Bus Structures: Frequently asked questions

This text is only intended as a quick overview of the FAQ on bus structures.

1. Why are there so many buses?
2. What is a CAN?
3. What do “High-speed” and “Low-speed” or “High” and ”Low” mean in connection with CAN buses?
4. What are the meanings of “ring”, “star” and “bus” in connection with data buses?
5. What do “sub-bus”, “master” and “secondary” mean?
6. What does “synchronous and asynchronous” mean in connection with bus communication?
7. What is a wake-up / activation wire?
8. Why does the PT-CAN have a wake-up wire on some model series but not on others?
9. What is the purpose of the terminating resistors?
10. What is the correct procedure to measure the terminating resistors in a CAN bus?
11. What do “K-wire”, “TxD1” and “TxD2” mean?
12. What is “D-CAN”, diagnosis-on CAN?
13. What does “BSD” mean: Bit-Serial Data interface?
14. Main characteristics of single wire buses i.e. CAS Bus, LIN, K-Bus protocol, CA bus, BSD, etc.
15. What is “FlexRay”: FlexRay bus system?

1. Why are there so many buses?

In principle there are three answers to this question:

1. In fact there are not so many buses, as: all CAN buses are derived from the original PT-CAN and K-CAN buses.
   - All PT-CAN's, as well as K-CAN2 and K-CAN3 have a high data transmission rate.
   - K-CAN has a low data transmission rate.
   - Many CAN buses in systems (sub-buses) are named according to these systems. This results in a large number of bus names.
   - The K-bus is similar: technically speaking the P-bus and I-bus are identical to the K-bus.
2. The buses have been developed for different data transmission rates.
   - Buses with very high data transmission rates: ***byteflight***, MOST bus, FlexRay and USB
   - Buses with medium data transmission rates: all the CAN buses such as PT-CAN, K-CAN and the related buses
   - Buses with low data transmission rates: e.g. the LIN bus, BSD, etc.
3. Viewed historically, the buses were either developed by various manufacturers or by BMW itself:
   - Bus standards developed by various manufacturers are: CAN, LIN bus, MOST and FlexRay.
   - BMW's own standards are: ***byteflight***, K-bus and K-CAN.

2. What is a CAN?

CAN (Controller Area Network) is a bus standard. CAN was developed in the 1980’s by Robert Bosch GmbH (together with universities).

The aim was to network control units for the drive and suspension.

In order for the control units to be able to communicate with one another a bus standard had to be defined. The bus standard determines how and which messages are transmitted between the control units.

Components of a CAN message are: SOF, CRC, ID, DEL, ACK, KBT, EOF, IFS

- SOF stands for ”Start of Frame”
- CRC means ”Cyclic Redundancy Check” (i.e. check sum comparison)
- ID stands for ”Identification Feature”
- DEL means ”Delimiter”
- ACK stands for ”Acknowledge” (the message is free of errors).
- KBT stands for ”Control Bits”
- EOF stands for ”End of Frame”
- IFS means ”Inter Frame Space”

CAN is currently the most common bus standard at BMW. CAN is a two-wire bus. There are several CAN buses with different data transmission rates in each car. CAN buses with different data transmission rates are connected with one another via gateways (i.e. data interfaces, e.g. JBE or ZGM).

3. What do “High-speed” and “Low-speed” or “High” and “Low” mean in connection with CAN buses?

“High-speed” and “Low-speed” indicate the data transmission rates of the CAN buses. At BMW there are two different data transmission rates for CAN buses:

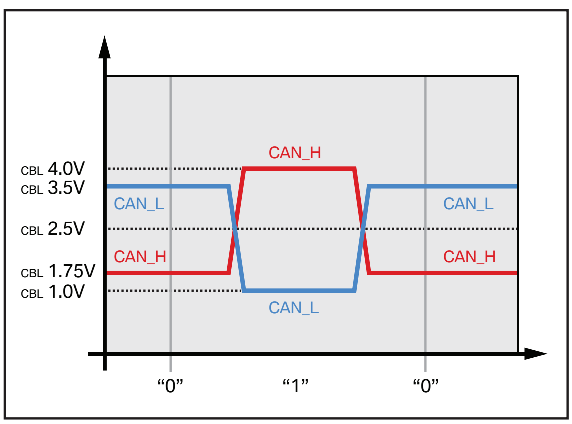
- 100 Kbps i.e. K-CAN
- 500 Kbps e.g. PT-CAN, F-CAN, ICM-CAN, etc.

