2002-07 GENINFO

Bus Systems - Overview - MINI

MINI BUS SYSTEMS

BUS SYSTEMS

The vehicle electrical architecture of the MINI has been designed to exploit the full potential of its technological advances. Rather than having a control unit dedicated to its system and unaware of the operation of other systems, the systems around the MINI are all linked together.

The control units are linked to each other via bus-systems, allowing communication and exchange of information. Harness bulk and complexity is kept to a minimum using this method to relay information to and from the different systems. This method used by MINI is called multiplexing.

Purpose of the System

Multiplexing is a technique which uses the same wiring repeatedly for communication between all systems. The systems are all inter-connected, forming a network of communication lines. The information from sensors and switches are converted into digital signals by the system control unit and relayed serially throughout the system network, which is also referred to as a data bus-system.

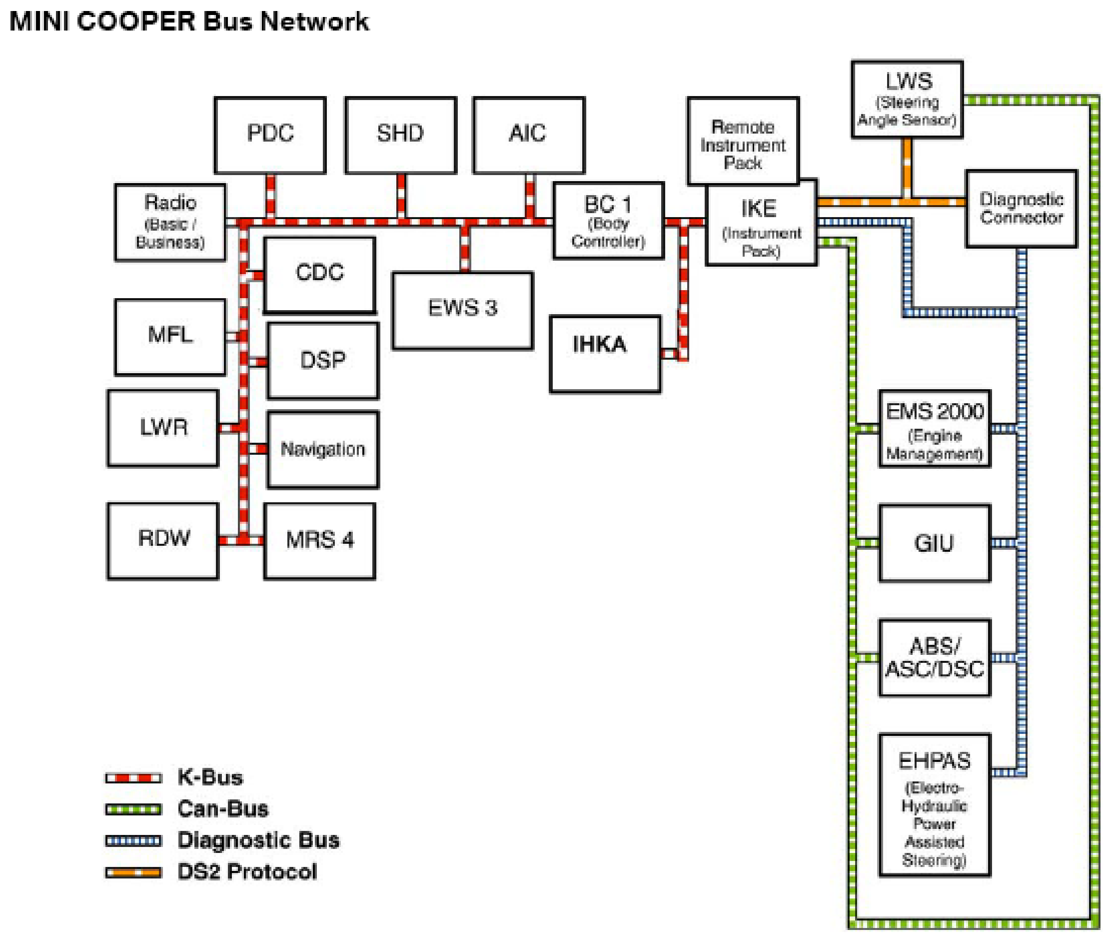


Fig. 1: Bus Systems Function Diagram
Courtesy of BMW OF NORTH AMERICA, INC.

