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Introduction to Bus Systems

Subject **Page**

Initial Print Date: 12/04 Revision Date:

Introduction to Bus Systems

Model: All from E38 to Present

Production: All

OBJECTIVES

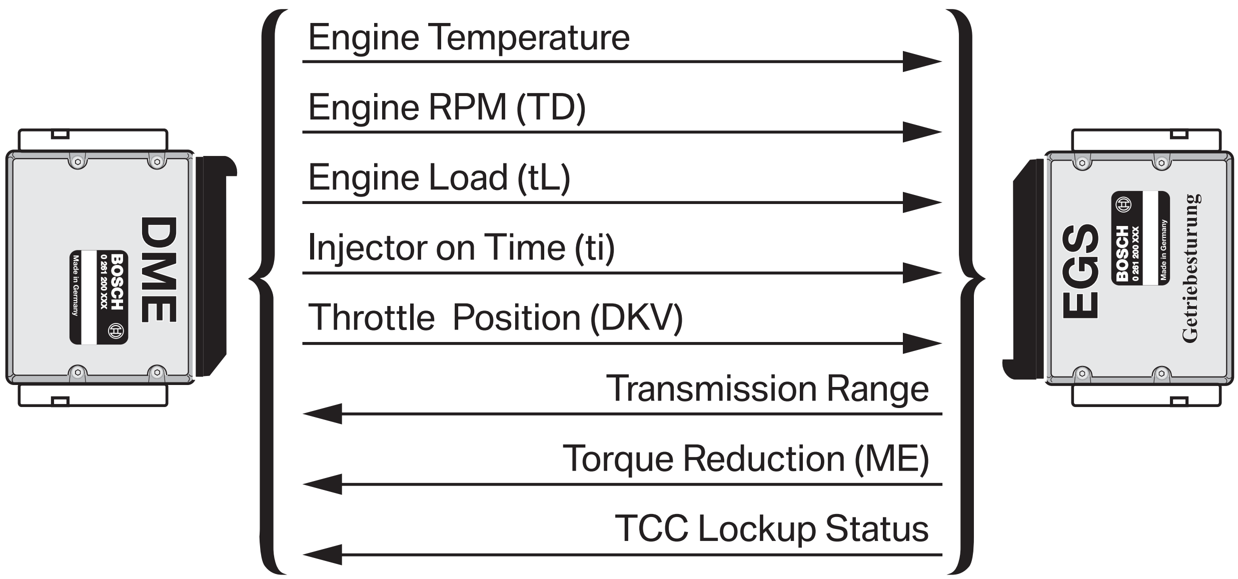
After completion of this module you will be able to:

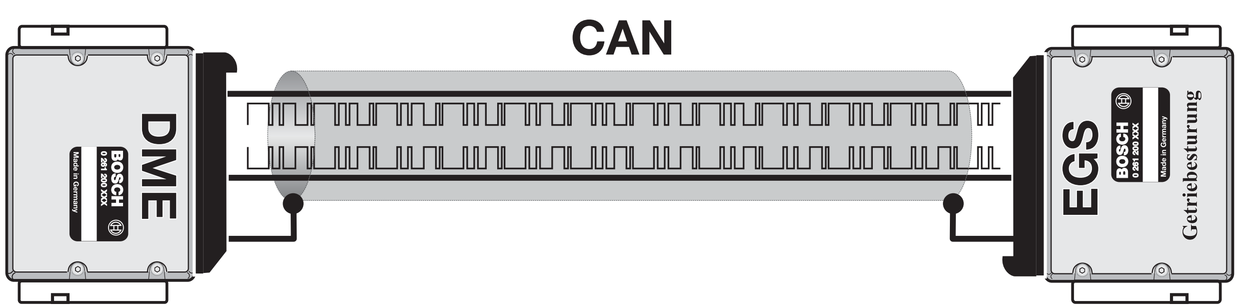
- Describe the operation of a basic bus system.
- Understand how signals and sensor information are shared between control units in a bus system.
- Identify bus systems currently used in BMW Group vehicles.
- Understand how bus networking technology is applied in BMW vehicles.
- Understand diagnostic techniques.

Introduction to Bus Systems

Up until the introduction of the E31, all of the information transferred between control units was transmitted on dedicated signal lines. As the various electronic systems grew more complex, the size of the wiring harness increased beyond practical limits.

Signals such as engine RPM, coolant temperature, throttle position, road speed etc. each used a dedicated signal line going to the control module that required this information. Each of these lines differed in the method of signal transmission. Some of the methods used were variable duty cycle, switched DC signals and signals with variable frequencies. This created a need for larger and more complex wiring harnesses.





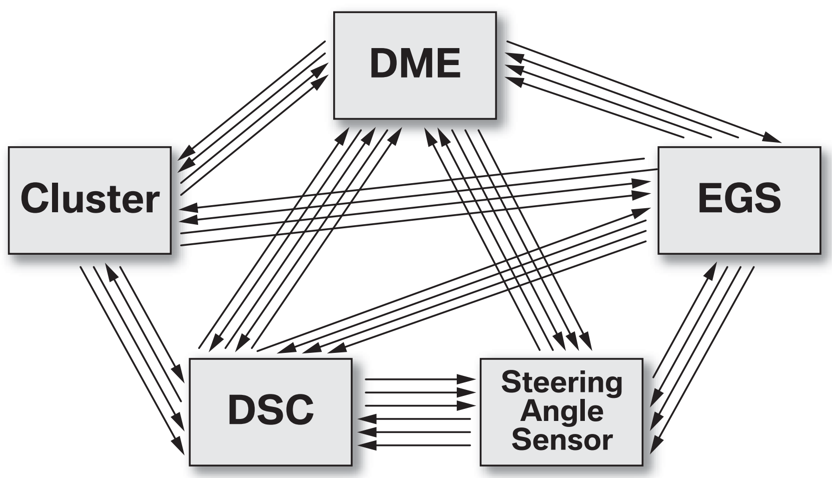
A solution to this problem was found by introducing bus networks to BMW Group vehicles. A bus system uses multiplexing technology similar to that used in the electronics and telecommunications industry. Multiplexing is a system of transmitting several messages on the same circuit or channel.

This technology allows control modules to transfer data bi-directionally at high speed and enables control modules to share sensor information. This also allows control modules to send and receive control commands at a faster rate than with conventional methods.

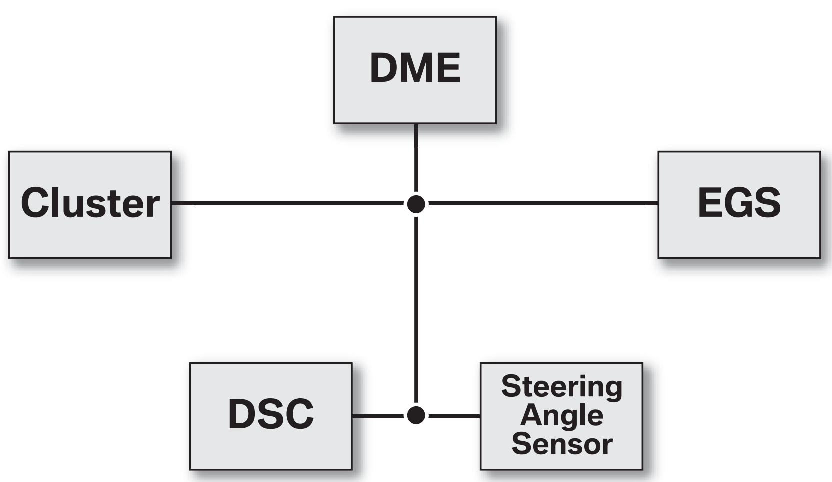
With the amount and complexity of features now available in modern vehicles, multiplexing is a necessary technology. There are numerous benefits to in-vehicle bus networks such as:

- A reduction in the size of the wiring harness by decreasing the number of interfaces between control units to one or two wires.
- Greater system reliability by reducing the number of connectors and components.
- A reduction in the number of redundant sensors by allowing the sharing of sensor information.
- Reduction of costs for components, assembly and troubleshooting.
- Flexibility in system configuration for addition of new systems.

Control module communication using individual signal lines



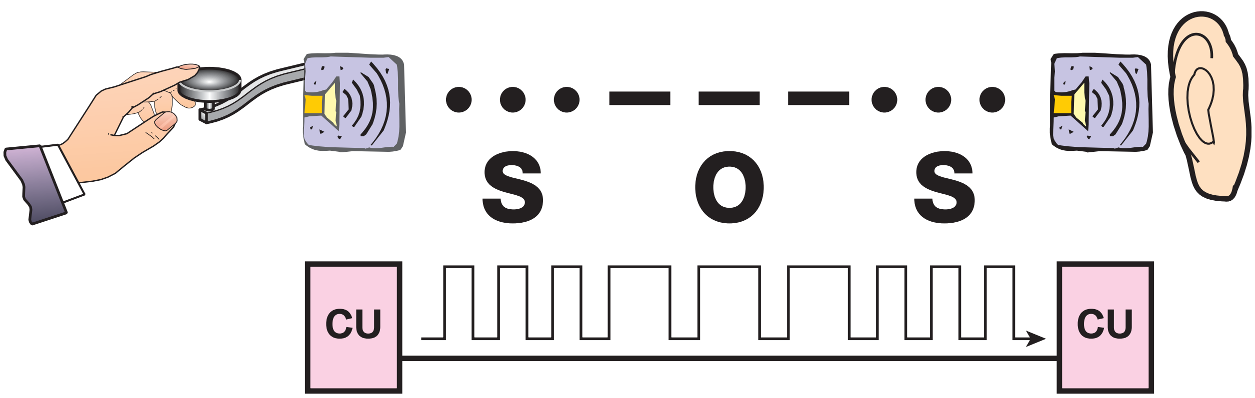
Control module communication using a bus network



Multiplexing

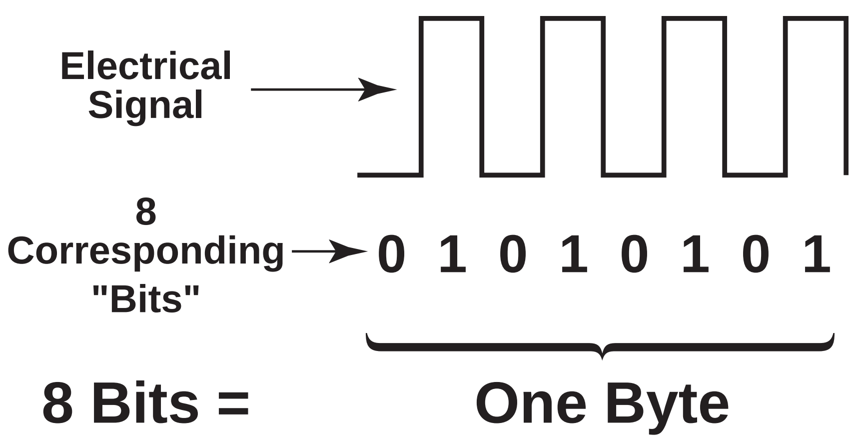
Multiplexing relies on the use of digital communication between control units. A digital signal consists of a series of high and low voltage signals which represent “bits” of information.

Using the example of morse code for explanation, the letters SOS are represented in morse code as three dots - three dashes - three dots. Expressed as an electrical signal SOS would be represented as three short pulses - three long pulses - three short pulses.



The basis for digital communication is binary code. Binary code uses only 2 digits - 0 and 1. Electrically, 1 is represented by a voltage pulse and 0 is represented by a low voltage signal usually 0 volts.