“High” and “Low” are statements about the two wires of a two-wire bus. For example:

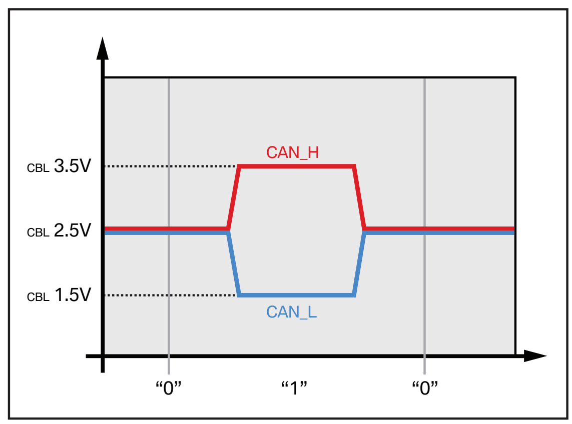
- “PT-CAN-High”: Wire for the signal with the higher voltage value @ Binary 1 (for this bus ~3.5V).
- “PT-CAN-Low”: Wire for the signal with the lower voltage value @ Binary 1 (for this bus ~1.5V).

Data transmission on two wires is secure, “immune” from interference, and supports the electromagnetic compatibility. Although CAN bus communication can use standard cabling without shielding or twisted pair wiring, BMW utilizes the later to reduce EMI (Electro Magnetic Interference).

CAN Low-speed e.g. K-CAN



CAN High-speed e.g. PT-CAN



The figures shows the two levels of data transmission in both the High-speed and Low-speed CAN’s.

The PT-CAN is the ”original” CAN (as developed by Robert Bosch GmbH).

The F-CAN is just a faster CAN bus in the area of the suspension (also used as a sub-bus of the PTCAN).

The K-CAN can continue to work as a single wire bus in the event of failure. If a wire fails in the K-CAN, the data is still transmitted via the second data line. For this reason K-CAN is a very reliable data transmission bus.

4. What are the meanings of “linear”, “ring”, and “star” in connection with data buses?

The individual control units can be arranged differently on a data bus:

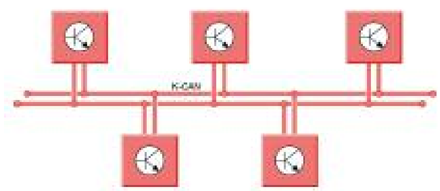
- If the control units are positioned one after another on the bus, this is called: “linear bus topology”.
- If the control units are arranged in a circle, this is called: “ring bus topology”.
- If the control units radiate outwards from a central control unit, this is called: “star bus topology”.

Examples:

CAN buses employ the **linear** bus topology.

- Benefits: Easy wiring and expansion of the bus structures through additional control units.
- Drawbacks: If too many control units are transmitting on this bus there are problems. The bus structure may only be loaded to ~30%. For this reason “sub-buses” are often added.

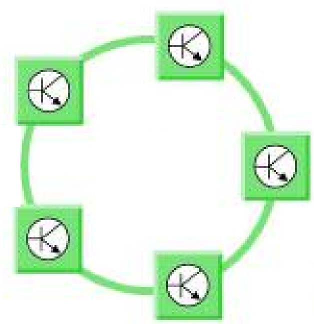
Linear bus topology



MOST bus utilizes the **ring** bus topology.

- Benefits: Predecessors and successors are defined.
- Drawbacks: Fuse protection required in case a control unit fails.