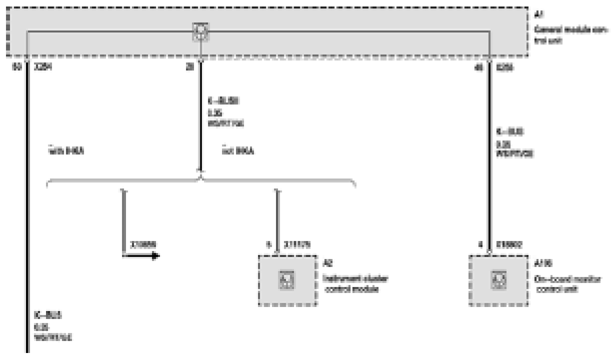
System Components

K-Bus System

The K-Bus system utilized in a serial communication network. It uses a the wire color white/red/yellow (white wire/red stripe/yellow tracer). The body bus (K-Bus) is responsible for the data exchange of telegrams that are required throughout the system. For instance, if the BC1 and IHKA have to communicate, they exchange information via the K-Bus.

The K-Bus system is divided into two segments named K-Bus I and K-Bus II. These "two" buses are essentially the same bus spliced inside the BC1.

K-Bus communication occurs at 9600 bits per second. The K-Bus switches between 0-12 volts (High/Low) and has a low impedance, making it resistant to electromagnetic interference. Most users are active on the bus when the ignition is switched to KLR.



ETM of K-Bus Showing Internal Splice

Fig. 2: K-Bus System Function
Courtesy of BMW OF NORTH AMERICA, INC.

The K-Bus network enters sleep mode 60 seconds after the ignition is switched off. While in sleep mode the K-Bus rests at 12 volts.

The BC1 is the Main Controller, supplying power and establishing message sequencing.

