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Bus structures: Frequently asked questions

Frequently asked questions on bus structures: All models from E38 and MINI

This text cannot provide an exhaustive picture of data transmission. The following frequently asked questions are responded to briefly:

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 ”slave” mean?
6. Which bus standards are ”K-bus” and ”P-bus”?
7. Why is there an ”I-bus Japan”?
8. Why can the I-bus and the K-bus also be sub-buses?
9. What is a synchronous or asynchronous channel on a MOST bus?
10. What does ”synchronous and asynchronous” mean in connection with the **byteflight**?
11. What is an activation wire?
12. Why does the PT-CAN have a wake-up wire on some model series but not on others?
13. What is the purpose of the terminating resistors?
14. What do ”K-wire”, ”TxD1” and ”TxD2” mean?
15. What does ”BSD” mean: bit-serial data interface?
16. What is ”D-CAN”, diagnosis-on CAN?
17. Why is there an ”S-CAN”: sensor CAN?
18. 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.

   The PT-CAN has a high data transmission rate.

   The 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 and FlexRay
   - Buses with medium data transmission rates: the two CAN buses PT-CAN and K-CAN and related buses
   - Buses with low data transmission rates: e.g. the LIN bus

3. Viewed historically, the buses were either developed by various manufacturers or by BMW themselves:

   - 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 1980s 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 commonest 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).

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 kBit/s: K-CAN
- 500 kBit/s: PT-CAN, F-CAN

”High” and ”Low” are statements about the two wires of a two-wire bus. e.g.

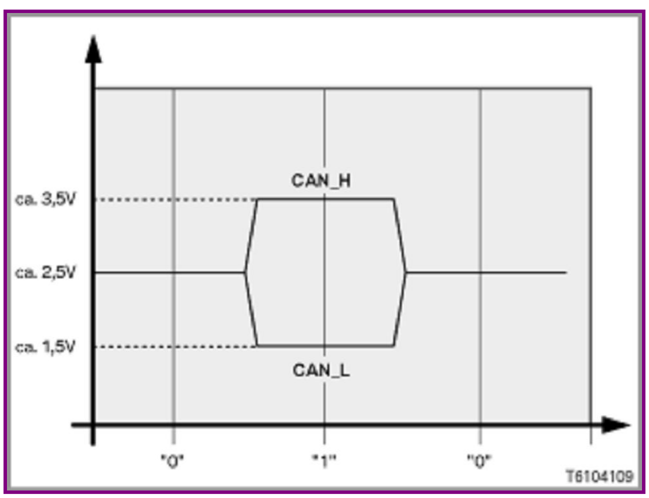
- ”K-CAN-High” or ”PT-CAN-High”:

  Wire for the signal with the higher voltage value.

- ”K-CAN-Low” or ”PT-CAN-Low”:

  Wire for the signal with the lower voltage value.

Data transmission on two wires is secure, immune from interference, and supports the electromagnetic compatibility.



CAN High-speed: PT-CAN or F-CAN

The figure shows the two levels of data transmission in the PT-CAN or F-CAN.

- CAN_H, i.e. CAN-High is the data wire for the signal with the higher voltage value.
- CAN_L, i.e. CAN-Low is the data wire for the signal with the lower voltage value.

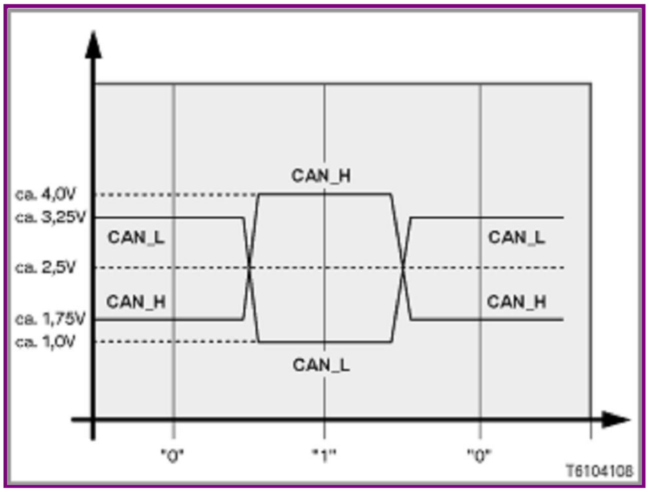
The PT-CAN is the ”original” CAN (as developed by Robert Bosch GmbH).

