

How is the priority of a data protocol recognized?

A code comprising eleven bits is assigned to each data protocol depending on its priority in the status field.

The priorities of three different data protocols are shown in the table below.

Priority	Data Protocol	Status Field
1	Brake I	001 1010 0000
2	Engine I	010 1000 0000
3	Transmission I	100 0100 0000



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All three control modules start sending their data protocol simultaneously. At the same time, they compare the data 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.

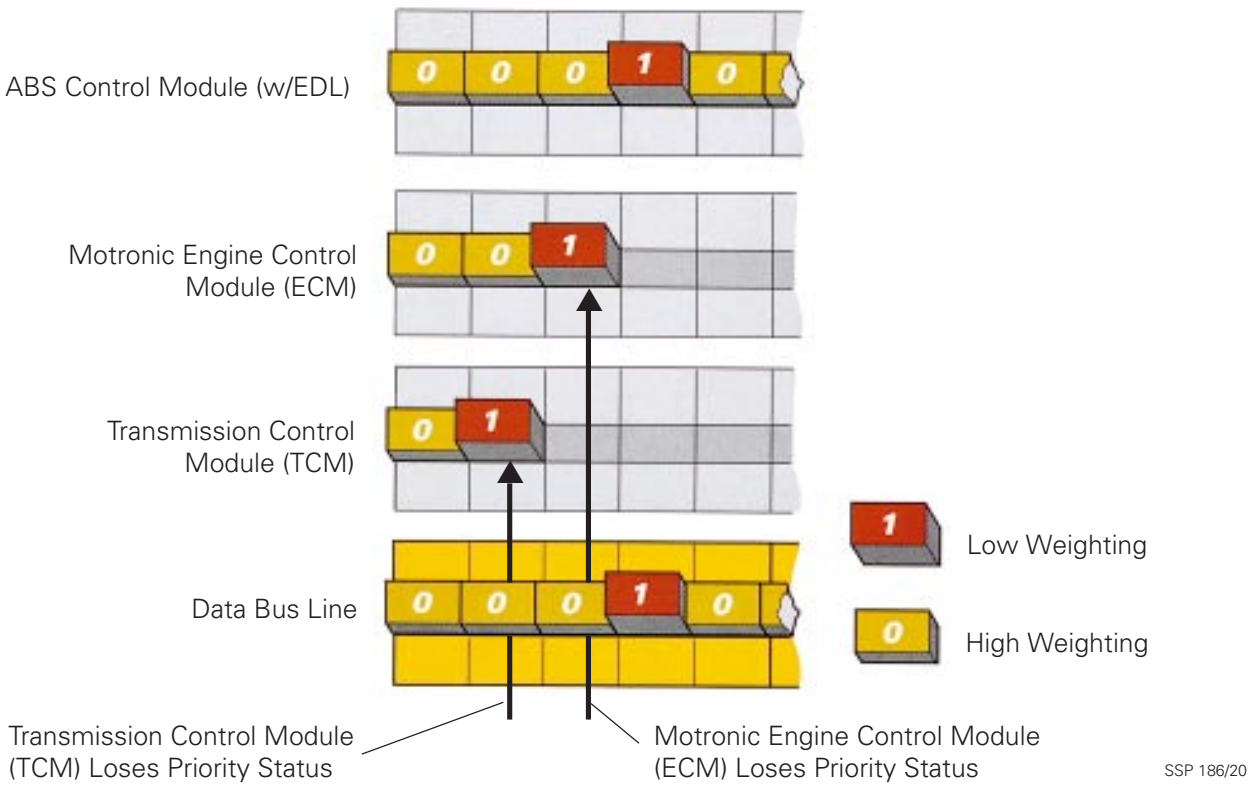
Example:

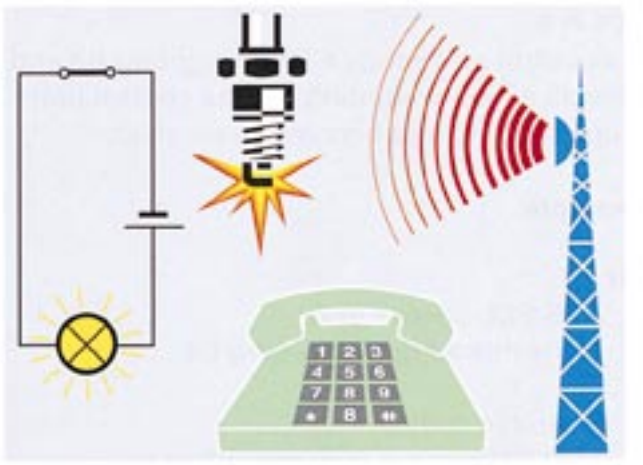
Bit 1:
- ABS Control Module (w/EDL) transmits a high weighting bit.
- Motronic Engine Control Module (ECM) also transmits a high weighting bit.
- Transmission Control Module (TCM) transmits a low weighting bit and detects a high weighting bit on the data bus line. Thus, it loses its priority status and becomes a receiver.