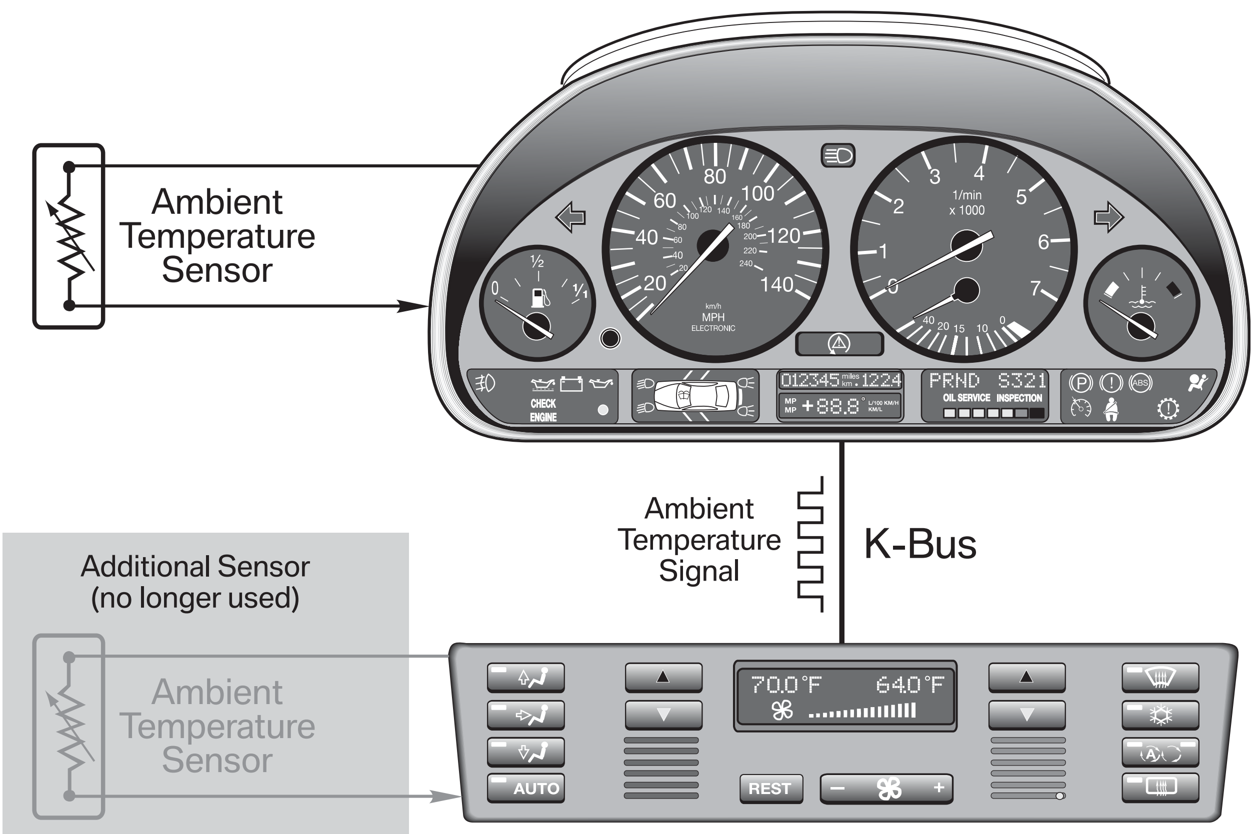
In digital communication, each pulse represents a “bit” of data. Eight “bits” of information in a series of pulses makes up one “byte”. A byte represents a character in a line of information (data).



In order to illustrate multiplexing in a vehicle application, an example of a K-Bus circuit will be used. The K-Bus (Body Bus) was introduced in the E38 as a low speed data transfer bus. One of the benefits of multiplexing is sensor sharing. The outside (ambient) temperature circuit is an example of “sharing” sensor information.

In the illustration shown below, the ambient temperature sensor is an analog input to the instrument cluster. The temperature information is used by the cluster for the outside temperature display for the driver. The outside temperature information is also needed by the climate control system (IHKA) for temperature control and additional functions.

In previous models (before bus systems), the IHKA required an additional dedicated outside temperature sensor. Using multiplexing principles, the K-Bus can transfer the temperature information (as well as additional data) from the cluster to the climate control system which eliminates the need for an additional sensor.



Bus Communication Speeds

Data must be transmitted at high speed in order to make digital communication practical. The speed of these signal is referred to as the data rate (formerly baud rate). Depending on the type of bus network used, data can be transmitted from 9600 bits per second (9.6k/bps) to 500K bits per second (500K/bps).

Current fiber optic systems can transmit and receive data up to 22.5 M/bps.

Model	Bus	Data Rate	Structure
E38	I/K/P Bus	9.6 K/bps	Linear
E38	CAN	500 K/bps	Linear
E38	D-Bus	9.6 K/bps	Linear
E65	K-CAN-S	100 Kbps	Linear
E65	K-CAN-P	100 Kbps	Linear
E65	PT-CAN	500 Kbps	Linear
E65	MOST	22.5 Mbps	Ring
E65	byteflight	10 Mbps	Star
E65	Sub-Busses	9.6 Kbps	Linear

Depending on the system requirements, bus networks communicate at different speeds. Systems such as powertrain control require a large amount of data to be transferred due to constantly changing values such as RPM, road speed and throttle position etc. Therefore the CAN-Bus (or PT-CAN) operates at 500K/bps.

Faster communication speeds are required for video and audio signals. Therefore, the MOST-Bus is designed to handle these needs and can communicate at 22.5 M/bps.

To accurately describe the speed of data transmission the term “bps” (bit per second) is used. This is not to be confused with baud rate. Baud rate refers to the rate that a change of state occurs on a signal line. Any voltage change on the signal line is a change of state, but this does not relate directly to the amount of bits per second. In other words, more that one bit can be transferred per baud. This is dependent upon the type of communication protocol.

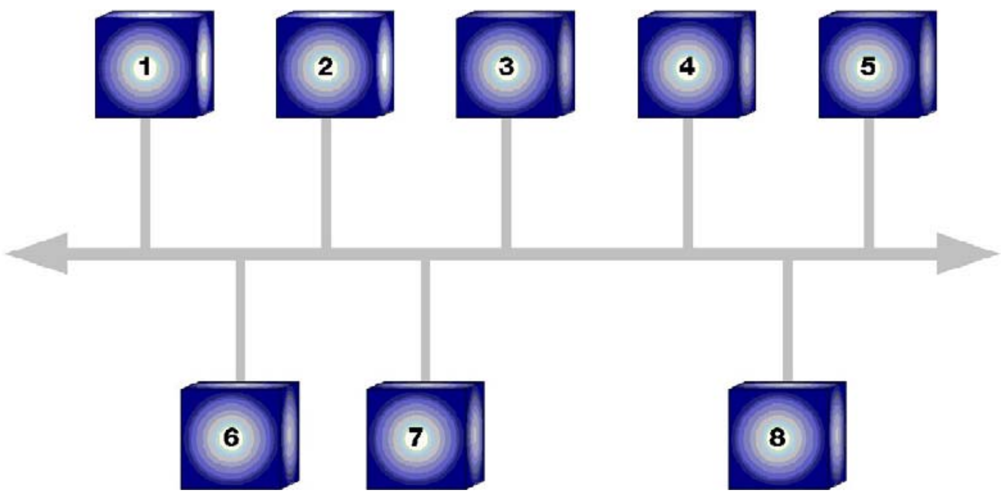
In this course, data communication speed will be referred to as bit per second (bps). A “bit” is an abbreviation for binary digit. A bit is the smallest information unit that a computer can process. A series of 8 bits make up one byte and a series of bytes make up a bus telegram message.

Bus System Structure

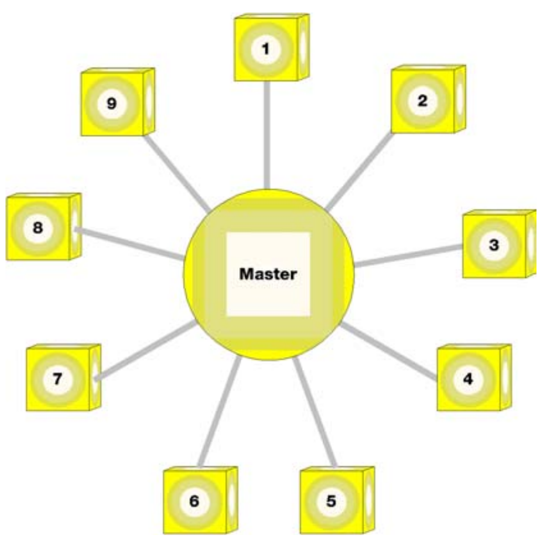
There are 3 possible arrangements for bus system structure in BMW vehicles. They are:

- Linear (or Tree Structure)
- Ring
- Star

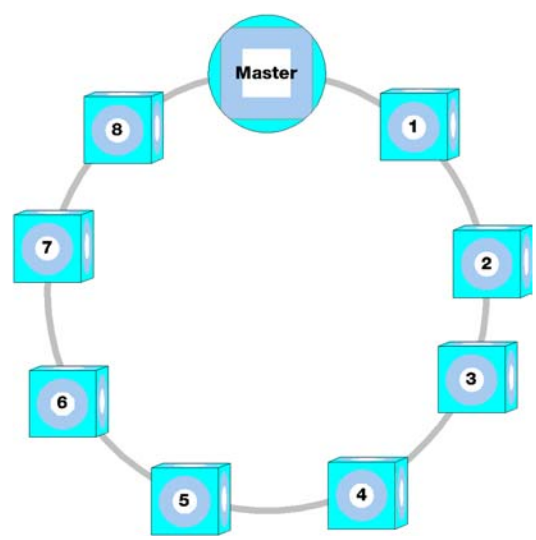
The linear bus structure is the most common arrangement. Up until the introduction of the E65, the linear structure was used exclusively. The 2 other bus structures are currently used for fiber optic networks. The ring structure is used on the MOST-Bus and the star structure is used on the ***byteflight*** system.