Ring bus topology

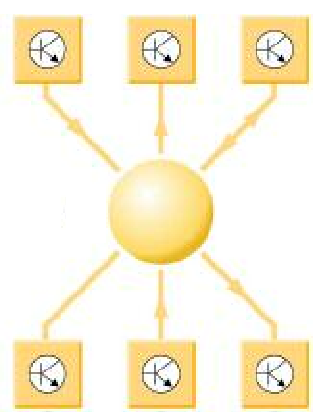


ISIS (ISIS: intelligent safety and integration system) on the former E65/E66 utilized the **star** bus topology.

In the first E65 and E66, the SIM (safety and information module) was the central control module in the star.

- Benefits: High data transmission rates. High security: if one control unit fails it does not affect the others.
- Drawbacks: Complicated wiring.

Star bus topology



5. What do “sub-bus”, “master” and “secondary” mean?

“Sub-buses”, as the name implies, are subordinate buses. Sub-buses are often present in CAN buses so that there is not too much data being transmitted via the CAN bus. If several control units or components belong to one system, a separate bus is branched off for this system.

The control unit on the data interface to other data busses is often called the “master control unit”. The control units within the sub-bus are referred to as “secondary”. The amounts of data transmitted between master and secondary control units only load the sub-bus, which means that the master/primary bus is not loaded.

There are several designations for sub-buses such as “Local CAN” or “Private CAN”. The names themselves typically indicate that they are subordinate buses.

There is also a ”master” and “secondary” on the MOST bus where there is a master control unit that manages all the functions and the “secondary” control units only carry out functions.

Also, the BMW diagnosis system functions as the “master”. During the diagnosis procedure all control units in the vehicle are “secondary”: The control units send data to the BMW diagnosis system. The BMW diagnosis system is the “Master” during diagnosis.

6. What does “synchronous and asynchronous” mean in connection with bus communication?

Some communication busses such as ***byteflight*** and MOST, combine synchronous and asynchronous data transmission so that amounts of data critical for safety can be safely transmitted at any time:

- **Synchronous data transmission:** the individual control units transmit cyclic (regular) messages.
- **Asynchronous data transmission:** in addition to synchronous data transmission, event-driven messages are also transmitted.

The advantage of this combination of data transmission is that all control units transmit data regularly without overloading the bus (overloading is the possible drawback of just having synchronous data transmission). Also, urgent messages can always be sent as high priority.

7. What is a wake-up / activation wire?
The PT-CAN needs an activation wire. Without an activation wire the PT-CAN cannot function. The activation wire (terminal KL_15 wake-up - WUP) is partly integrated in the ribbon cable for the PT-CAN (3-core ribbon cable). In the E90 the activation wire is also partly guided separately and not in the ribbon cable of the PT-CAN's.

8. Why does the PT-CAN have an activation wire on some model series but not on others?
Most vehicles with electrical system **BN2000** have an activation wire for PT-CAN control units. On these vehicles, the CAS (Car Access System) activates the other control units on the PT-CAN with a wake-up signal as soon as terminal KL_15 is switched on. Earlier model series had a PT-CAN without activation wire. This is because on earlier model series (e.g. E85), each control unit had its own input for terminal KL_15. This meant that each control unit was activated via the terminal KL_15 input as soon as terminal KL_15 was switched on. A separate activation wire was not necessary.

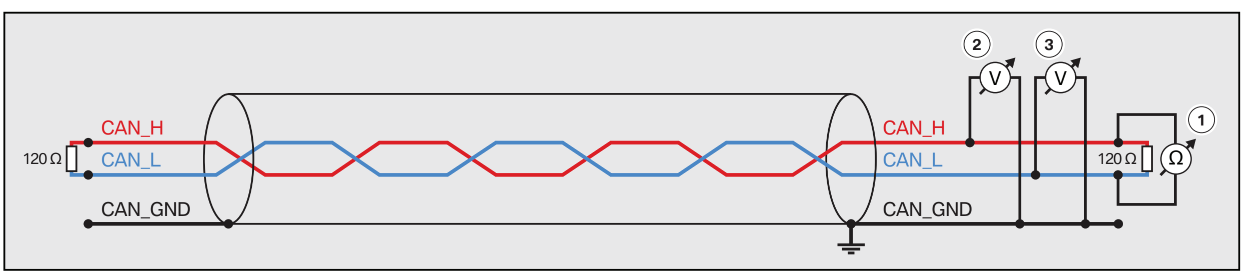
On vehicles with electrical system **BN2020** an activation wire is still used but not shown in the Bus Overview charts.