Bit 2:
- ABS Control Module (w/EDL) sends a high weighting bit.
- Motronic Engine Control Module (ECM) transmits a low order bit and detects a higher weighting bit on the data bus line. This, it loses its priority status and becomes a receiver.

Bit: 3:
- ABS Control Module (w/EDL) has the highest priority and thus receives the allocation. It continues to send its data protocol until it ends.

After the ABS Control Module (w/EDL) has finished sending its data protocol, the other control modules try again to transmit their data protocol.





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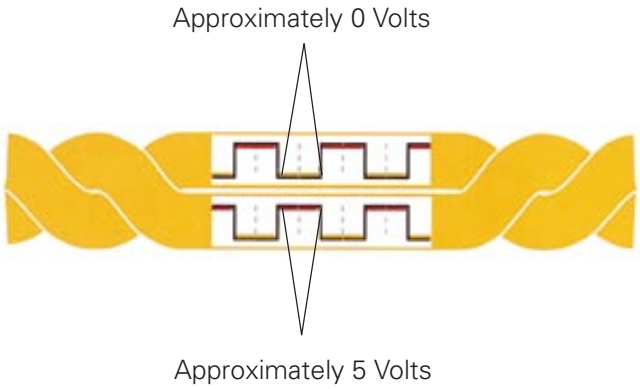
Sources of Interference

Sources of interference in the vehicle are components which produce sparks or in which electric circuits are open or closed during operation.

Other sources of interference include mobile telephones and transmitter stations, i.e. any object which produces electromagnetic waves. Electromagnetic waves can affect or corrupt data transfer.

To prevent interference with the data transfer, the two data bus lines are twisted together. This also prevents noise emission from the data bus line.

The voltage on both lines is opposed.



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That means:

If a voltage of approximately 0 Volts is applied to one data bus line, then a voltage of approximately 5 Volts is applied to the other line and vice versa.

As a result, the total voltage remains constant at all times and the electromagnetic field effects of the two data bus lines cancel each other out.

The data bus line is protected against received radiation and is virtually neutral in sending radiation.

The Data Bus in the drive train

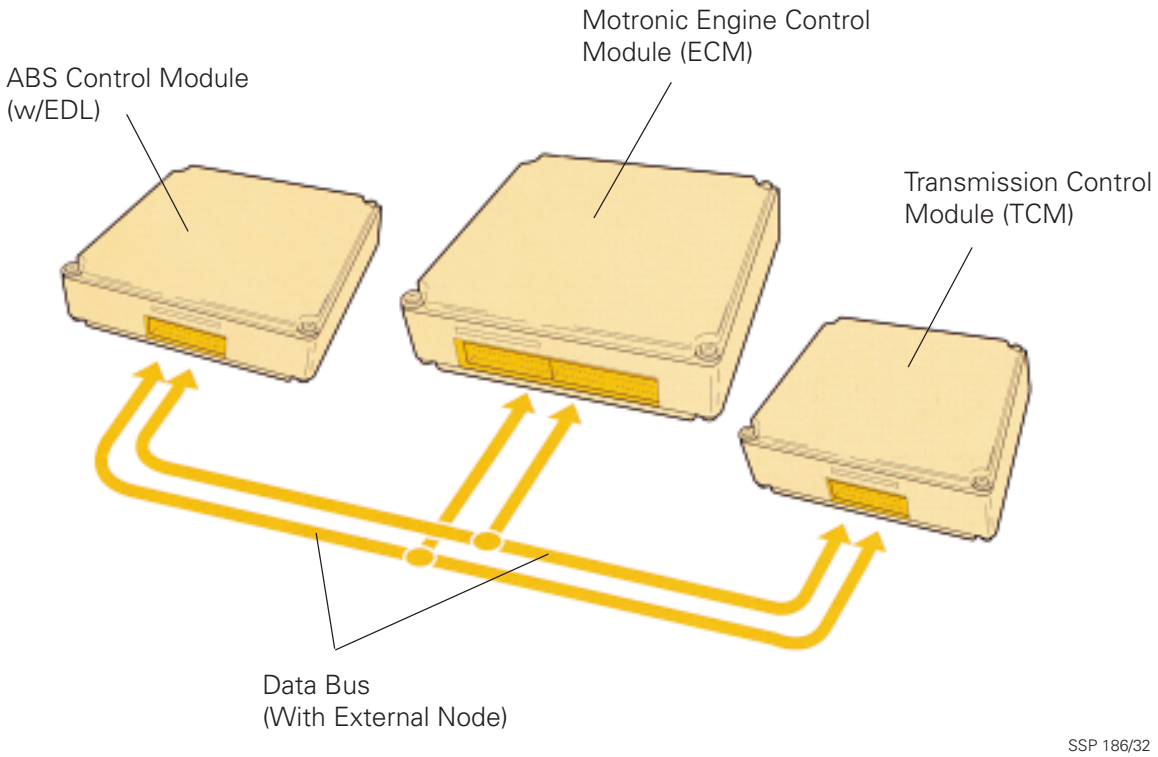
The CAN data bus links the following:

- The Motronic Engine Control Module (ECM)
- The ABS Control Module (w/EDL)
- The Transmission Control Module (TCM)

At the moment 10 different types of data are transferred.
Five from the Motronic Engine Control Module (ECM), three from the ABS Control Module (w/EDL) and two from the Transmission Control Module (TCM).