Linear or "Tree" Structure



Star Structure



Ring Structure

Bus System Application

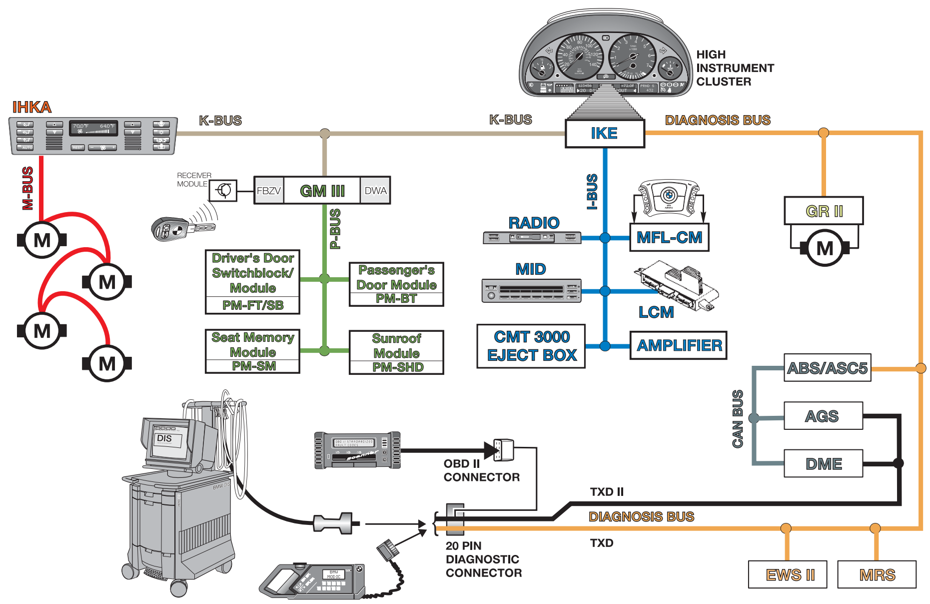
In the following pages of this course and subsequent courses, all BMW bus systems will be discussed. Starting from the earliest bus networks up to the latest fiber optic networks used today. Below is a listing by model of the major bus networks in use. (Some sub busses are not shown)

	TXD/RXD	D-Bus	CAN-Bus	I-Bus	K-Bus	P-Bus	M-Bus	K-Can (P&S)	PT-CAN	MOST-Bus	*byteflight*	LIN-Bus	Notes
E31	X		X	X									CAN-Bus used on M60, M62 and M73 engines.
E32	X		X										CAN-Bus used on M60 engine.
E34	X		X										CAN-Bus used on M60 engine.
E36	X		X				X						CAN-Bus used on M52 engine. M-Bus used from 96 model year.
E38	X	X	X	X	X	X	X						New bus systems introduced in 95 model year (D, K, P and M-Bus)
E39	X	X	X	X	X	X	X						I-Bus used on vehicles with high version cluster.
E46	X	X	X		X		X					X	LIN-Bus added in 2003 model year (face lift). CAN changed PT-CAN in 2000 model year.
E53	X	X	X	X	X	X	X						I-Bus used on vehicles with high version cluster.
E65/E66		X					X	X	X	X	X	X	E65 introduced new bus systems in 2002. First BMW to use fiber optics.
E60		X						X	X	X	X	X	K-CAN S and K-CAN P are combined into K-CAN. LIN used on IHKA, AHL and driver's switch block.
E63/E64		X						X	X	X	X	X	K-CAN S and K-CAN P is combined into K-CAN.
E83		X			X		X		X	X		X	E83 Does not use byteflight. LIN-Bus is used on

Diagnosis Bus (D-Bus)

The D-Bus is actually the oldest bus system used in BMW vehicles. It is used as a serial communications bus to transmit data between the DISplus or GT-1 and the connected control units for diagnosis purposes.

The D-Bus was introduced as TXD (and RXD) in 1987. The term D-Bus was adopted with the introduction of the E38 in 1995, however it is still referred to as TXD in the ETM.



The control unit subject to diagnosis is selected by sending a diagnosis telegram to the control unit address. By request from the diagnosis equipment (DISplus/GT-1), the control unit will transmit information such as the contents of the fault memory or activate a control unit output.

All modules in the vehicle are not connected directly to the D-Bus, some systems are connected through a gateway such as the IKE or cluster. The gateway handles all diagnostic "traffic" and routes the necessary information to the correct bus system.

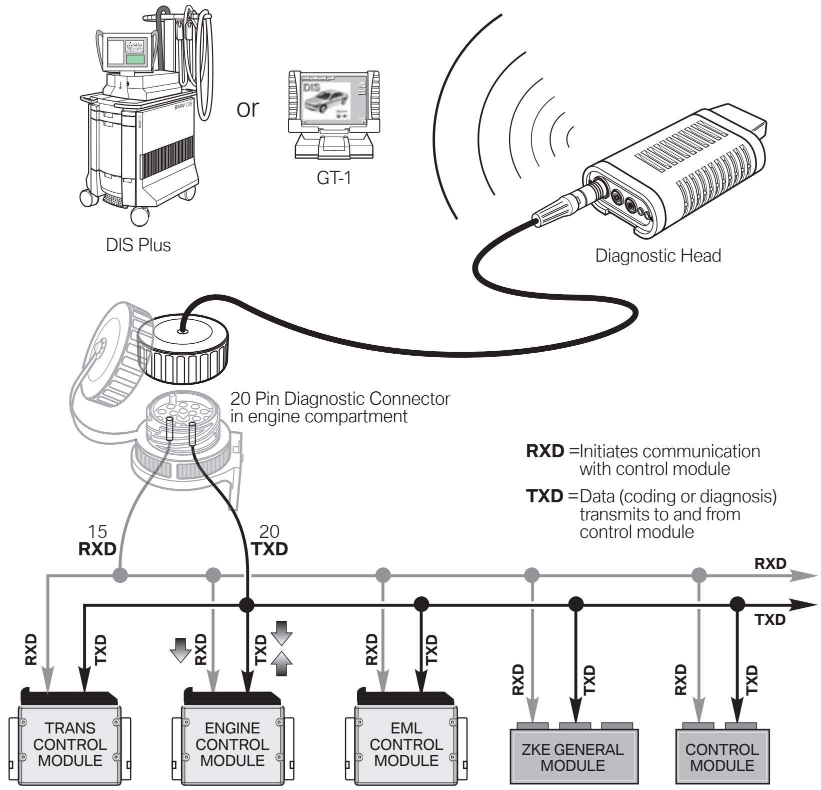
The D-Bus is only active when the DISplus or GT-1 is connected to the diagnostic socket and communicating. Data over the D-Bus operates at a rate of up to 9.6 Kbps (9600 bits per second) on earlier vehicles. The D-Bus on current models (from E65) operates at 110 K/bps.

The D-Bus connects various diagnoseable control units to the DISplus or GT-1 via the diagnostic connector. Earlier vehicles also used a second diagnosis line called RXD to allow the diagnostic equipment to establish communication. RXD is not a bus line but a one way communication link used to wake up the diagnosis of the connected control unit.

Diagnostic Connector

There have been numerous changes to the diagnostic connector since it's introduction in 1988. Early vehicles until the 2001 model year used the 20-pin diagnostic connector located in the engine compartment. On vehicles equipped with the 20-pin connector, diagnostic communication is carried out through the TXD/RXD interface (D-Bus).

RXD is a 12 volt one-way digital signal which is sent to the module subject to diagnosis. This signal was used to wake-up the control module and initiate diagnostic communication. RXD was gradually phased out starting in 1997 (until 2001) and TXD (D-Bus) is now used for all diagnostic communication.



The TXD signal line is bi-directional and allows information to be retrieved (such as fault codes) and commands to be carried out (such as component activation). On vehicles equipped with the 20-pin diagnostic connector, TXD is in pin 20 and RXD in pin 15.

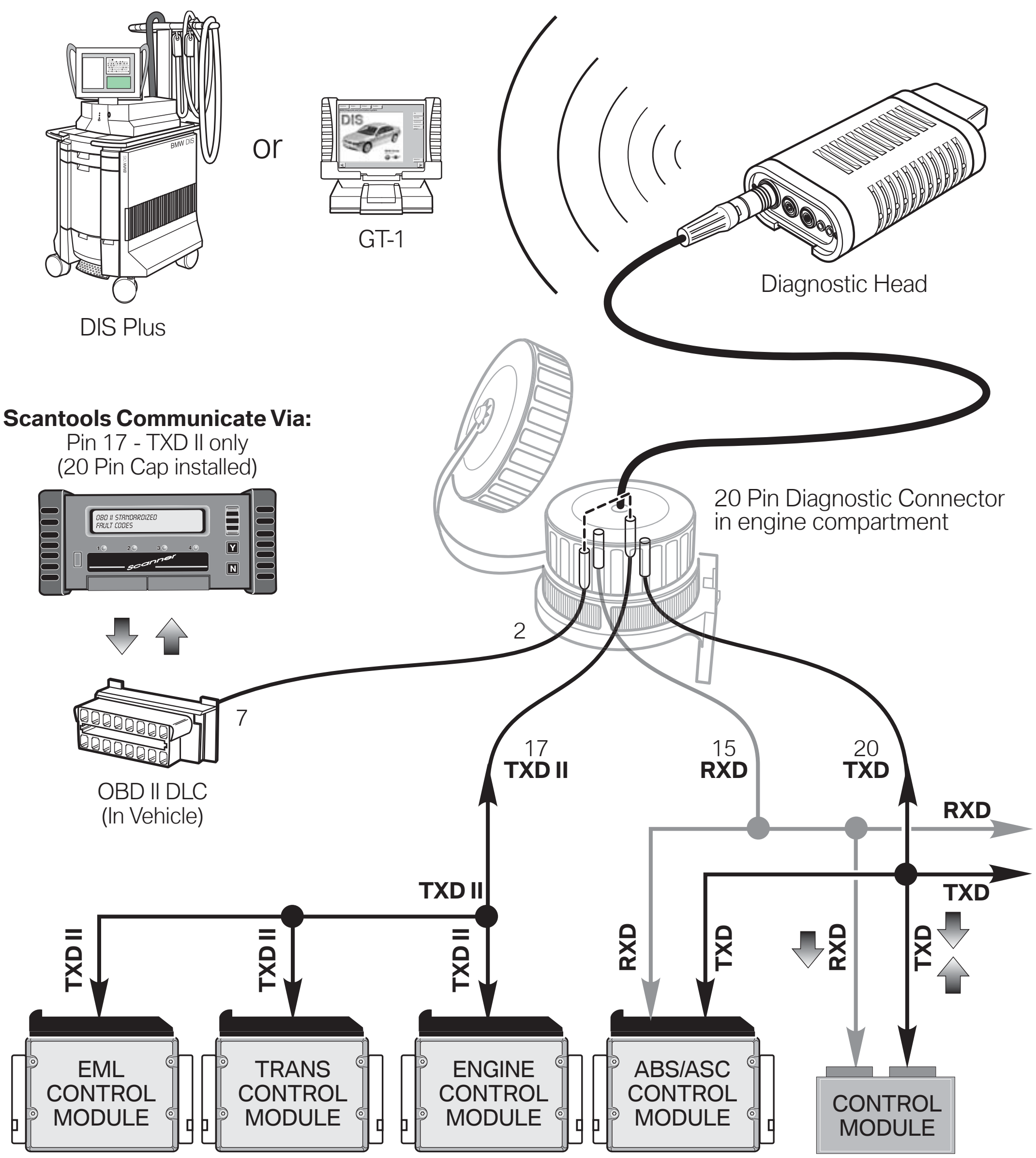
Later control modules (from 1997) no longer required the separate RXD to establish communication, (DS2 protocol) so Pin 15 was removed from the Diagnostic socket of most vehicles. Pin 15 (RXD) was still used in the E38 until the end of production in 2001.

In 1995, to satisfy the requirements of OBD II, a standardized 16-pin connector was installed inside of all vehicles. Up until 2001, the 16-pin OBD II connector was not used by BMW diagnostic equipment to access diagnosis, it was reserved for aftermarket scan tool usage. The 20-pin connector was eliminated from all BMW vehicles from 2001 and the 16-pin OBD connector is now used exclusively.

TXD II (pin 17) was introduced as a communication line exclusive to DME (ECM), AGS (TCM) and EML. Pin 2 provided a connection to the 16 pin OBD connector via a bridge in the cap of the 20-pin connector. TXD II is technically identical to the D-Bus (TXD).