Not all bus circuits utilize WUP lines. Please refer to the latest SSP. DO NOT rely on the Bus Chart Overview handed in ST401 – BEII as that chart does not contain all the detail found in SSP's.

9. What is the purpose of the terminating resistors?
Buses need terminating resistors to prevent reflections from messages. Without terminating resistors, messages and signals are reflected on the data bus. The result is interference in the transmission of data on the bus with a faulty terminating resistor. The terminating resistors are arranged to suit the data buses. For example: CAN buses employ two 120 Ω resistors connected in parallel thus yielding a total value of 60 Ω.

Depending on the fitted equipment, the terminating resistors may be in different control units.

Simplified diagram of a CAN network



Index	Explanation
1	Bus Resistance Measurement
2	Bus Voltage/Signal Measurement
3	Bus Voltage/Signal Measurement

10. What is the correct procedure to measure the terminating resistors in a CAN bus?

First, it is of paramount importance to turn off all power supplies of the attached CAN nodes and make sure all bus activity has stopped. An easy way to do this is to look at the CAS push button light. If it is not lit, there is no bus activity and you can measure resistance with all of the modules hooked up as they would normally be.

If the CAS light is lit and won't go out, you most likely have issues that are keeping the bus awake, but if you need to measure resistance, you must then disconnect the battery “B-” cable and have the charger disconnected as well. **Any voltage on the bus while attempting a resistance test will result in an incorrect measurement and misdiagnosis!**

Also remember that any activity with doors, locking, latches, etc., will reawaken the bus and cause an inaccurate resistance measurement.

Second, measure the DC resistance between CAN_H and CAN_L at the middle and ends of the network “1” (see figure on previous page). The nominal value is 60 Ω but measured values are typically between 50 and 70 Ω. The measured values should be nearly the same at each point of the bus network.

If the value is below 50 Ω, please check the following:

- there is no short circuit between CAN_H and CAN_L
- there are no more than two terminating resistors (each 120 Ω)
- the nodes do not have faulty transceivers.

If the value is higher than 70 Ω, please check the following:

- there are no open circuits in CAN_H or CAN_L
- the bus system has two terminating resistors (one at each end) and that they are 120 Ω each.

An easy way to know if the CAN bus is “out” is to reference if the CAS light is extinguished. If unsure of bus activity, you can disconnect the “B-” from the Battery and disconnect the battery charger. All “participants” need to be hooked-up. Please refer to the Terminal Resistor table found elsewhere in this book.

11. What do ”K-wire”, ”TxD1” and ”TxD2” mean?

These 3 designations stand for the following different diagnosis wires:

K-wire is the official, internationally applicable description for the diagnosis wire. Vehicles with electrical system **BN2000** have a central gateway and 1 diagnosis wire. The diagnosis wire is on the gateway at pin 7 of the diagnosis socket. The diagnosis wire connects all control units with the BMW diagnosis system (via the central gateway).

A new diagnosis protocol was developed for the electrical system BN2000: BMW Fast Protocol - Fast Access for Service and Testing.

The OBD protocol addresses all control units relevant to emissions. All control units that influence the maintaining of exhaust emissions regulations, are emissions-relevant. The gateway recognizes scan tools from the OBD protocol. When a scan tool is connected to the diagnosis socket, the gateway transmits the OBD protocol on the PT-CAN. Only emissions-relevant control units respond.

TxD1 and TxD2 are data wires for diagnosis on model series without a central gateway (data interface).