What special advantage does the CAN data bus have in the drive train?

- A high data transfer rate, with the result that the control modules are very well-informed about the momentary state of the overall system and can execute functions optimally.



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CAN Data Bus in the Drive Train

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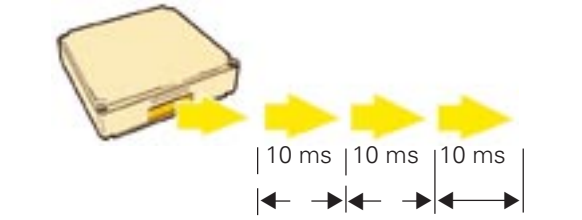

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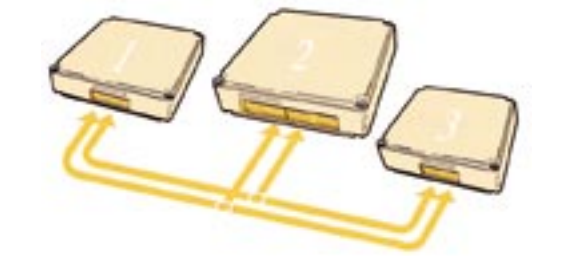

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The features of the CAN Data Bus in the drive train

- The data bus comprises two lines along which informaton is transferred.

- In order to avoid electromagnetic interference and radiation emission, the two data bus lines are twisted together. Note the twist length.

- The data bus operates at a speed of 500 kbit/s (500,000 bits per second). This means that it lies in a speed range (high speed) from 125 - 1000 kbit/s. A data protocol transfer takes approximately 0.25 milliseconds.

- Each control module (depending on type) tries to send its data at intervals of 7 - 20 milliseconds.

- Order of priority:
  1. ABS Control Module (w/EDL) ➔
  2. Motronic Engine Control Module (ECM) ➔
  3. Transmission Control Module (TCM) ➔

In the drive train, it must be possible to transfer the data very quickly so that it can be fully utilized.
For this purpose, a high-performance transceiver is required.

This transceiver facilitates data transfer between two ignition systems.
This means that the received data can be used for the next ignition impulse.

The Information in the Drive Train

What information is transferred?

The information transferred is very important for the tasks of the individual control modules. For example, the ABS Control Module (w/EDL) may need information for reasons of safety. The Engine Control Module (ECM) needs information for controlling ignition timing and fuel injection quantity. The Transmission Control Module (TCM) needs information for reasons of driving convenience and shifting comfort.

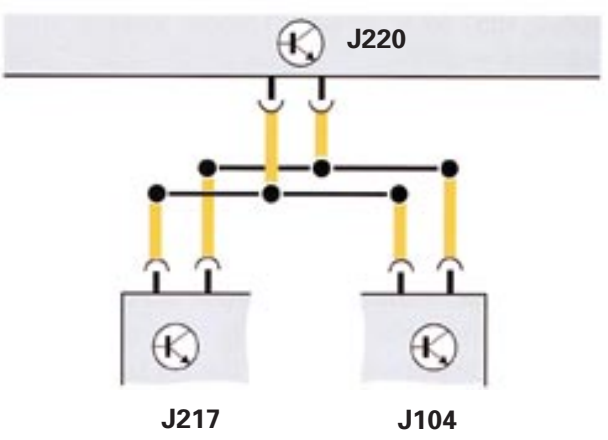
Order of Priority	Data Protocol Form	Examples of Information
1	ABS Control Module (w/EDL)	- Request for engine braking control (EBC) - Request for Traction Control System (TCS)
2	Engine Control Module (ECM), data protocol 1	- Engine speed - Throttle valve position - Kickdown
3	Engine Control Module (ECM), data protocol 2	- Coolant temperature - Vehicle speed
4	Transmission Control Module (TCM)	- Gearshift - Transmission in emergency mode - Selector lever position

In the table below you can find examples of the format of an individual item of information. On account of the sheer number of items of information which have to be transferred, only one part is displayed.

The current position of the throttle valve is transferred with 8 bits, giving a possible 256 bit permutations.
Thus, throttle valve positions from 0° to 102° can be transferred at 0.4° intervals.