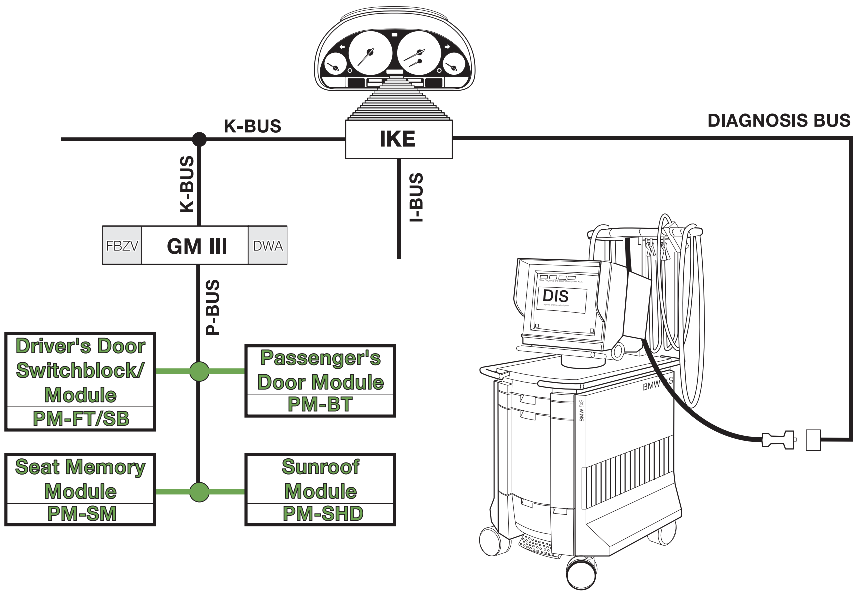
Note: On vehicles equipped with both the 20-Pin and 16-Pin OBD connector, the cap on the 20-pin connector must be installed to access diagnostic information from the OBD II connector.

Beginning with the introduction of the E65, TXD has been omitted and TXD II is now used exclusively for diagnostic communication. TXD II is in pin 7 of the 16 pin OBD connector.



Gateways

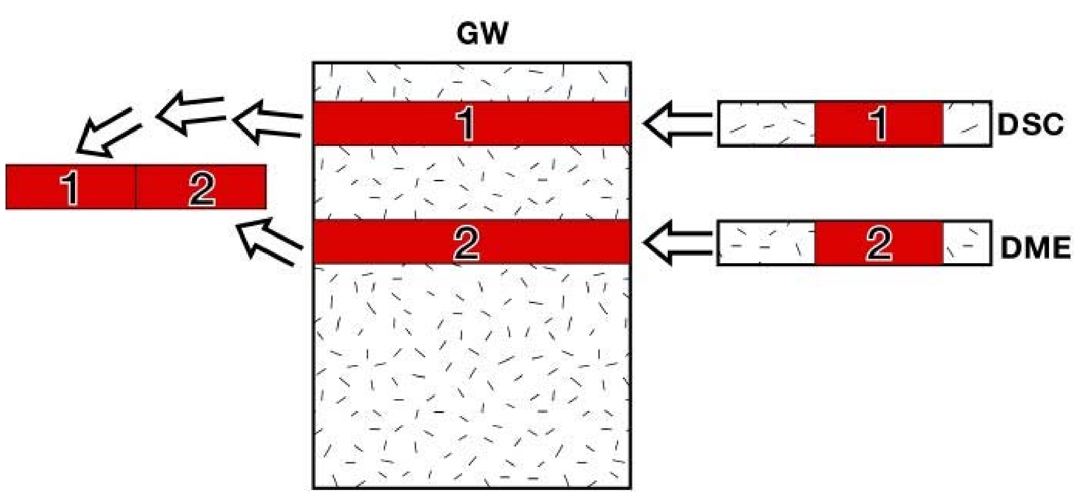
On some of the early models the D-Bus was connected directly to some modules. Some modules were diagnosed through a gateway module such as the IKE or cluster. For instance as the diagram below shows, modules that are on the I, K and P-Bus must be diagnosed through the IKE. In this case the IKE acts as a “gateway” module. The gateway routes all diagnostic “traffic” to the correct bus system.



On newer vehicles such as the E65, the ZGM acts as a gateway and all diagnostic data is routed through this module.

A gateway allows information to be transferred from one bus system to another. Due to the difference in communication speed, the gateway must “translate” the data and then route the data to the correct network.

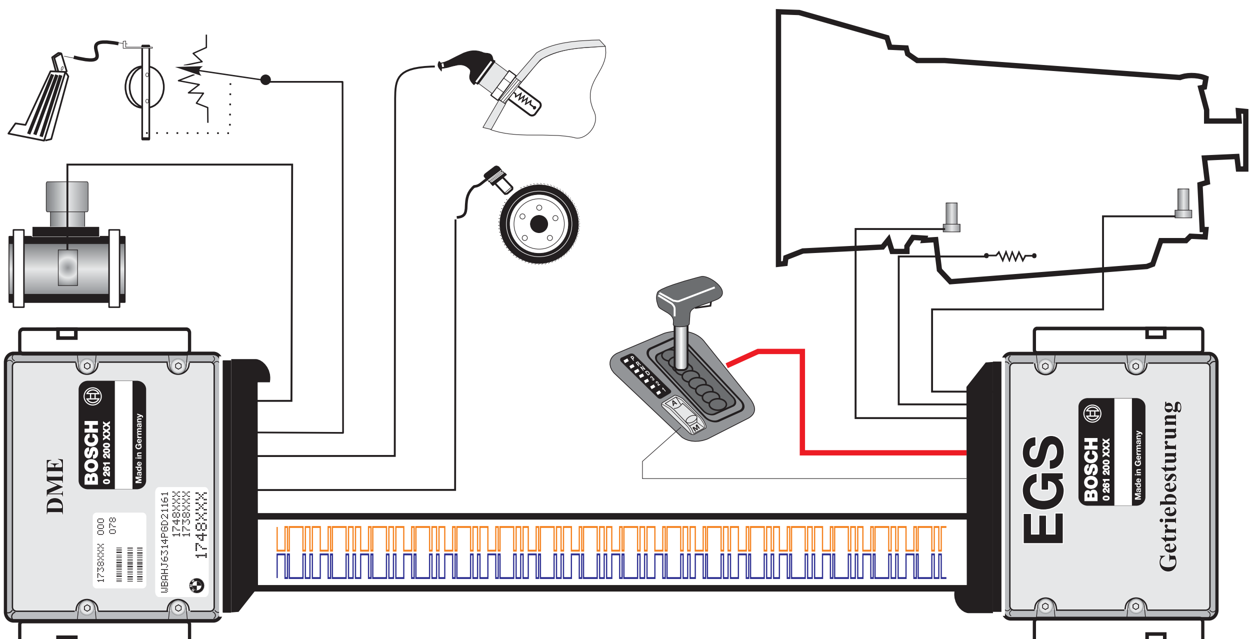
In addition to the above functions, the gateway will also allow data messages with a higher priority to be transmitted first.



Controller Area Network (CAN-Bus)

The CAN protocol was originally developed by Intel™ and Bosch in 1988 for use in the automotive industry. CAN provides a standardized, reliable and cost-effective communications network which allows vehicle manufacturers to combat the increasing size of vehicle wiring harnesses.

The CAN-Bus was introduced on BMW vehicles in 1993 in the 7 and 5 series vehicles with the M60 engine and automatic transmission. The CAN-Bus connected the DME (ECM) with the EGS (TCM) control units. This network allowed data to be transferred between DME and EGS at rate of up to 500 Kbps (Kilobits per second).



Example of Early CAN-Bus on M60 engine

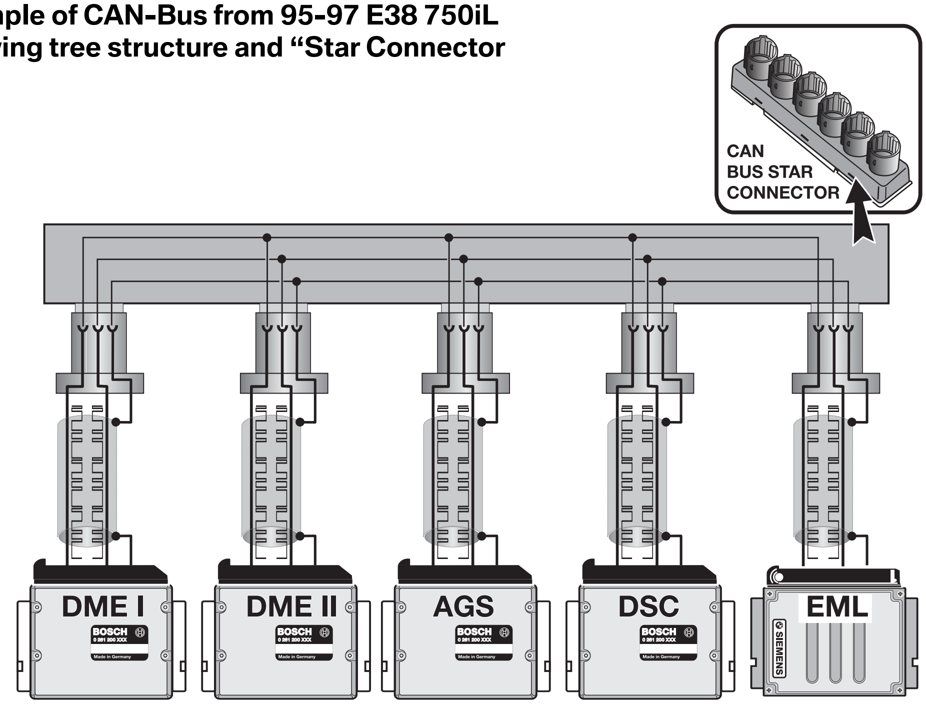
As shown in the above picture, the original CAN-Bus network contained only 2 control units or "subscribers". Since it's introduction, subscribers on CAN have increased as system needs dictated.

Beginning with the 1995 model year, new systems were added to the CAN-Bus. The introduction of the E38 750iL necessitated major changes to the CAN-Bus structure. EML and DSC were added as well as DME II for the M73 engine.

For the 1998 model year, the instrument cluster and the steering angle sensor were also added to expand the signal sharing capabilities of the vehicle.

When introduced, the CAN-Bus consisted of 2 copper wires and a third connection which served as a shield. The shield was needed to protect the CAN-Bus from electrical interference. Since the CAN-Bus uses relatively low voltage (approx 2.5), it is vulnerable to signal interruption from higher voltage circuits or aftermarket systems such as cell phones etc.

Example of CAN-Bus from 95-97 E38 750iL showing tree structure and "Star Connector



The shield on the CAN-Bus was only used until the 99 model year, after which the entire CAN-Bus network went to twisted pair wiring. Twisted pair configuration allows the same level of interference suppression and creates more flexibility in wiring due to the elimination of the extra shielding.

The two signal wires used in CAN are referred to as CAN-High and CAN-Low. Each wire carries the same information bi-directionally. The two wire configuration is used for redundancy in the event of failure.

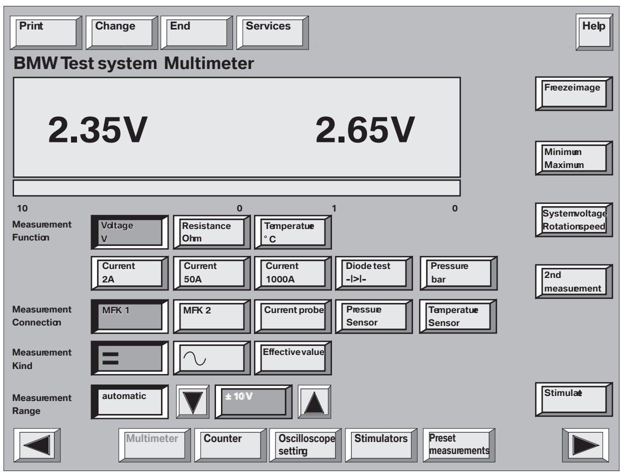
Due to the linear structure of the network, the CAN-Bus is available for other modules in the event of a disconnected or failed control unit. This is referred to as a "Tree" structure with each control unit occupying a branch.