- TxD1 is the diagnosis wire for all control units on the powertrain that are not relevant to emissions.
- TxD2 is the diagnosis wire for all emissions-relevant control units on the powertrain. TxD2 transmits all officially prescribed data to the tester's scan tool with the OBD protocol.

All other control units are diagnosed via the gateway control unit (e.g. instrument cluster). Technical background of the two TxD wires was that only the emissions-relevant control units are read off via the diagnosis socket. This eliminated the risk of interference on other control units. These two wires were bridged in the diagnosis socket on the BMW diagnosis system. This allowed the BMW diagnosis system to read off and evaluate both TxD wires at the same time.

12. What is “D-CAN”: Diagnosis-on CAN?

D-CAN (Diagnosis-on CAN) supersedes the previous diagnosis interface in all parts of the world.

The change was done from the previous protocol because of a new legal requirement in the USA that stipulates that all vehicles from Model Year 2008 (MY2008) must be equipped with D-CAN.

D-CAN has a data transmission rate of 500 Kbps and comprises a two (2)-wire cable.

The terminating resistors for the D-CAN are fitted in the DME/DDE and in the wiring harness close to he diagnosis socket. Thus from date of production 03/2007 there are no more terminating resistors in the diagnosis socket cap.

All single wire buses, e.g. LIN/BSD/K-Bus/PA Bus, etc., should be treated the same way while diagnosing. Please refer to the laminated Bus Specification Overview Table for specs on single wire buses.

13. What does “BSD” mean: bit-serial data interface?

BSD refers to “Bit-Serial Data interface” because the bits are not transmitted and received in parallel but rather in series.

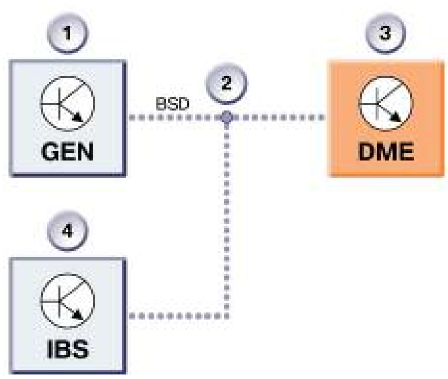
Some examples of BSD usage include DME communication with the following components.:

- Alternator voltage regulation (varies according to version, e.g. E90)
- Intelligent Battery Sensor (depending on model series, e.g. E90)
- Electrical coolant pump (depending on variant, e.g. E90 w/N52)

The following data is interchanged between the DME/DDE and the connected components:

- Functional requirements from the DME/DDE to the components
- Identification data of the components to the DME/DDE
- Operating values of the components and their functions to the DME/DDE
- Fault messages of the components to the DME/DDE

Bit-serial data interface example



Index	Explanation
1	Alternator
2	Bit-Serial Data interface (BSD)
3	Digital Motor Electronics
4	Intelligent Battery Sensor (IBS)

14. Main characteristics of single wire buses i.e. CAS-Bus, LIN, K-Bus protocol, CA-Bus, BSD, etc.

All of our vehicle's single wire buses should be treated the same way with regards to diagnosis in the workshop. Even though the buses may have some design differences, the process for diagnosis will remain the same and this will make for less confusion.

Single wire buses (Secondary buses) are designed with a Master controller (Master modules) that supports the bus voltage. Master modules are located on Primary buses (you can identify them in the short test on ISTA) and you can communicate with them via diagnosis request, i.e. K-CAN I and II, PT CAN etc. The remaining control modules that subscribe to the bus are considered secondary modules and are directed and diagnosed through the Master. The secondary modules will not support any bus communication without the Master.

Like the Primary buses, the voltages used on the Single Wire buses are binary in design and have to meet a voltage value to express either Binary 1 or 0. Voltage above the 9 volt level equals binary 0 (generally we see the voltage around **12.6** volts). When the module communication wants to change to binary 1, then the voltage will pull low to around 900 mV-1100 mV (0.9 volts – 1.1.volts). Voltages that do not meet these values are not compliant.