Bit Order	Throttle Valve Position
0000 0000	000.0° Throttle valve opening angle
0000 0001	000.4° Throttle valve opening angle
0000 0010	000.8° Throttle valve opening angle
• • •	• • •
0101 0100	033.6° Throttle valve opening angle
• • •	• • •
1111 1111	102.0° Throttle valve opening angle

CAN Data Bus in the Drive Train



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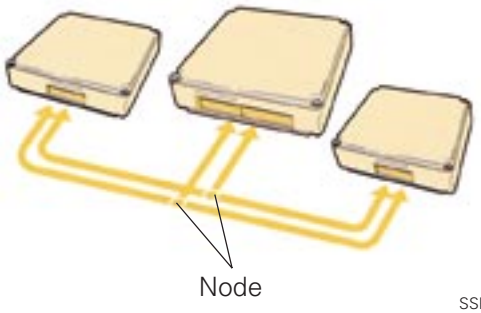

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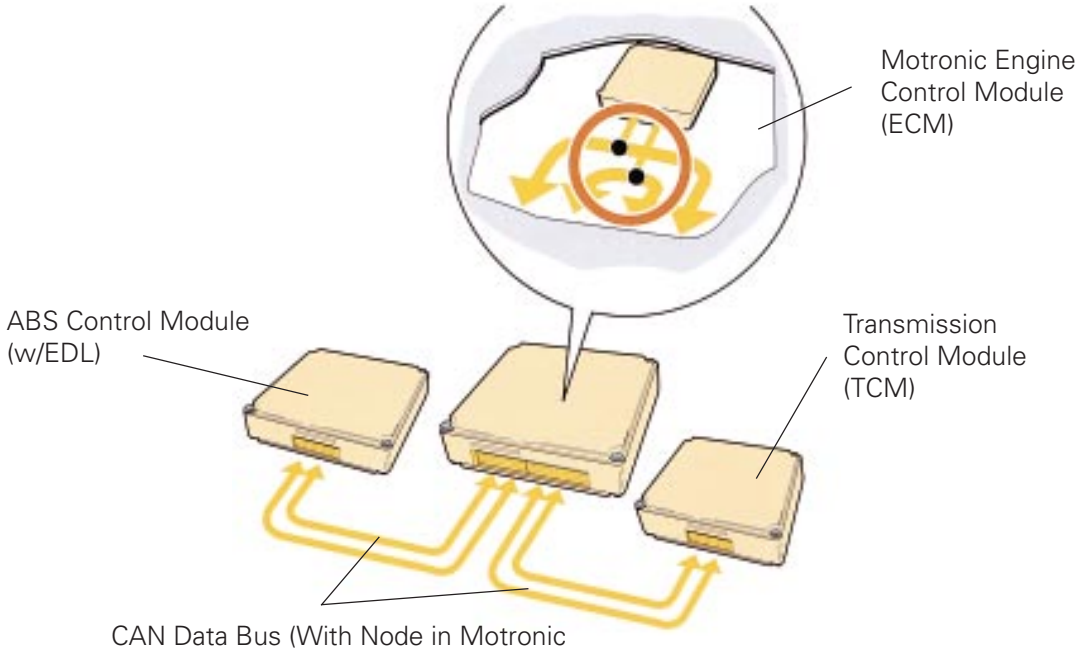
Networking of the Control Modules in the Drive Train

J104 ABS Control Module (w/EDL)
J217 Transmission Control Module (TCM)
J220 Motronic Engine Control Module (ECM)

In contrast to the convenience system, only a part of the overall system is displayed in the drive train.
In this case, only the networking of the control modules is shown.

The node is usually located outside the control module (in the wiring harness).

In exceptional cases, the node may be located in the Engine Control Module (ECM).
In the illustration below, you can see the node at which the wires in the Engine Control Module (ECM) converge.



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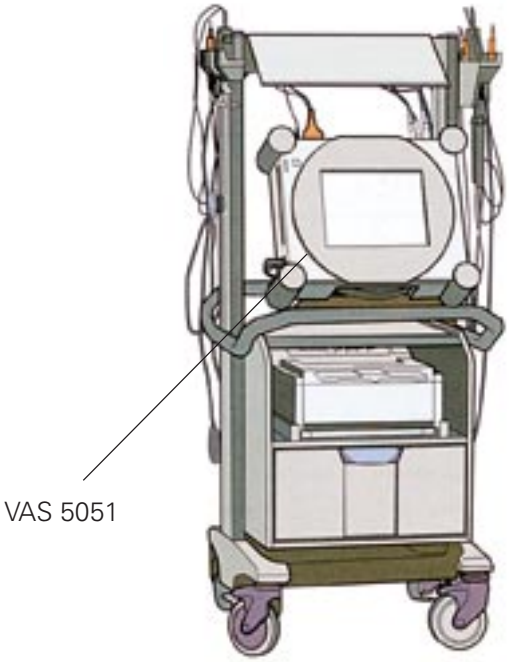
Self-Diagnosis of the CAN Data Bus in the Drive Train

Self-diagnosis can be performed with the V.A.G. 1551/52 or VAS 5051 under these address words:

01 for engine electronics
02 for transmission electronics
03 for ABS electronics

All control modules which interchange information must be regarded as an integrated system during self-diagnosis and troubleshooting.