MINI COOPER K-Bus

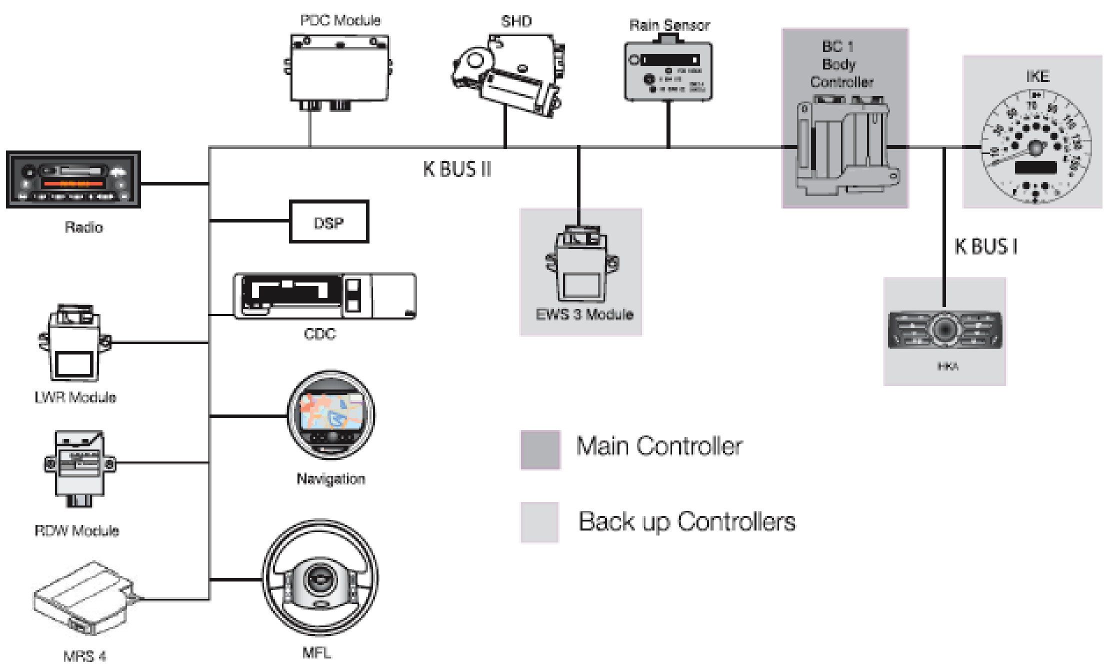


Fig. 3: K-Bus System Function
Courtesy of BMW OF NORTH AMERICA, INC.

CAN-Bus

The CAN protocol was originally developed by Intel™ and Bosch in 1988 for use in the automotive industry to provide a standardized, reliable and cost-effective communications bus for a cars electronics to combat the increasing size of wiring harnesses.

The CAN-bus system is a high speed serial data bus-system linked by an unshielded twisted pair of wires: yellow/black and yellow/brown. The wires are twisted to minimize electromagnetic interference. Both wires carry information and for the CAN-Bus to operate, both signals must be present.

The CAN-system is the fastest of the bus systems used in the MINI, transmitting at 500,000 bits per second. This speed is recognized as the fastest practical operating speed without shielded cable. It is used for systems where the speed of exchange of information is vital for their performance; engine management systems, automatic transmission and automatic stability control.

The CAN-system uses a linear topology which consists of the main bus length and shorter branches. The main bus length terminates at the EMS 2000 and the IKE. The shorter stubs must be as short as possible and no longer than one meter. Any untwisted portion of the bus must not be longer than four centimeters.