Currently, the CAN-Bus is used on all BMW vehicles and has been expanded to other systems. The introduction of the E65 brought about new variations of CAN. The new PT-CAN and K-CAN will be discussed in a later module.

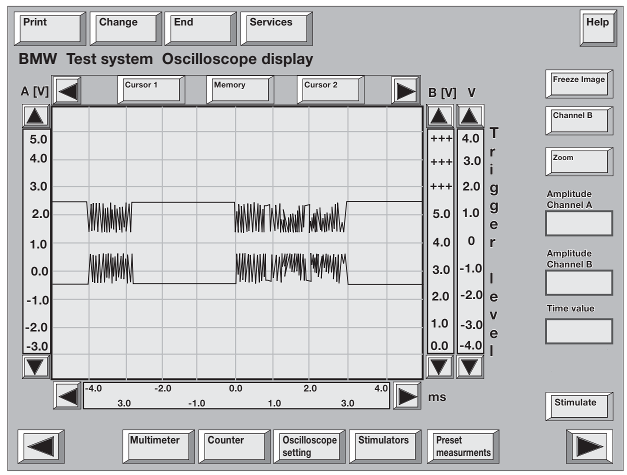
CAN-Bus Operation

The primary function of the CAN-Bus is to exchange data at a high transfer rate between CAN subscribers. This is accomplished using two signal lines referred to as CAN-High and CAN-Low. Both of these signal lines transfer the same data at the same time. Two signal lines are used for redundancy in the event of a signal line failure.

Voltage on the CAN-Bus is divided between the two data lines. for an average of 2.5 volts per line. Voltage is measured from each data line to ground. Each module on CAN contributes to this voltage.



CAN-Bus viewed on Multimeter



CAN-Bus viewed on Oscilloscope

When viewing the CAN-Bus signals on an oscilloscope, CAN-Low with be approximately 2.5 volts. The signal will be “pulled” low during communication. CAN-High will be at 2.5 volts, but the signal will be “pulled” high during communication. However, the fact that 2.5 volts are present does not indicate that the CAN-Bus is fault free, it just means that the voltage level is sufficient to support communication.

Terminal Resistors

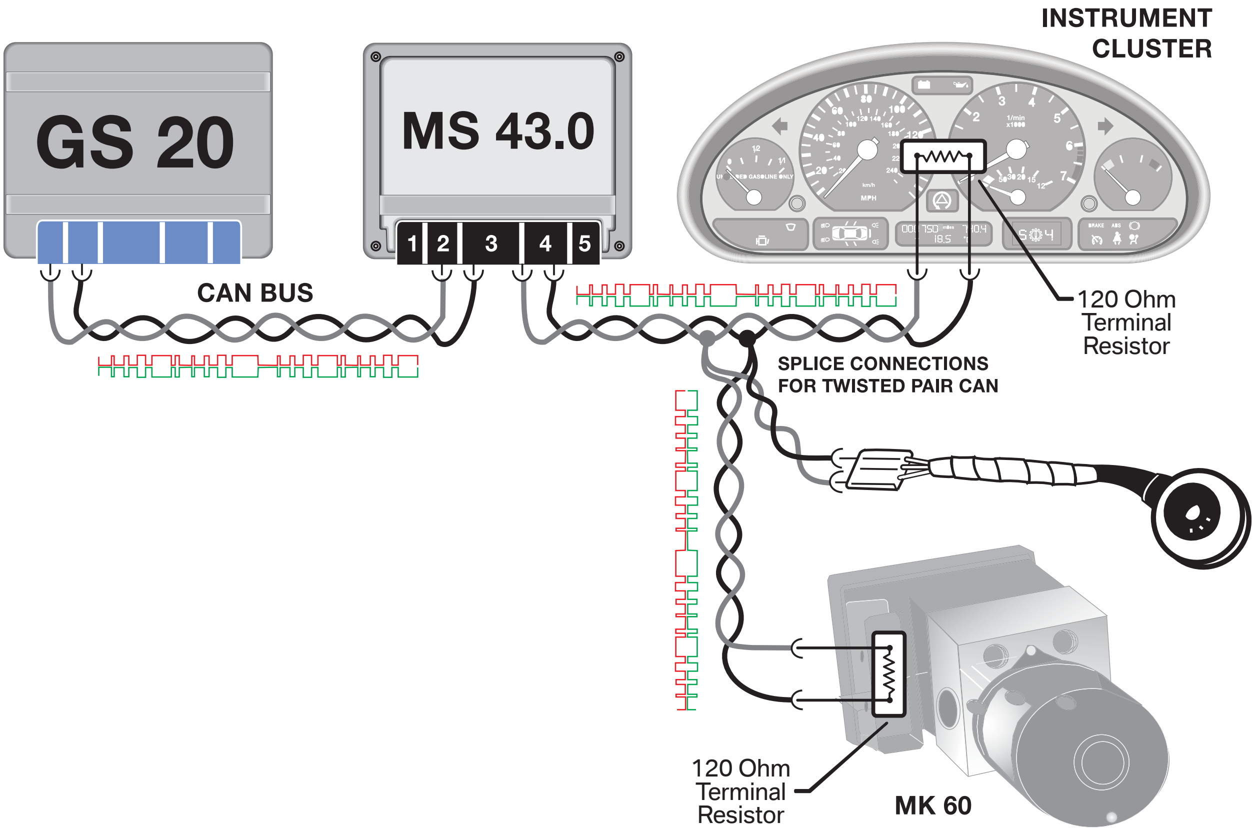
Two 120 Ohm resistors are used in the CAN-Bus circuit to establish the correct impedance to ensure fault free communication. A 120 Ohm resistor is installed in two control units of the CAN between CAN-H and CAN-L. Because the CAN is a parallel circuit, the effective resistance of the complete circuit is 60 Ohms. On some vehicles there is a jumper wire that connects the two parallel branches together, others have an internal connection at the instrument cluster.

The resistance is measured by connecting the appropriate adapter to any of the modules on the CAN and measuring the resistance between CAN-L and CAN-H. The resistance should be 60 Ohms. The CAN-Bus is very stable and can continue to communicate if the resistance on the CAN-Bus is not completely correct; however, sporadic communication faults will occur.

The terminal resistors are located in the ASC/DSC control unit and either the instrument cluster or in the DME.

Early 750iL vehicles that used the star connector have a separate external resistor which connect CAN-H and CAN-L together.

Modules which do not have the terminal resistor can be checked by disconnecting the module and checking the resistance directly between the pins for CAN-H and CAN-L. The value at these control units should be between 10 kOhms and 50 kOhms.



CAN Communication Protocol

The CAN-Bus network uses a unique communication protocol. Bus telegram messages are not “addressed” to the intended receiver (module) as on other bus networks. Instead, the content of the message (RPM, TD, Temp,etc) is labeled by an identifier code that is unique throughout the CAN. All of the subscribers receive the message and each one checks the message to see if it is relevant to that particular control unit.

If the message is relevant then it will be processed, if not, it will be ignored. The identifier code also determines the priority of the message. In a case where two control units attempt to send a message over a free bus line, the message with the higher priority will be transmitted first. The protocol of the CAN ensures that no message is lost, but stored by the Master Controller and then re-transmitted later when it is possible.

Information and Body Bus (I and K-Bus)

Initially the I-Bus was introduced on the E31 as the information bus. The E31 version of the I-Bus was used for body electronics and driver information systems. With the introduction of the E38, the I-Bus is now referred to as the instrument bus. The K-Bus was added to the E38 along with the I-Bus. Models without Navigation or IKE will use the K-Bus only. Both of these bus systems are technically identical, the only difference is their use by model.

The I and K-Buses are a serial communications bus in which all connected control units can send as well as receive information over one wire. From this point forward they will be referred to as the I/K-Bus and differences will be pointed out separately.

The data transfer rate is approximately 9.6Kbps (bits per second).

The I/K-Bus is always active when terminal R is switched on. If the bus line is quiet more than 60 seconds, all of the control modules will go into Sleep Mode.

When receiving messages over the bus line, the control unit first determines if the message is error free before accepting it.

The information sent over the bus is configured serially. Each message consists of:

1. **Transmitter address (8 bit address)**
    - The senders name.
2. **Length of data (number of following message bytes)**
    - How long the sender will speak.
3. **Receiver address (8 bit address)**
    - Whom the sender wishes to speak to.
4. **Command or Information**
    - What the sender wants done.
5. **Detailed description of message (maximum 32 bytes of data)**
    - How the sender wants it done.
6. **Summary of transmitted information (check sum)**
    - The sender summarizes everything said.

The sender of the message then waits (100ms) for an acknowledgement that the message was received.

All of the connected control units will receive the information, but only the module addressed will accept and react to the data.

The rules for communication on the bus line are:

- Only one module speaks at a time.
- Everybody speaks at the same speed.
- Messages are acknowledged by the recipient.
- The message is repeated if the addressed module fails to respond.
- The Master Controller has priority.
- Quit sending message after 5 failed attempts.

Communication between busses - On vehicles equipped with an I-Bus (E38, E39, E53 High) messages to be sent back and forth between the K-Bus and I-Bus have to be transferred via a Gateway. This Gateway is the IKE. The IKE determines by the address of the message recipient whether the message needs to be passed along to the other bus. The D-Bus and CAN-Bus also utilize the IKE or KOMBI as a gateway.

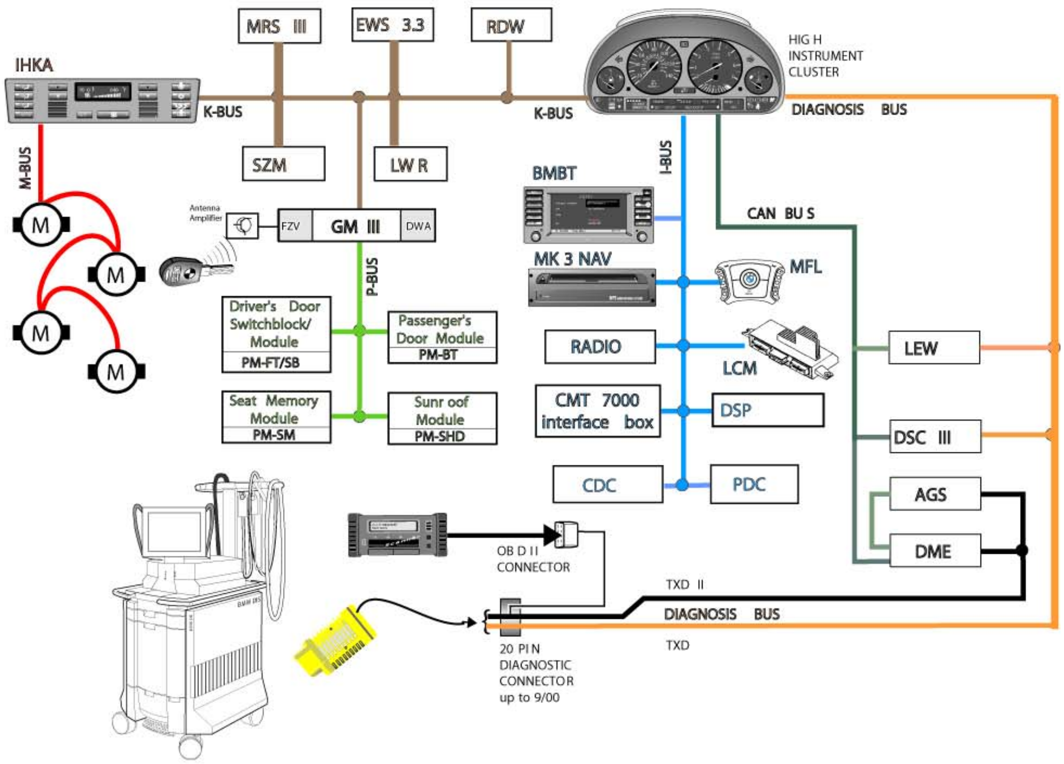
Polling - Each module on the I/K-Bus is informed by a message from the Master Controller as to the ready status of all of the other connected modules. The modules polled are according to the coding of the Master Controller. Every 30 seconds after KL R is switched on, each module on the bus line is polled.