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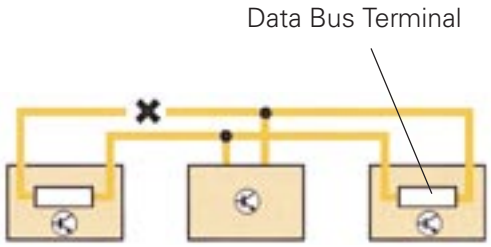
Th following function is relevant to the CAN data bus:

Function 02 - Interrogate fault memory

A fault is stored in the control modules if data transfer between the control modules is disturbed:

- Open circuit in one or more data bus lines.
- Short circuit between data bus lines.
- Short circuit to ground or positive in a data bus line.
- One or more control modules are defective.



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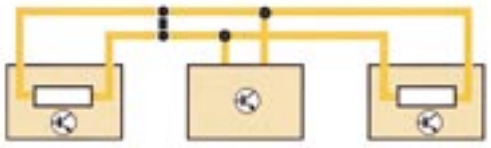

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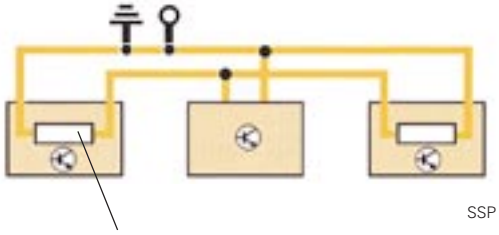

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Notes

CAN Data Bus in the Convenience System

Future Use of the CAN Data Bus in the Convenience System

In the future, the CAN data bus will be used to connect the individual control modules of the convenience system.

These are:

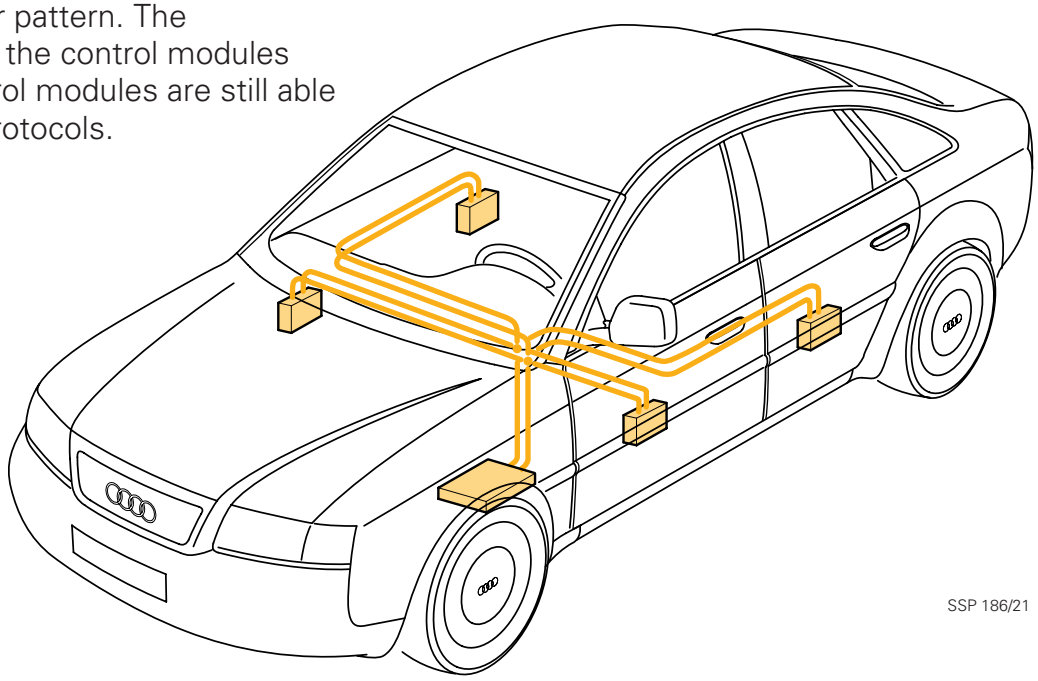
- A central control module and
- Two or four door control modules

The structure of the CAN data bus in the convenience system

The lines of the control modules converge at one point in a star pattern. The advantage: if one of the control modules fails, the other control modules are still able to send their data protocols.

The following functions of the convenience system transfer data:

- Central locking
- Electric windows
- Switch illumination
- Electrically adjustable and heated door mirrors
- Self-diagnosis



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What are the advantages of the CAN data bus in the convenience system?

- Fewer lines are routed via the door connections.
- In the event of a short circuit to ground, to positive or between lines, the CAN data bus goes to emergency running mode and changes over to single-wire mode.
- Fewer diagnosis lines are required, because self-diagnosis is handled entirely by the central control module.