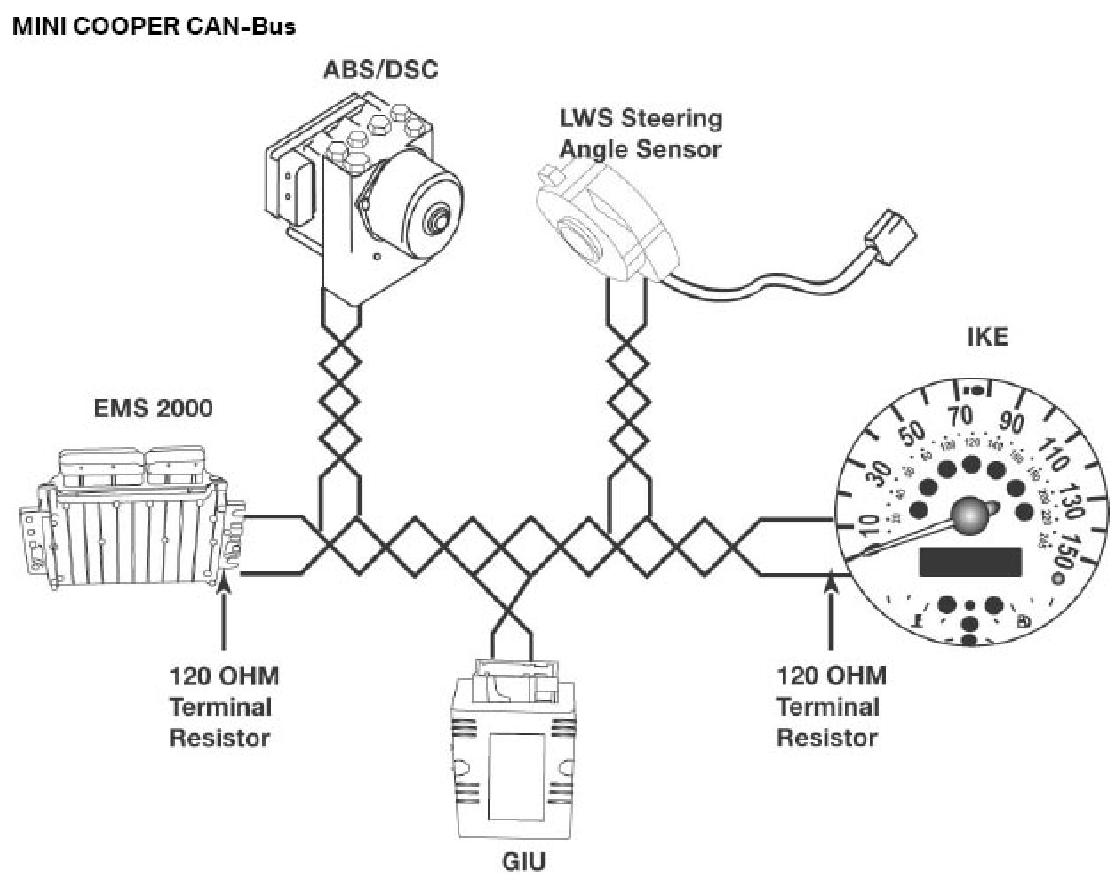


Fig. 4: CAN-Bus Function
Courtesy of BMW OF NORTH AMERICA, INC.

Diagnostic Bus

The Diagnostic bus system is made up of two separate bus-systems which allow the DISplus to communicate with the vehicle control units via the diagnostic socket:

- The Diagnostic bus (ISO 9141-2 OBD II):
  - This allows communication with the DISPlus and powertrain (emission) related control units
- The DS2 Protocol bus:
  - This connects to the control units that do not affect emissions and to the instrument cluster (IKE), which enables communication with all the control units on the K-Bus system

The Diagnostic bus uses a single wire transmitting at 9,600 bits per second. The diagnostic line is used by DISPlus to interrogate each control unit on the network and helps in the fault finding process. It uses a protocol very similar to that of the K-Bus system and is accessed by DISPlus via the 16 pin diagnostic connector located in the driver's footwell (under the dash, close to the A post).