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

CAN Low-speed: K-CAN

The figure shows the two levels of data transmission in the K-CAN (see above).

The K-CAN is a reduced PT-CAN: The data



transmission rate is lower than for the PT-CAN.

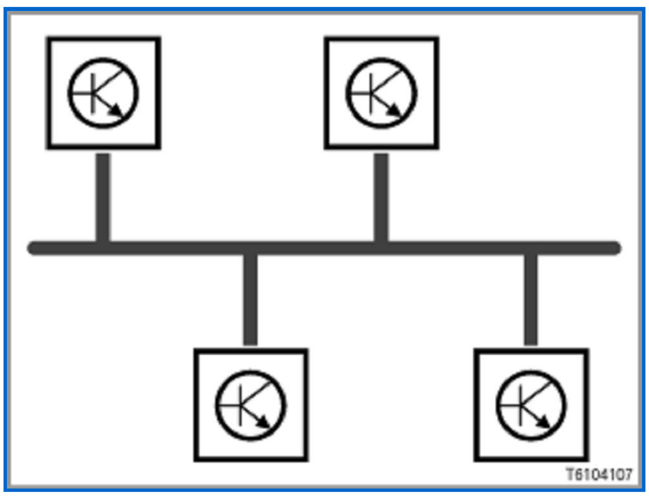
Note: The K-CAN can continue to work as a single wire bus in the event of failure.

If a wire fails in the K-CAN, the data are still transmitted via the second data line. For this reason the K-CANs are very secure against failure.

4. **What are the meanings of "ring", "star" and "bus" 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".
- If the control units radiate outwards from a central control unit, this is called: "star".
- If the control units are arranged in a circle, this is called: "ring".

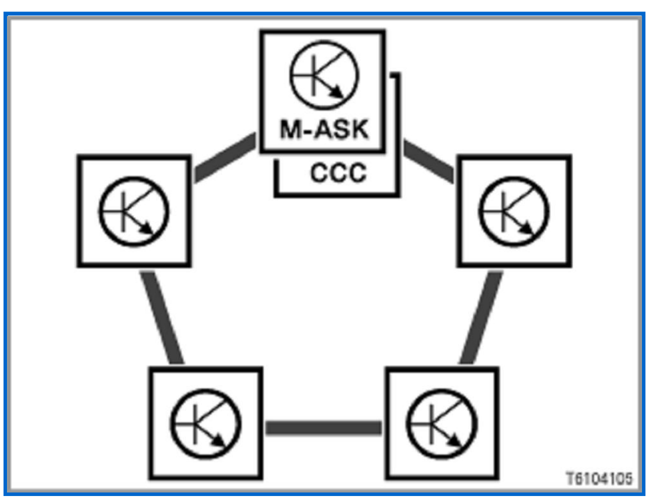


Arrangement of **linear** control units

CAN buses have this structure.

- 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 approx. 30 %.

  For this reason "sub-buses" are often added (see below).



Arrangement of control units in a **ring**

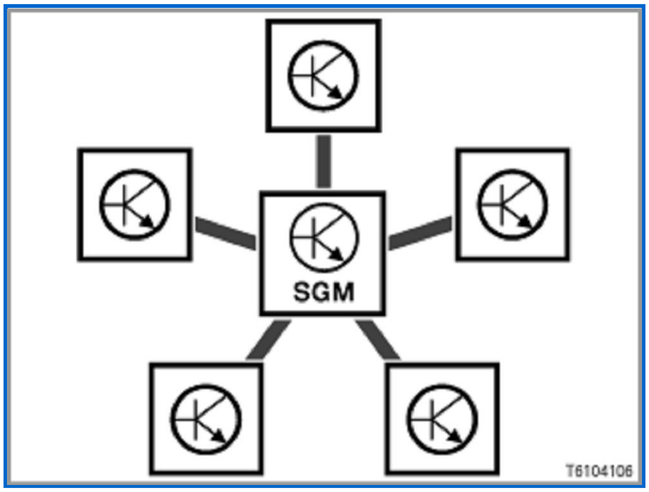
The MOST bus at BMW has this structure.
M-ASK or CCC are the gateways to the remaining buses.