CAN Data Bus in the Convenience System

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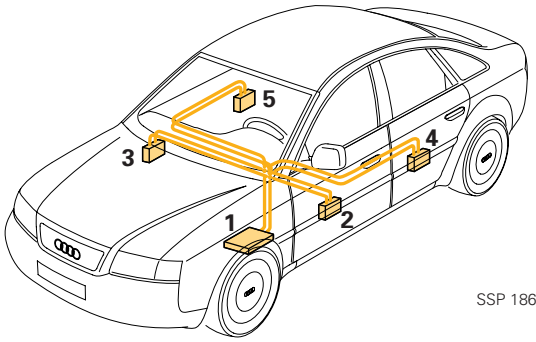

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The Features of the CAN Data Bus in the Convenience System

- The data bus comprises two lines along which information is sent.

- To avoid electromagnetic interference and radiation emission, the two data bus lines are twisted together.

- The data bus operates at a speed of 62.5 kbit/s (62500 bits per second). This means that it lies in a speed range (low speed) from 0 - 125 kbit/s. A data protocol transfer takes approximately 1 millisecond.

- Each control module tries to send its data at intervals of 20 milleseconds.

- Order of priority:
  1. Central control module ➔
  2. Control module on driver's side ➔
  3. Control module on front passenger's side ➔
  4. Control module on rear left ➔
  5. Control module on rear right

Since the data in the comfort system can be transferred at a relatively low speed, it is possible to use a transceiver with a lower power output.

The advantage is that it is possible to change over to single-wire mode if a data bus line fails. The data can still be transferred.

Information in the Convenience System

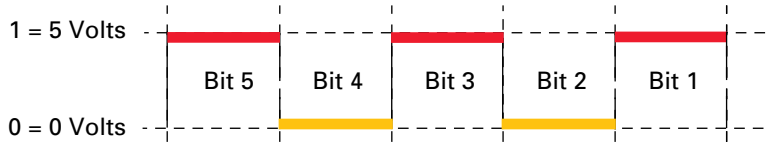
The information relates to states of the individual functions.
For example, information about which radio-wave remote control was operated, current status of central locking, do errors exist, and so on.

The table shows you part of the data field of the driver's door control module by way of an example.

You can see how and what information regarding the status of the central locking and the electric windows is transferred.

Function Status	Information	Bit Order Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Value of Bits
Central locking	Basic status			0 Volts,	0 Volts,	0 Volts	000
	Safe			0 Volts,	0 Volts,	5 Volts	001
	Locked			0 Volts,	5 Volts,	0 Volts	010
	Door unlocked			0 Volts,	5 Volts,	5 Volts	011
	The central locking is unlocked			5 Volts,	0 Volts,	5 Volts	101
	Door locked			5 Volts,	0 Volts,	0 Volts	100
	Signal error, input sensors			5 Volts,	5 Volts,	0 Volts	110
	Status error			5 Volts,	5 Volts,	5 Volts	111
Electric windows	In motion	0 Volts,	0 Volts				00
	Not moving	0 Volts,	5 Volts				01
	Within range	5 Volts,	0 Volts				10
	Upper stop recognized	5 Volts,	5 Volts				11

Example showing a possible bit order



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Bit Order	Value	Voltage Applied to Data Bus Line	Meaning of Information
3 to 1	101	5 Volts, 0 Volts, 5 Volts	The central locking is unlocked
5 to 4	10	5 Volts, 0 Volts	The window is located in the zone between the upper stop (completely closed) and 4 mm below the window seal

CAN Data Bus in the Convenience System

Networking of Control Units in the Convenience System

Control Units:

J386 Door control module, driver side

J387 Door control module, passenger side

J388 Door control module, rear left

J389 Door control module, rear right

J393 Central control module for comfort system

Fuses:

S6 Fuse, terminal 15 - central control module
S14 Fuse, terminal 30 - central control module
S37 Power Window Fuse, terminal 30
S238 Fuse, terminal 30 - central locking

Color Coding:

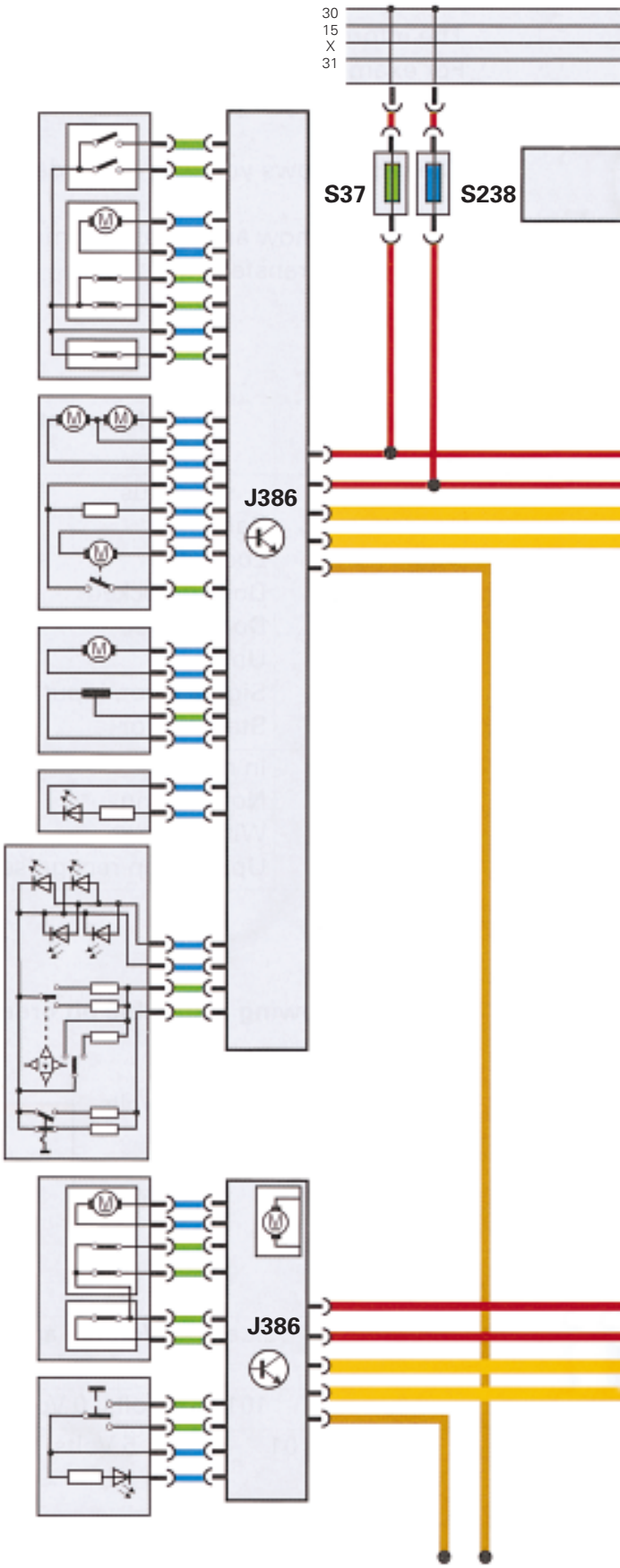
Input Signal

Output Signal

Positive

Ground

Data Bus Line High/Low



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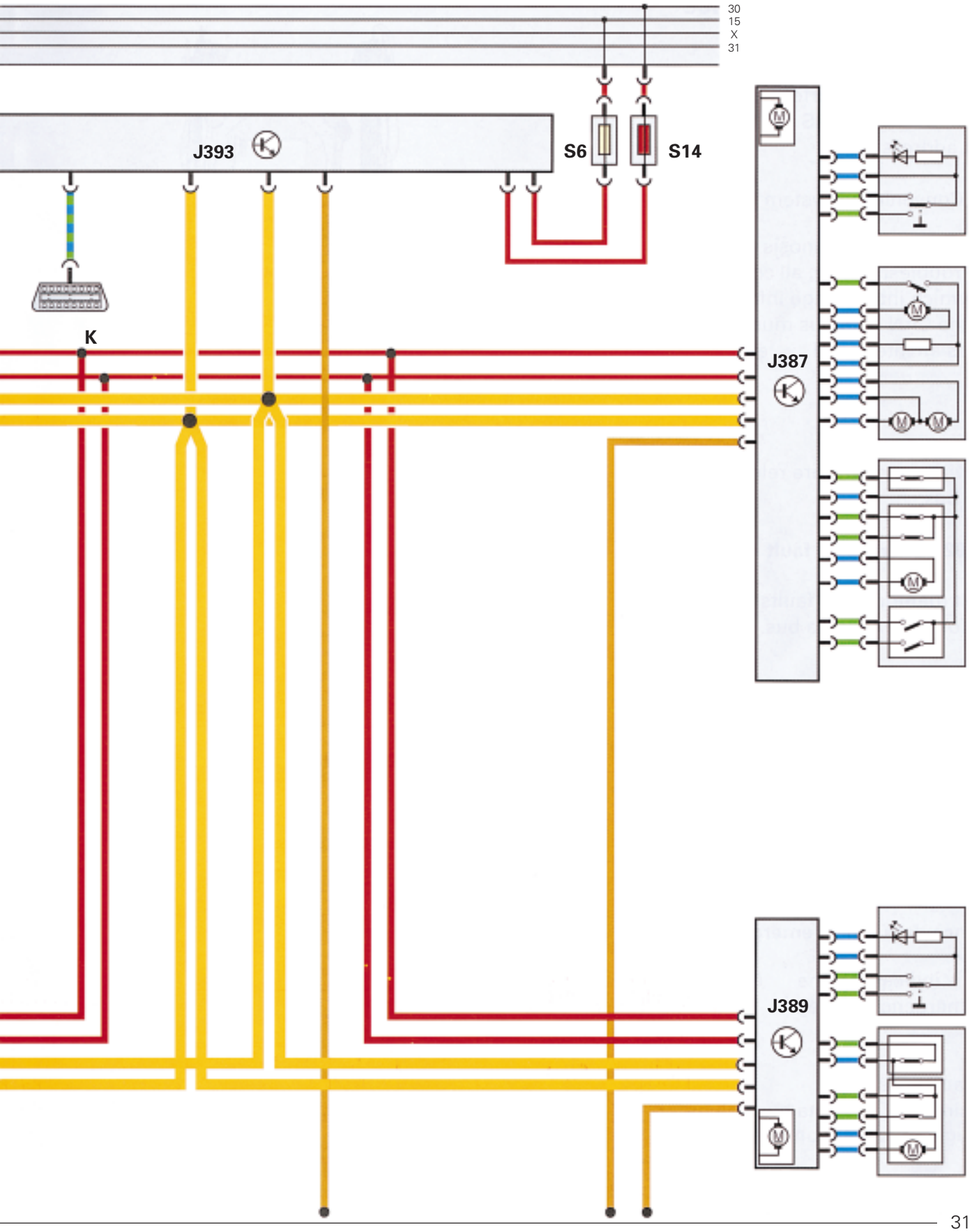
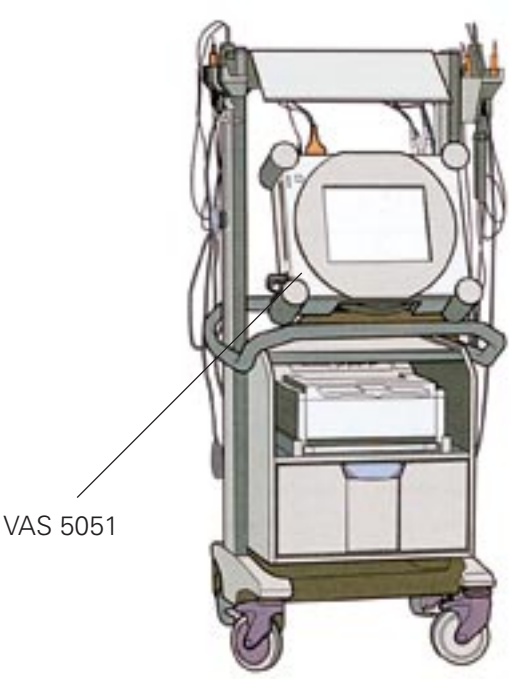
CAN Data Bus in the Convenience System