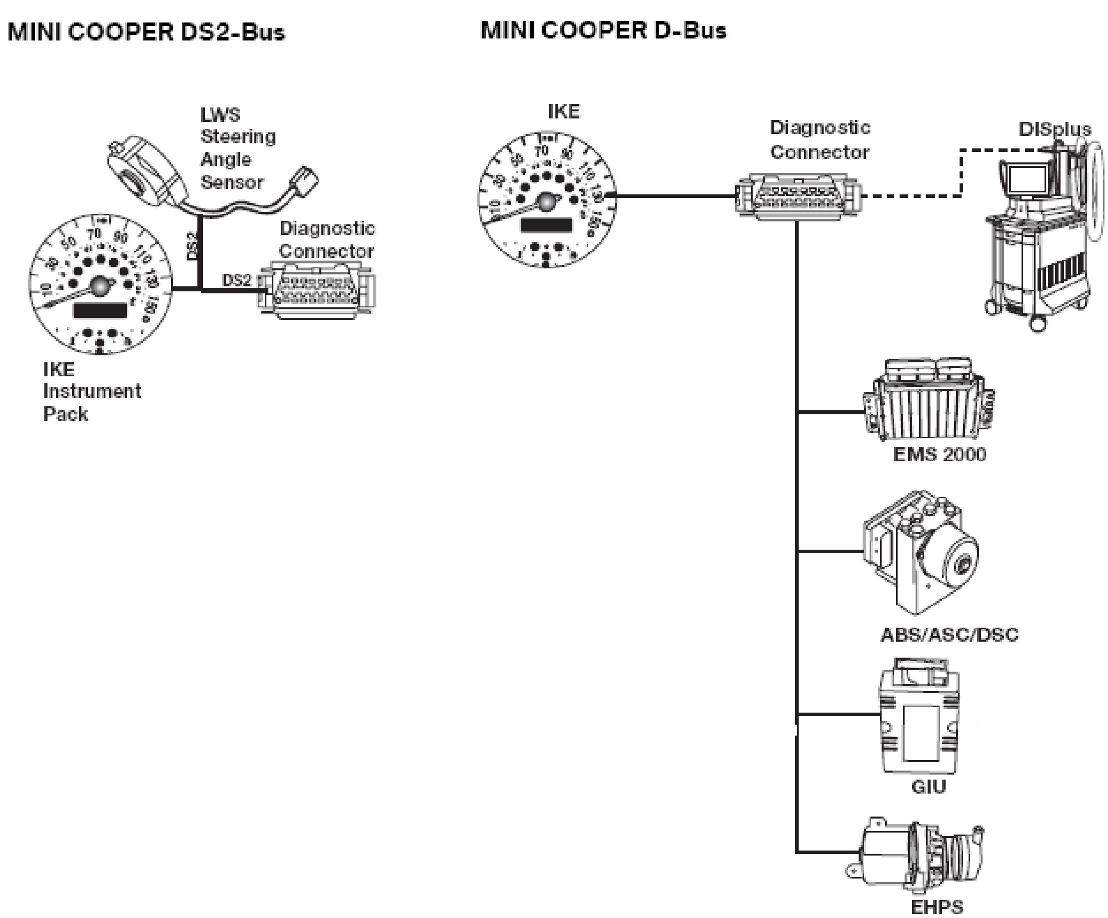


Fig. 5: D-Bus Function
Courtesy of BMW OF NORTH AMERICA, INC.

Principle of Operation

Bus Network

The MINI network system uses a number of interconnected bus-systems. The bus systems in use on the MINI

COOPER are the CAN-Bus, the K-Bus and the Diagnostic buses (D-Bus and DS2 Bus). Most control units are connected to this system and can transmit and receive messages on the system.

The IKE acts as the communication gateway, enabling transfer of data from one bus system to another. The IKE contains a microprocessor, which converts and processes all signals into the format required for transmission on to another bus system.

Control units transmit and receive commands and information on the buses as digital messages. Units connected to the same bus use a common protocol (format) and baud rate (transmission speed (kbit/s)) for the messages they transmit. The protocol and baud rate varies from bus to bus.

All messages transmitted on the bus systems are made up of binary digits, referred to as bits (BInary digiTS). The bit can be either 0 or 1. A combination of bits that make up a signal is transmitted on the bus system. Each control unit converts the digital signal back to an analog value for its own use.

Each message contains coded information indicating the message beginning and ending, and an identifier or address to route the message to the correct destination. The signal also contains a check function which a receiving control unit uses to check the plausibility of the signal. The transmitting control unit monitors the return of the signal on the bus from the receiving control unit. This way the transmitting control unit confirms the signal received is the same as the one transmitted and any faults can be dealt with.

A priority system of control unit or message importance is established providing a smooth flow of information, ensuring that important messages are processed first.

Information from a single sensor is passed on to many control units reducing the number of sensors needed. (e.g. Raw vehicle speed is received at the DSC unit which uses this information for unit operation and a processed road speed is sent to the IKE over the CAN-Bus. The IKE converts this signal into a K-Bus message and transmits this via the K-Bus to the BC1 for the speed dependent wiper control and the radio for the speed dependent volume adjustment).

Advantages of multiplexing:

- Harnesses are smaller and less complex
- Harnesses are cheaper and lighter
- Improved reliability, reduced wires and connections
- New systems can be added easily `Plug and Play'

K-Bus

The K-Bus system is primarily an event-driven system. Messages are sent after a request has been made for component operation or status change.

Each of the K-Bus users are continually monitoring messages on the system. When a user needs to transmit, it waits until there is no activity and then transmits its message. The sender then listens to the system for its own message to be returned by the receiver. If it doesn't receive its own message, a user with higher priority has also transmitted and its message was ignored. The lower priority user then has to wait until the bus becomes inactive and retransmits. When it receives its own message back (correctly) successful transmission is confirmed.