A message concerning bus subscriber status is updated continuously based on the results of these polls. If a subscriber fails to respond with “device status ready” the Master will try again after 1 second.

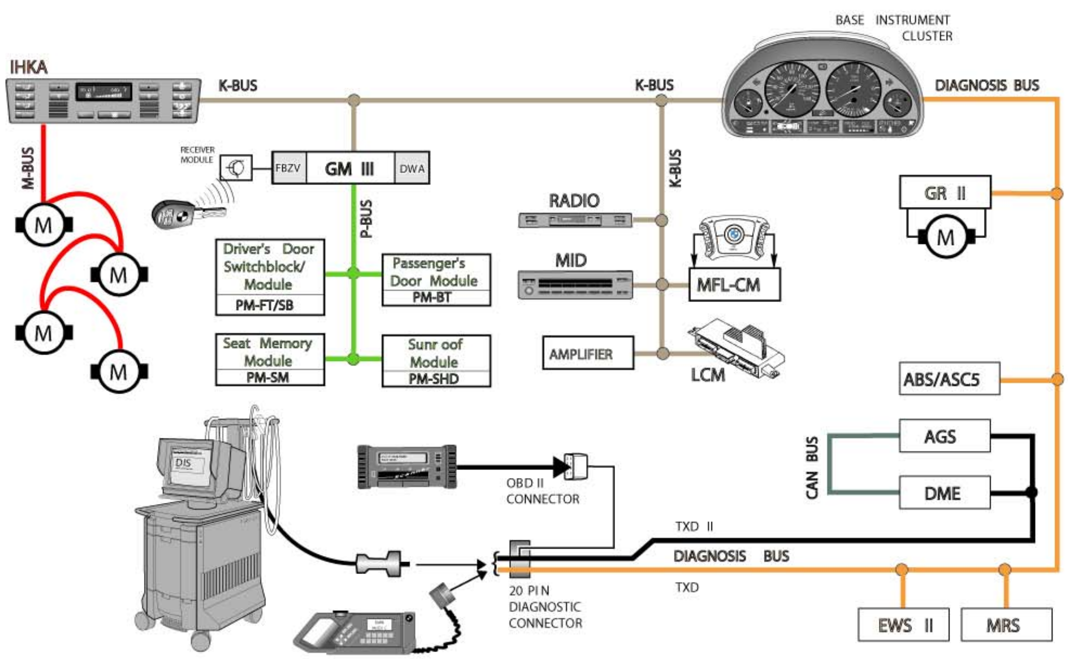
If the module fails to reply again, the Master will assume that the subscriber is defective and send the message “subscriber inactive” to all connected modules. The inactive module will continue to be polled until the key is switched off in case the module resets itself.

Bus System Overview

Example of vehicle with I and K-Bus



Example of vehicle with K-Bus



The I/K-Bus consists of a single copper wire. The wire color of the I and K-Bus is uniform throughout the vehicle with: I-Bus WS/GR/GE and the K-Bus WS/RT/GE (Note: 2001 E39s with base Kombi have changed K-Bus wire color to the same as the I-Bus, WS/GR/GE).

Due to the linear structure of the network, the I/K-Bus is available for other modules in the event of a disconnected or failed control unit. Just as the CAN-Bus, this is referred to as a "Tree" structure with each control unit occupying a branch. The I/K-Bus provides the diagnostic connection to the control units located on those busses (except IKE/KOMBI).

Always refer to the ETM to determine the exact wiring configuration and color for a specific model.

Troubleshooting the I/K-Bus

The failure of communication on the I/K-Bus can be caused by several sources:

- Failure of the bus cable.
- Failure of one of the control units attached to the bus.
- Failure of the voltage supply to individual modules.
- Interference in the bus cables.

The I/K-Bus is active when KL R is switched on, it remains active until 60 seconds after the last message. If the key is switched off (KL30) the bus may be activated for a time by individual users via a "wake-up" message.

Unlike the CAN-Bus where each control unit (subscriber) provides voltage for communication, the I/K-Busses use only determined Main (master) or Stand-by Controllers to supply B+for communication. The voltage level on the I/K-Bus must be above 7V. The nominal value should be close to the system voltage of the vehicle.

Just like the CAN-Bus, the fact that voltage is present does not mean that the bus is fault free, it just means that the voltage level is sufficient to support communication.

Control units that provide operating voltage to the I/K-Bus are:

On E38 and E39/E53 High version vehicles:

- The LCM is the Main (master) Controller of the I-Bus. The IKE and MID/BMBT are Stand-by Controllers.
- The GM is the Main (master) Controller of the K-Bus.

On E46, E52 and E39/E53 Base version vehicles:

- The GM is the Master Controller for vehicles equipped with only the K-Bus.
- The LCM/LSZ is the Stand-by Controller.

Failure of the Bus Cable

The following faults can occur to the I/K-Bus wiring:

- Short Circuit to B+
- Short Circuit to B-
- Bus line down (open)
- Defective plug connections (damaged, corroded, or improperly crimped)

Short Circuit to B+: Modules that send a message see that the message was not received and that the bus remains high. However, subscribers are unable to decide whether the fault is due to a shorted line or a defect in the communication interface. The module will repeat its message 5 times before discontinuing and faulting. The module will continue to operate as normal minus any commands that could not be delivered by the bus.

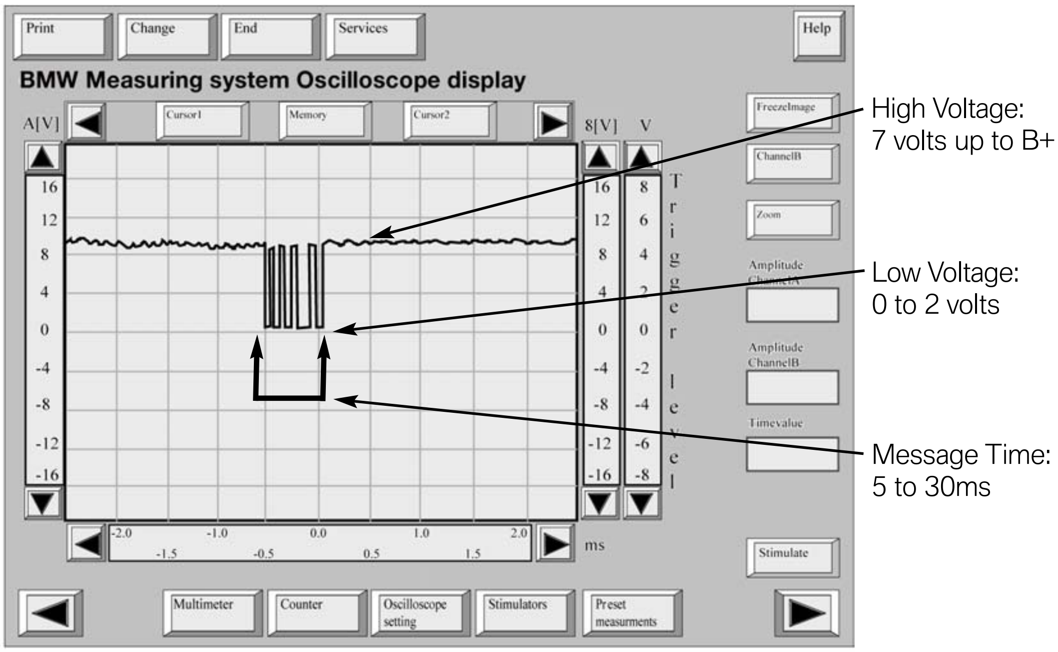
Short Circuit to B-: The subscribers do not interpret a low bus line as a fault but just as a bus line deactivation. The Master and Standby controllers do detect the short and enter it as a bus fault. (No communication).

Bus Line Down: The bus line may be open at any of several locations. As long as the Master or Stand-by is still connected, communication can occur with any modules still remaining. The fault situation will be the same as if the disconnected modules were defective themselves.

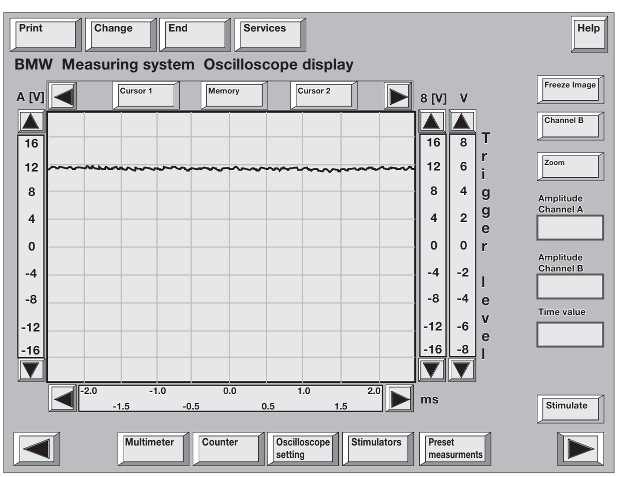
Checking the bus line is carried out just like any other wiring. Perform continuity tests between the connections of different modules (all modules disconnected) without forgetting to make sure that the bus has not shorted to ground or another wire. It is recommended to use the “Wire Test” in “Preset Measurements” which is more sensitive than just a resistance check.

If Voltage level and the wire test are O.K. then looking at the communication signal may be useful. In order to get a signal, operate different devices on the I/K-Bus (e.g. MID/MFL) to stimulate conversations.

The following are some examples of scope patterns that may be observed when checking the I/K-Bus.

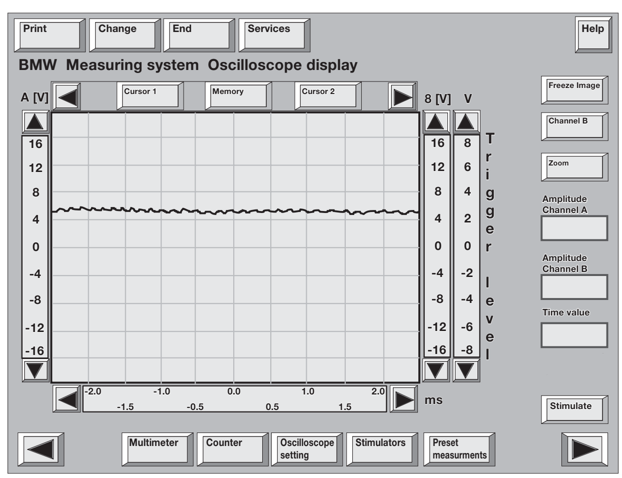


The example shown above is of a correctly operating K-Bus signal. The high portion of the signal is approximately 12 volts. The signal is active when communication is occurring of the bus.