- Benefits:

  Predecessors and successors are defined.

- Drawbacks:

  Fuse protection required in case a control unit fails.



Arrangement of control units in a **star**

The ISIS has this structure on the BMW E65 and E66 (ISIS: intelligent safety and integration system).
The SGM (safety and gateway module) is the central control unit in the star.

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.

5. **What do ”sub-bus”, ”master” and ”slave” mean?**

   ”Sub-buses” are subordinate buses. Sub-buses are often present in CAN buses so that it is not necessary to transmit too much data via the CAN bus. If then 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 on the sub-bus are ”slaves”.

   The amounts of data transmitted between master and slave only load the sub-bus. The superior bus is not involved.

   There are several designations for sub-buses: ”Local CAN”, ”Private CAN”. The names themselves indicate that they are subordinate buses.

   There is also a ”master” and ”slaves” on the MOST bus: a superior control unit is the master control unit. The master control unit controls all functions. The ”slaves” only carry out functions.

   For diagnosis the BMW diagnosis system functions as the ”master”. During the diagnosis procedure, all control units in the vehicle are the ”slaves”: The control units send data to the BMW diagnosis system. The BMW diagnosis system is the ”Master” during diagnosis.
6. **Which bus standards are ”K-bus” and ”P-bus”?**

   K-bus and P-bus are BMW's own developments with a special bus standard.

   The P-bus is the K-bus in the are of the general module and sliding/tilting sunroof. The P-bus has been developed because the K-bus was already fully loaded to capacity (E38).
7. **Why is there an ”I-bus Japan”?**

   In the Japanese national version of the E65 and E66, JNAV and TEL have **not** been adapted for the MOST bus (for technical reasons). These two control units are connected to the I-bus Japan and connected with the MOST bus via the FBI (FBI: Flexible Bus Interface).

8. **Why can the I-bus and the K-bus also be sub-buses?**

In principle every bus can become a sub-bus to another bus. This requires that the sub-bus is connected to the superior bus with a gateway (data interface). 2 examples:

- The I-bus is a sub-bus in the E87. The I-bus connects the MRS and TCU control units.
- The K-bus in the E87 and E90 is a sub-bus from the CAS to the TAGE.

  E83, E85, E86, E87, E90: The K-bus is a sub-bus from the DWA to the SINE.

Note: Sub-busses are shown with dotted lines in the illustrations.

I-bus, K-bus and F-CAN may also be sub-busses. Sub-busses are shown with dotted lines in the illustrations.

9. **What is a synchronous or asynchronous channel on a MOST bus?**

The MOST bus has various channels for data transmission in the fibre-optic cable:

- Synchronous data transmission: TV (data transmission of digital audio signals), CD, DVD ...
- Asynchronous data transmission: NAV and TV (transmission of teletext and list of stations, for instance).
- Transmission of monitoring data: status, diagnosis, messages from the gateway.

10. **What does ”synchronous and asynchronous” mean in connection with the byteflight?**

The **byteflight** combines 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 synchronous and asynchronous data transmission in the **byteflight**:

All control units transmit data regularly without overloading the **byteflight** (overloading is the possible drawback of synchronous data transmission).

Urgent message can always be sent as high priority.

11. **What is an activation wire?**

The PT-CAN needs an activation wire. Without an activation wire the PT-CAN cannot function. The activation wire (terminal 15 wake-up) 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-CANs.
In the system overviews in this technical service information bulletin (SBT) the activation wire is shown as a line between the two wires of the PT-CAN: PT-CAN-High and PT-CAN-Low.