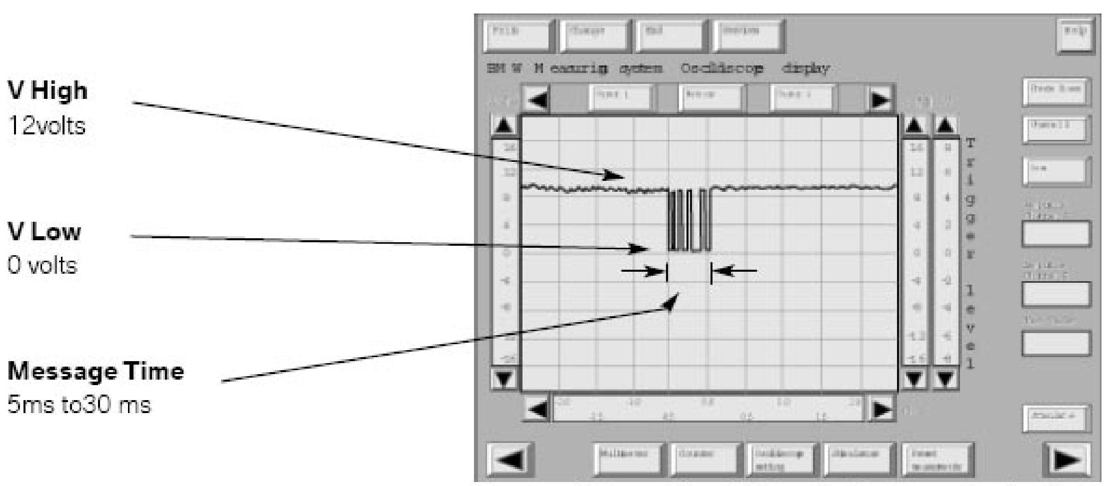
All control units on the K-Bus receive all messages, but only the module addressed in the message will accept and react to the data.

The K-Bus remains operational in the event of a disconnected or failed control unit. This parallel circuit is referred to as a "Tree" structure with each control unit occupying a branch.

The K-Bus provides the diagnostic connection to the control units located on the bus (except for the IKE).

Rules for operation:

- Only one module speaks at a time (serial communication).
- Everybody speaks at the same speed.
- Messages are acknowledged by the recipient.
- The message is repeated if the addressed module fails to respond.
- The BC1 has priority.
- Quit sending message after 5 failed attempts.



Correctly Operating K-Bus during communication

Fig. 6: K-Bus Voltage Wavefrom
Courtesy of BMW OF NORTH AMERICA, INC.

CAN-Bus

The CAN-Bus consists of a twisted pair of wires:

- CAN High (CAN-H, yellow and black)
- CAN Low (CAN-L, yellow and brown).

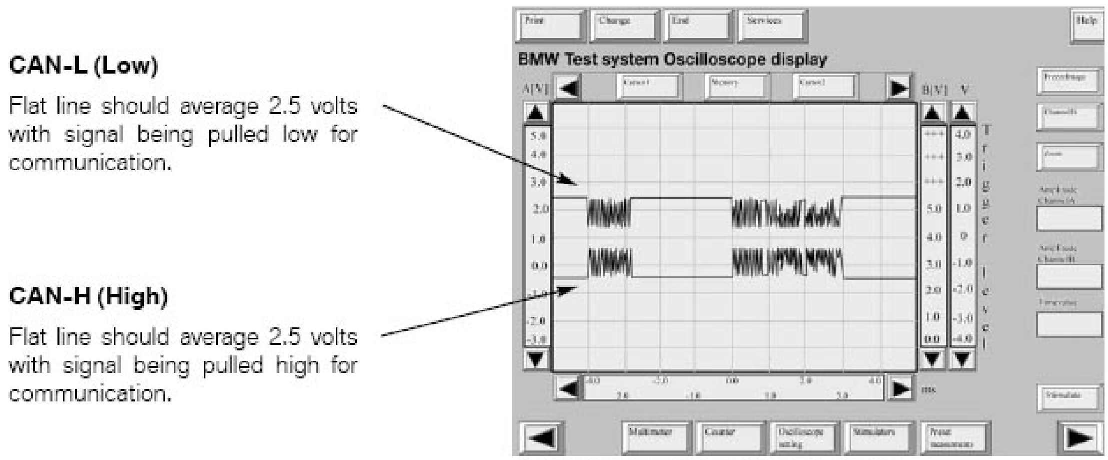
Both Can-H and CAN-L have a standing voltage of 2.5 volts. CAN-L is pulled low to approximately 1.5 volts while CAN-H is pulled high to approximately 3.5 volts.