Flat Line at 12 volts

No communication is taking place. The bus may be temporarily off line or shorted to B+.



Flat Line at 5 volts

No output voltage from the Main (master) or standby controllers. Bus line may be open or control unit may be defective.

Failure of one of the control units attached to the I/K-Bus.

Each control unit connected to the bus has an integrated communication module that makes it possible for that control unit to exchange information. Failure of a control unit normally triggers a fault code in the other control units connected to the bus.

As a quick check for the I/K-Bus, activate the four way flashers. The flash indicators must light up in the instrument cluster. Switch on the Radio, and adjust volume using the MFL or MID/BMBT, the volume must change accordingly.

On High version vehicles press the recirculation button on the MFL, The IHKA should respond to the request. This test checks the gateway link as well as the the I and K-Bus communication.

If the tests prove O.K, this means that communication on the bus is O.K. Any faults still existing can only be related to faults specific to a control unit or a local I/K-Bus wiring defect to a module.

There are instances where failures may be software related. A faulted module may paralyze or take down the entire bus. This scenario would be evident by functions not being carried out and and possible faults stored.

In order to isolate the defective control unit, the control units can be disconnected one at a time. Repeat the bus test after each disconnected control unit. If the disconnected control module is the defective one the faults will only point to communication with that interrupted module and no one else.

Once the module has been replaced (observing current S.I.Bs) and coded, perform the I or K-Bus Test Module in the Diagnosis Program to ensure that communication is O.K.

Failure of the voltage supply to individual modules.

A slowly dropping battery voltage on a vehicle with discharged battery can lead to sporadic communication faults in various control units on the bus. The reason is that not all control units will switch off communication at the same voltage level leaving some modules still trying to communicate. Always verify a properly charged battery and charging system and fuses before beginning troubleshooting on the bus. Also, do not forget to check for a proper ground to a control unit, this may not allow the bus to see a signal low (0-2V)

Interference in the Bus Cables.

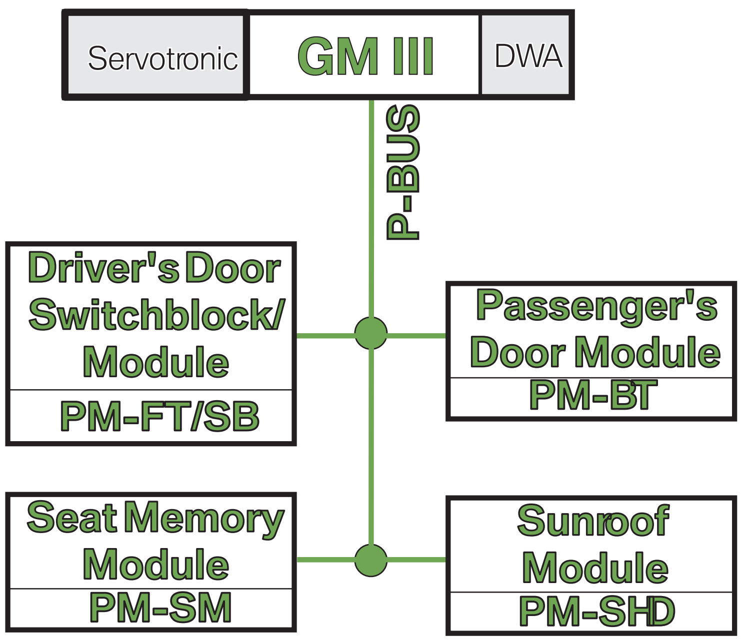
Interference will have a similar effect to shorting or disturbing the bus wiring. Excessive interference created by a defective alternator or aftermarket devices such as cell phones or amplifiers may induce a voltage into the bus line and disrupt communication. This type of interruption may be intermittent and faults may only be stored in some modules and not in others. These faults are often difficult to reproduce. Isolate any aftermarket wiring in the vehicle and see if the fault returns.

Peripheral Bus (P-Bus)

The P-Bus is a single wire serial communications bus that is used exclusively on vehicle that are equipped with ZKE III. These vehicles are the E38, E39 and E53.

The P-Bus provides the Central Body Electronics system with a low speed bus for use by the General Module (GM) to control various functions. These functions are carried out by various peripheral modules. The peripheral modules are located in areas of the vehicle close to sensors or actuators where wiring the components separately would create an excessively large wiring harness. In some cases (e.g. Sunroof module) these peripheral modules are integrated into an actuator or switch to create one unit.

The P-Bus is only used within the ZKE system and is very similar in communication protocol and speed to the I/K-Bus. The P-Bus is not designed for a rapid exchange of continuous information. Instead, the messages on the P-Bus are short control commands. This limited message flow allows for fast reaction time by the Peripheral module. (e.g. a door lock request).

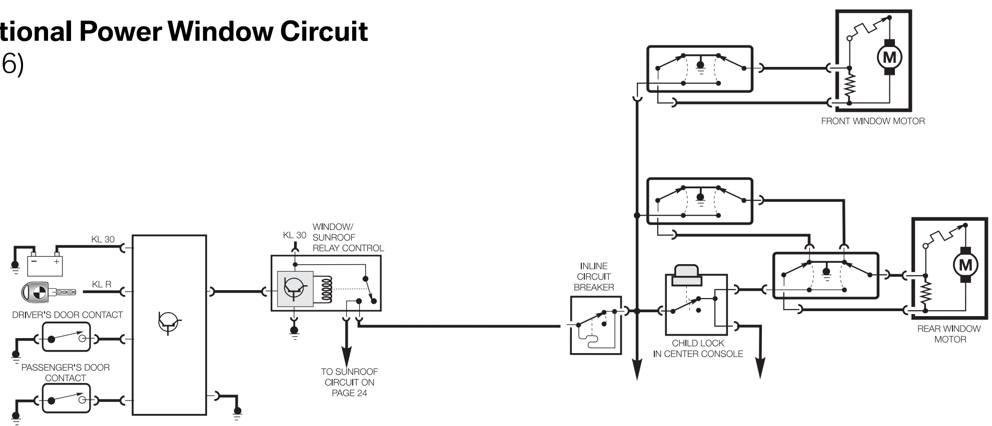


In comparison with previous electronic systems, bus networks provide a simple method to operate various body electronic systems. Using the example of a power window circuit, the previous methods to operate a window were inefficient. The power window circuit carried a large amount of current which required larger gauge wires and heavy duty switches. Window switches were subject to wear from arcing contacts and the wiring size did not allow much flexibility when passing through bulkheads and door jamb areas.

A bus network needs less high current circuits and uses a smaller amount of heavy gauge wire. The switches are only used to signal the modules and they do not carry high current. The switches are used to provide a low current ground input signal which increases the life of the switch and improves reliability considerably.

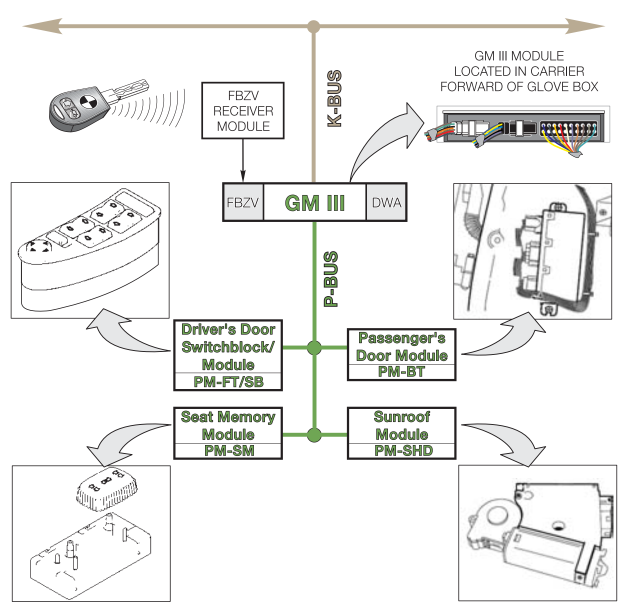
The drivers side window switch is a control unit on the P-Bus. If the driver needs to open the front passenger side window, a signal is sent from the driver's side switch block module to the passenger side door module. The passenger side door module contains the load circuits for switching the window motor. The passenger side door module will respond to the "window open" telegram from the drivers door switchblock by actuating the switching circuit for the window motor.

Conventional Power Window Circuit
(Early E36)



In addition to simplifying the power window circuit, the bus network also allows functions that were not possible with a conventional power window circuit. For example, the remote operation of the power windows from the key transceiver (convenience open feature).

The convenience open feature on the E38 operates by a radio frequency signal from the key transceiver. The "open request" signal is received by the FBZV module. The FBZV module sends a digital signal to the General Module (GM III). The GM then sends an "open windows and sunroof" telegram over the P-Bus and all 4 windows and sunroof will open. This type of feature is much too complex for a conventional window circuit. The bus network allows new features like this to be possible.



Troubleshooting the P-Bus

The failure of communication on the P-Bus can be caused by several sources:

- Failure of the bus cable.
- Failure of one of the control units attached to the bus.
- Failure of the voltage or ground supply to individual modules.
- Interference in the bus cables.

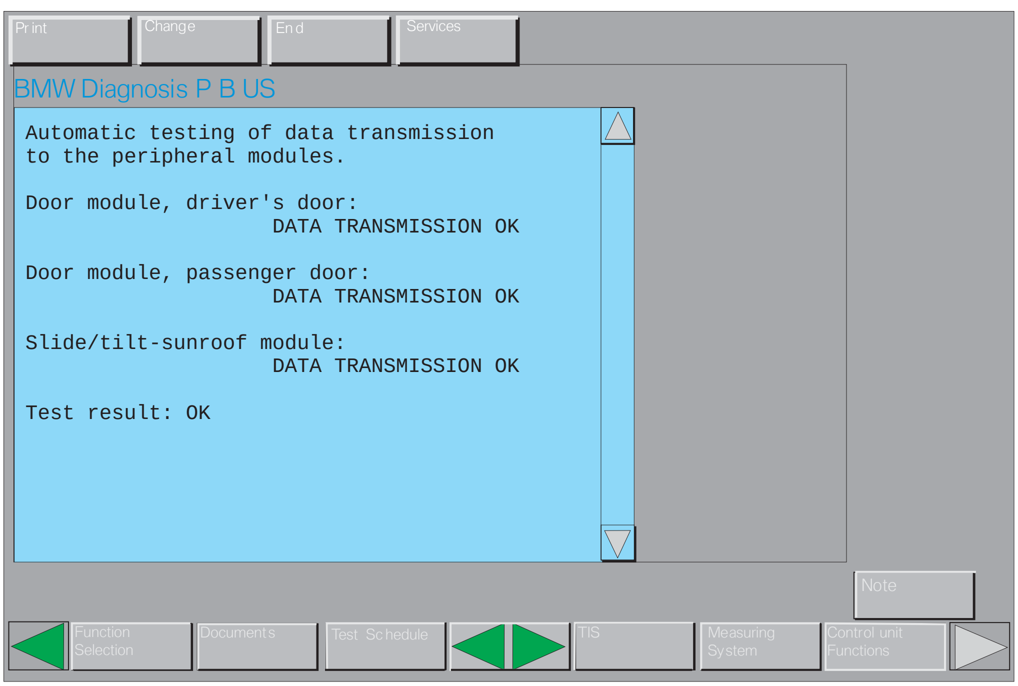
The P-Bus may be active at any time following a wakeup call. The GM provides the voltage necessary to support communication. The voltage level of the P-Bus is 12V.