Do not use a multi-meter to diagnose the bus authenticity since the meter displays average voltages, instead use an approved Oscilloscope.

Example of message for single wire buses (secondary control units) structure on LIN-bus

The identifier byte contains the following information:

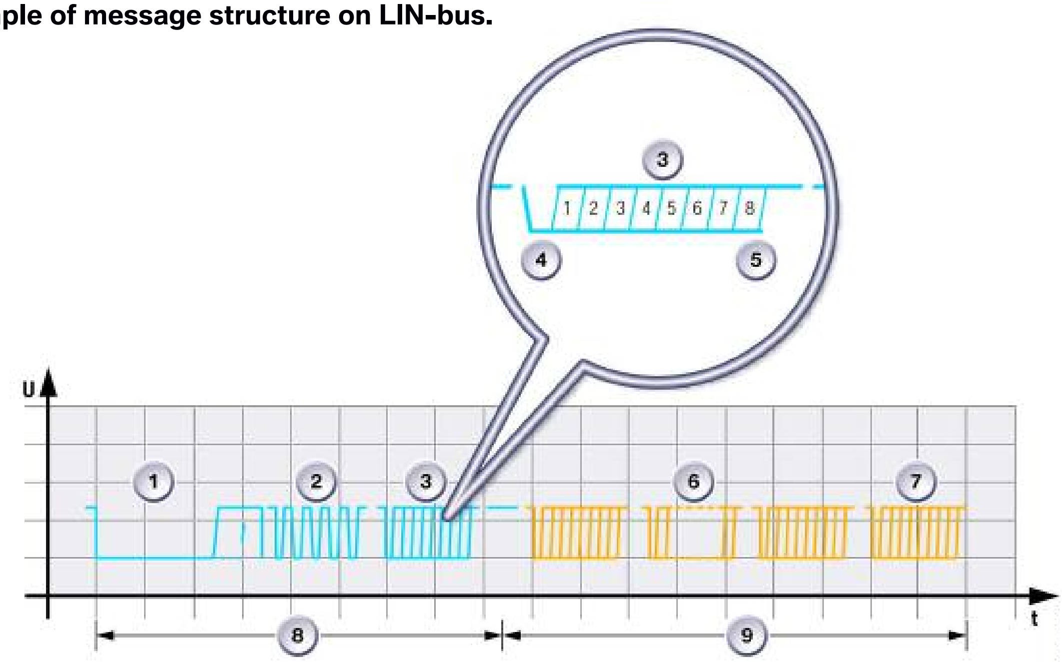
- Address of the secondary control unit
- Message length
- Two bits for data safeguarding

The identifier determines whether the master sends data to the secondary control unit or whether it expects an answer from the slave. The main body contains the message for the secondary control unit. The checksum is located at the end of the message.

The checksum ensures effective data safeguarding during transmission. The checksum is created by the master via the data bytes and is attached at the end of the message.The current messages are transmitted cyclically by the LIN-bus master.

The LIN-bus secondaries wait for commands from the LIN-bus master and communicate with it only on request.

Example of message structure on LIN-bus.



Index	Explanation	Index	Explanation
1	Synchronization pause	6	Data field
2	Synchronization range	7	Checksum
3	Identifier	8	Message header
4	Start	9	Message body
5	Stop		

15. What is "FlexRay": FlexRay bus system?

FlexRay is a new communication system designed to meet the heightened demands of the future networking of current and future functions in the vehicle. Growing technical demands on a communication system for networking control units in the vehicle and recognition of the fact that an open solution that can be standardized is desirable for infrastructure systems - these were the motives for developing FlexRay.

The FlexRay consortium was founded to develop FlexRay. This included nearly all major automobile manufacturers and suppliers worldwide, plus semiconductor manufacturers and systems experts for the field of communications technology.

FlexRay offers an extremely efficient, real time data transfer between the electrical an mechatronic components of the vehicle. With a data transfer rate of **10 Mbps**, FlexRay is significantly faster than the data buses employed in the areas of body and powertrain/suspension on today's vehicles.