With CAN-H and CAN-L both at 2.5 volts there is no potential difference (voltage) between them. This is known as the recessive state and is equivalent to logic 1. With CAN-H pulled to 3.5 volts and CAN-L pulled to 1.5 volts there is a potential difference of 2 volts between them. This is known as the dominant state and is equivalent to logic 0. CAN-H and CAN-L always switch together. These two states (0 or 1) are the only two possible.

When a control unit transmits a signal, it is made up of a series of dominant and recessive states. The signal is a combination of the two possible states, in effect 0 and 1, hence a digital signal.

For correct operation CAN-Bus must be terminated at both ends (EMS 2000 and IKE) with a control unit resistance of 120 ohms, connected between CAN-H and CAN-L. These terminations ensure that bit errors due to signal reflections are avoided.

Data transmitted from any subscriber on a CAN-Bus does not contain addresses. Instead the content of the message (RPM, TD, Temp, etc) is labeled with an identifier code unique throughout the CAN. All of the subscribers receive the message and each one checks the message to see if it is relevant to its own operation.



Correctly operating CAN system

Fig. 7: CAN-Bus Voltage Wavefrom
Courtesy of BMW OF NORTH AMERICA, INC.

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 responsible control unit and then re-transmitted later when it is possible.

CAN-Bus Terminal Resistors

Terminal resistors used in the CAN-Bus circuit 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. (Ohms' Law of a Parallel Circuit).

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.

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 10kOhms and 50kOhms.

NOTE: When checking the resistance of the CAN-Bus remember to disconnect the power to the circuit and to leave all modules connected.

D-Bus System

The D-Bus is a serial communications bus that transmits data between the DISPlus and the connected control units. The control unit subject to diagnosis is selected by sending a diagnosis telegram to the control unit address. By request from the DISPlus, the control unit transmits information and the contents of the fault memory or activates a control unit output.

The D-Bus is only active when the DISPlus or GT1 is connected to the diagnostic socket and communicating.

- D-Bus is connected to power train (emission) related control units.
- DS2 Protocol Bus is connected to control units that do not affect emissions and the IKE. Through the IKE communication with the entire K-Bus is possible.

The normal operating voltage of the D-Bus is 12 volts even though it can support communication with as low as 2 volts. The voltage measurement is taken from each data line connection to ground. Each module on the D-Bus provides its own voltage used for communication.

D-Bus operation and signals are similar to K-Bus.

Diagnostics

K and D-Bus Faults

The failure of communication on the K or D-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 or ground to individual modules.
- Interference in the bus cables.
- Bus interrupted
- Bus shorted to battery voltage
- Bus shorted to ground
- Bus line open

- Defective plug connections (damaged, corroded, or improperly crimped)

If problems are encountered trying to establish communication with a control module consider first:

- Battery charge level of the vehicle. Maintain a battery charger on the vehicle at all times during diagnosis.
- Always check that the diagnosis head and connection are OK before working through a test module for lack of communication.

If identification of the vehicle is carried out by the diagnostics without any problems then the D-Bus is OK.

If several control units are not recognized this indicates that a bus link is defective. Continue troubleshooting using the test modules for those particular bus systems.

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.

NOTE: **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.

Failure of one of the control units attached to the 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 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 the volume must change accordingly.

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 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.B's) and coded, perform the K bus Test Module in the Diagnosis Program to ensure that communication is O.K.