12. **Why does the PT-CAN have an activation wire on some model series but not on others?**

    Most vehicles with electrical system 2000 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 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 15. This meant that each control unit was activated via the terminal 15 input as soon as terminal 15 was switched on. A separate activation wire was not necessary.

13. **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 concerned:

    The PT-CAN needs different terminating resistors than the F-CAN.

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

14. **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 2000 have a central gateway and 1 diagnosis wire (e.g. BMW 7-Series from 2000, BMW 5-Series and BMW 6-Series). 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 2000: BMW Fast Protocol - Fast Access for Service and Testing.

      This diagnosis protocol is transmitted to all control units with a data transmission rate of 115 MBit/s.

      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 recognises 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

      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: 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.

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

BSD means ”bitserial data interface” because the bits are not transmitted and received in parallel but rather in series.

The engine control unit communicates with the following components via the bitserial data interface (depending on model series, engine and equipment fitted):

- Alternator

  - Alternator voltage regulation

    The bitserial data interface supports the regulation of the alternator voltage as follows: Every time the engine is started, the engine control unit checks the alternator via the BSD. The alternator transmits data about the model, output and manufacturer to the engine control unit.

    From this, the engine control unit computes the nominal values for the alternator.

  - Charge-current indicator light

    On vehicles with BSD, the alternator is not directly connected to the charge-current indicator light. The alternator only transmits data to the engine control unit. The charge-current indicator light is activated by the engine control unit.

    Signal path: Alternator -> BSD -> DME or DDE -> Central gateway (SGM or ZGM) -> Instrument cluster

- Combustion preheating control unit

  The combustion preheating control unit and DDE control unit communicate as follows via the bitserial data interface:

  - The DDE control unit specifies the heat output needed from the glow plugs in the combustion preheating system (depending on coolant temperature and on-board supply voltage). The DDE control unit stores data from the combustion preheating control unit that is relevant to diagnosis.
  - The combustion preheating control unit monitors the actuation of the individual glow plugs. The combustion preheating control unit detects faults in the glow plugs (e.g. short circuit to earth, open circuit, temperature at output stage too high). The combustion preheating control unit

reports any such faults to the DDE control unit. The DDE control unit will store an entry in the fault memory.

- **Electrical coolant pump**

  > Only with engine N52

  The N52 engine has an electrically driven coolant pump (no longer mechanically driven by drive belt). The electrical coolant pump is regulated by the engine control unit (via the BSD) according to actual requirements.

- **Oil condition sensor**

  The oil condition sensor registers the engine oil quality, level and temperature. These data are transmitted to the engine control unit via the BSD. The engine control unit evaluates these data.

16. **What is ”D-CAN”: Diagnosis-on CAN?**

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

The background for the conversion is a new legal requirement in the USA that stipulates that all vehicles from Model Year 2008 must be equipped with D-CAN.

D-CAN has a data transmission rate of 500 kBit/s and comprises a 2-wire cable.
For diagnosis, an optical programming system (OPS) or an optical testing and programming system (OPPS) and a new adapter cable (with green marking and the lettering ”CAN included”) are needed, as the diagnosis head does not have a D-CAN connection.

17. **Why is there an ”S-CAN”: sensor CAN?**

The sensor CAN connects the control unit for longitudinal dynamics management with the long range sensor and the close-range sensors.
The S-CAN was needed because of the large volume of data from the radar sensors.
This volume of data would have exceeded the transmission capacity of the existing bus systems.

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

Benefits of FlexRay:

- High bandwidth
    - Data transfer rate of 10 MBits/s (cf. CAN: 0.5 MBit/s)
    - Short cycle time of 2.5 ms (cf. CAN: 10 ms)
    - Simple and easy-to-follow bus structure possible
      (e.g. avoidance of gateways)
- Fixed-time, describable operation (determinism)
    - Guaranteed real-time transmission of messages (cf. CAN: not capable of real time)
    - Control unit synchronisation

      The spatially spread control system allows nominal values for various control units to be adopted at the same time.
- High availability and security
    - due to determinism and optional 2nd channel

      (2nd channel for redundant data transfer)
- Simplified system integration