CAN Data Bus in the Convenience System



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Printout on V.A.G. 1551 printer
01328 Convenience data bus

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Printout on V.A.G. 1551 printer
01329 Convenience data bus in emergency running mode

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The Self-Diagnosis of the CAN Data Bus in the Convenience System

Self-diagnosis is performed with V.A.G. 1551/52 or with VAS 5051 under the following address word:

46 "Convenience system"

During self-diagnosis and troubleshooting, all control modules which interchange information with the CAN data bus must be regarded as an integrated system.

The following functions are relevant to the CAN data bus:

Function 02 - Interrogate fault memory

In the fault memory, two faults are indicated specially for the CAN data bus.

Convenience data bus
This fault is set if data transfer between two or more control units fails.

Possible fault causes are:
- Defective control modules
- Open circuit in both data bus lines or in plug and socket connections

Convenience data bus in emergency running mode
This fault is indicated if the CAN data bus has entered emergency mode.

Possible fault causes are:
- Open circuit in one data bus line or in a plug and socket connection

Function 08 - Read measured value block

Display group number 012 - **Central control unit** - displays four display fields relevant to the data bus.

Display field 1: Check bus
This field indicates whether the data bus is OK or faulty (e.g. fault in single wire).

Display field 2: Equipment front
This field indicates which front control modules are installed and participate in data transfer.

Display field 3: Equipment rear
This field indicates which rear control modules are installed and participate in data transfer.

Display field 4: Accessories
This field indicates whether the seat and mirror adjustment memory system is installed. Both systems (convenience system and memory system) interchange data.

Direct CAN data transfer currently cannot be checked using the available workshop facilities.

Display Group 012 - Central Control Unit					
Read measured value block 12 →				◀ Display on monitor	
xxx	xxx	xxx	xxx	◀ Display fields	**Setpoint**
1	2	3	4	Accessories	Memory / empty1)
				Equipment rear	RL RL and RR RR empty1)
				Equipment front	Driver Driver and FP FP empty1)
				Check Bus	Bus OK Bus NOK

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Notes

Knowledge Assessment

An on-line Knowledge Assessment (exam) is available for this SSP.

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

You can find this Knowledge Assessment at:

www.accessaudi.com

From the accessaudi.com homepage:

- Click on the “ACADEMY” Tab
- Click on the “Academy Site” Link
- Click on the ”CRC Certification” Link

For assistance, please call:

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Learning Management Center Headquarters

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