The Diagnosis of the central body electronics is carried out via the K-Bus. The GM converts diagnosis request from the DISplus into diagnostic mode messages and transmits them the the peripheral modules over the P-Bus.

Automatic testing of the P-Bus connection is carried out every time the GM communicates with the diagnosis program (not during a short test).

Checking the bus line is carried out just like any other wiring. Perform continuity tests between the connections of different modules (all modules disconnected) without forgetting to make sure that the bus has not shorted to ground or another wire. It is recommended to use the “Wire Test” in “Preset Measurements” which is more sensitive than just a resistance check.

Troubleshooting of the P-Bus network is carried out the same as the I/K-Bus.

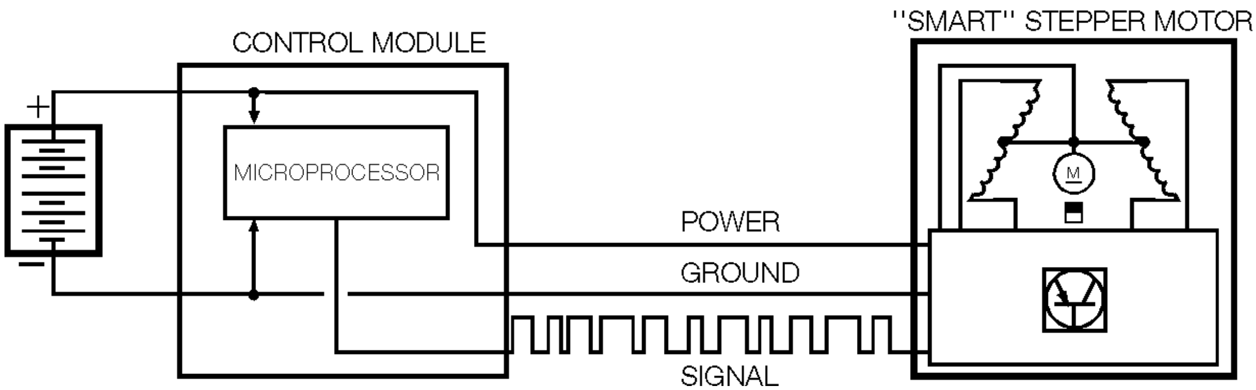


M-Bus

The M-Bus is used exclusively in the climate control systems for the control of the “smart:” stepper motors. These stepper motors are used to control various air distribution flaps. In previous climate control systems, such as E32/E34, the stepper motors were directly controlled by the climate control module.

The M-Bus was introduced on the E38 climate control system (IHKA). The M-Bus was also installed on subsequent models equipped with IHKA and IHKR.

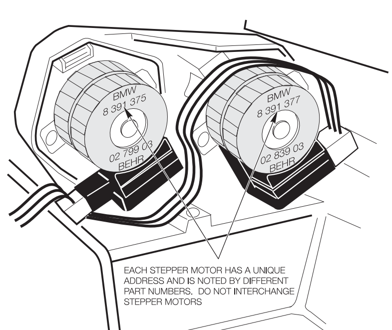
The M-Bus communicates with the “smart” stepper motors which contain a processor capable of transmitting and receiving messages. The stepper motor is then operated by final stage transistors located within the stepper motor electronics.



The M-Bus consists of a three wire ribbon cable containing the following wires:

- Power (B+)
- Ground
- Bi-Directional Signal Line

Each stepper motor on the M-Bus has a unique part number to distinguish it’s location on the climate control housing. The part number corresponds to a unique electronic address on the M-Bus. Since each stepper motor contains a unique electronic address, the motor will only respond specific commands. A stepper motor installed in the wrong location would result in improper operation.



Communication Protocol

Each stepper motor acts as a “subordinate” module, it listens to all data on the bus, but only responds as long as the message is transmitted without errors and recognizes it’s own address.

The M-Bus protocol differs from the CAN and the I/K/P-Busses in that communication takes place within a framework time of 650 microseconds.

When the climate control module (IHKA/R) is commanding a change in position of one or more stepper motors, the sequence of data is:

1. **Start bit** - Informs the stepper motors that a command is coming.
2. **Synchro bit** - Establishes the message as originating from the IHK control module.
3. **Data Field** - The command to move a stepper motor to a particular position.
4. **Address Field** - The IHK control unit names the stepper motor the command is intended for.

If the message was received by the stepper motor without error, the stepper motor will carry out the command and transmit it’s acknowledgement which is as follows:

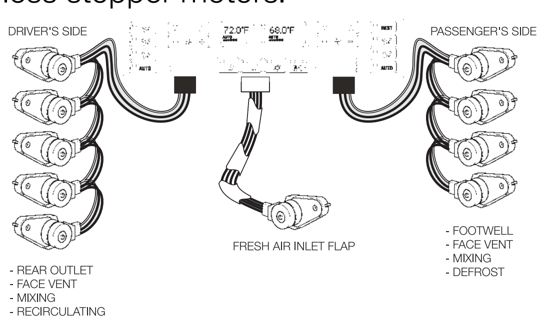
1. **Synchro Bit** - Establishes the message as originating from the stepper motor
2. **Data Field** - Status information from the actuator (feedback)
3. **End of Frame** - Closes the communication Session

Communication continues on the M-Bus until the GM send the “go to sleep” command over the K-Bus.

M-Bus Topology

The M-Bus consists of a three wire ribbon attached to the climate control housing and connecting all of the “smart” stepper motors in the system. The number of stepper motors depends upon the vehicle model and climate control system (IHKA,IHKR etc.).

For example, the E38 (shown) with IHKA uses 9 “smart” stepper motors and one motor that is conventionally controlled. The M-Bus is divided into two circuits due to the large number of stepper motors. Other models such as the E39, E46 and E53 only use one circuit for the M-Bus and less stepper motors.



M-Bus Troubleshooting

The failure of communication on the M-Bus can be caused by several sources:

- Failure of the bus ribbon, e.g. open or shorted.
- Failure of one of the stepper motors attached to the bus, e.g. shorted to B+ or B-.
- Failure of the voltage or ground supply to the IHK control unit.

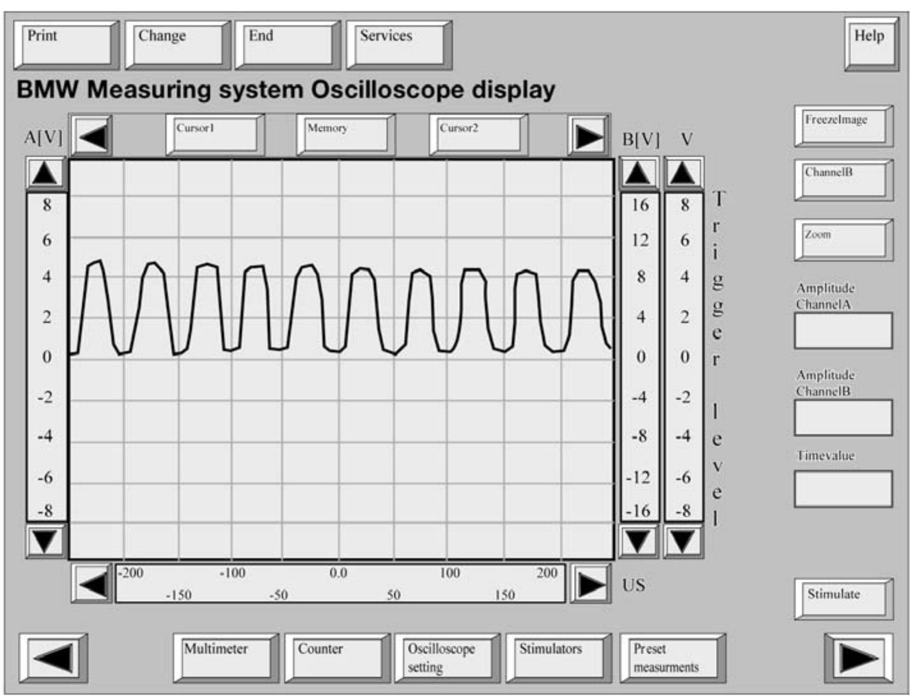
The M-Bus is active at any time following KLR on. The IHK module provides the voltage necessary to support communication. The voltage level of the M-Bus is 5V, but because status communication occurs at an average 50% duty cycle the observed voltage is approximately 2.5V. The presence of 2.5V means that communication is occurring.

Checking the M-Bus ribbon is carried out just like any other wiring. Perform continuity tests between the connections of the stepper motors (all motors disconnected) and the control unit without forgetting to make sure that the data line has not shorted to ground or power.

It is recommended to use the "Wire Test" in "Preset Measurements" which is more sensitive than just a resistance check.

If Voltage level and the wire test are O.K, then looking at the communication signal may be useful.

The following is an example of a scope pattern that may be observed when checking the M-Bus. Notice the very high frequency of the signal at approximately 20 kHz.



Workshop Exercise

Using an instructor designated vehicle, perform "Quick Delete" to ensure that there are no present system faults.

Using the correct ETM and appropriate test cables, connect oscilloscope the CAN-Bus at the DME (ECM) or other accessible control module. Use MFK 1 and 2 and display both CAN signals on the oscilloscope.

What is observed regarding the CAN-Bus signals? (voltage levels, frequency etc.)

Using the appropriate fused jumper, ground the CAN- High signal and observe. (fault codes, functionality etc.)

What is observed when the CAN High signal is disabled?

Using the appropriate fused jumper, ground the CAN- Low signal and observe. (fault codes, functionality etc.)

What is observed when the CAN Low signal is disabled? Are there any differences between the failures of CAN high and CAN low?

Workshop Exercise

Using the multimeter functions of the diagnostic equipment, measure the resistance between CAN High and CAN low.

What is the resistance observed?

Locate the CAN-Bus terminal resistors in this vehicle and measure the resistance.

Where are the CAN-Bus terminal resistors located? And what is the resistance?

Remove the CAN-Bus resistors from the circuit (by disconnecting the resistor or module, whichever is appropriate).

What is observed when the terminal resistors are removed from the circuit?
(fault codes etc.)

What is the purpose of the terminal resistors?

Workshop Exercise

Using the oscilloscope, connect the the I/K-Bus.

What is the observed voltage?

Using the appropriate fused jumper, ground the I/K-Bus and observe functions and fault codes.

What is observed regarding vehicle operation? (fault codes, functionality etc.)

With the I/K-Bus grounded, operate the turn signals.

Do the turn signals function properly? Why or Why not?

If the vehicle has a P-Bus, perform the P-Bus test With the DISplus/GT-1.

Ground the P-Bus and perform the P-Bus test again.

What is observed regarding the P-Bus test and the operation of the P-Bus and related systems?

Classroom Exercise - Review Questions

1. Where are the Terminal resistors located in the CAN-Bus network? What should the measured resistance of the CAN circuit be? How is it checked?

2. Explain the differences of CAN-High and CAN-Low? How can they be distinguished from one another?

3. What is the minimum voltage required at the D-Bus?

4. Why is checking a bus signal with an oscilloscope a practical option?

5. Describe some quick tests that can help to determine if a bus line is currently operating.

Classroom Exercise - Review Questions

6. What bus systems use the linear arrangement?

7. What is the difference between the communication protocol on the CAN-Bus and the I/K-Bus?

8. What modules are connected to the P-Bus?

9. What are some of the main advantages (benefits) to bus networks?

10. On what systems is the M-Bus used?