NOTE:	**If K-Bus 1 is grounded or shorted to B+, it will affect K-Bus 2 (and vice-versa). If the bus is open at any point, the bus communication will still communicate with modules still connected to the bus.**

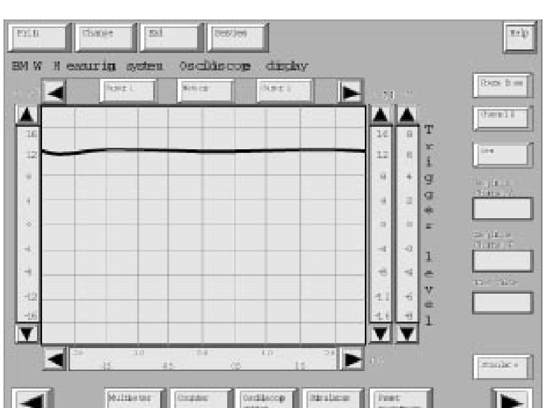
Failure of the voltage supply to individual modules.

Slowly dropping battery voltage on a vehicle with a 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.

Examples of defective K/D-Bus signals



Flat line at 12 volts

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

Fig. 8: Defective K/D-Bus Signals (1 Of 2)

Courtesy of BMW OF NORTH AMERICA, INC.

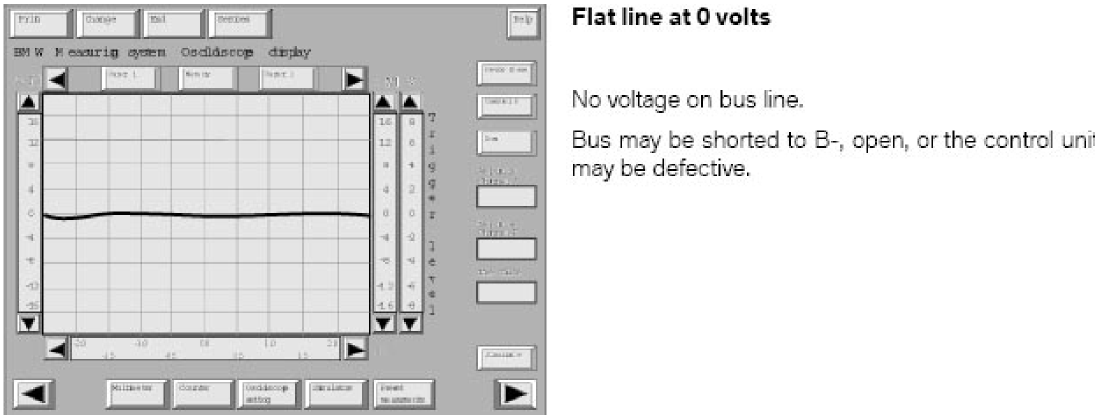


Fig. 9: Defective K/D-Bus Signals (2 Of 2)
Courtesy of BMW OF NORTH AMERICA, INC.

CAN Bus

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

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

Failure of the CAN-Bus cables

The following faults can occur to the CA-Bus wiring:

- CAN-H/L interrupted
- CAN-H/L shorted to battery voltage
- CAN-H/L shorted to ground
- CAN-H shorted to CAN-L
- Defective plug connections (damaged, corroded, or improperly crimped)

In each instance, the connected control units will store a fault due to the lack of information received over the CAN-Bus.

The term **"Timeout"** this refers to a module not being able to communicate with another module on the bus. Each module on the CAN-Bus will attempt communication several times. If unsuccessful, the module will store a "Timeout" or "CAN-Bus" fault and determine that there is a problem with either the bus line or the module that it is trying to communicate with.

These types of faults may indicate a problem with the bus wiring, interference, missing data or failure of the communication module of an individual control unit.

Checking the CAN lines 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 two CAN lines have not shorted to ground or to each other. 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 are some examples of scope patterns that may be observed when checking the CAN-Bus.

Examples of defective CAN-Bus signals

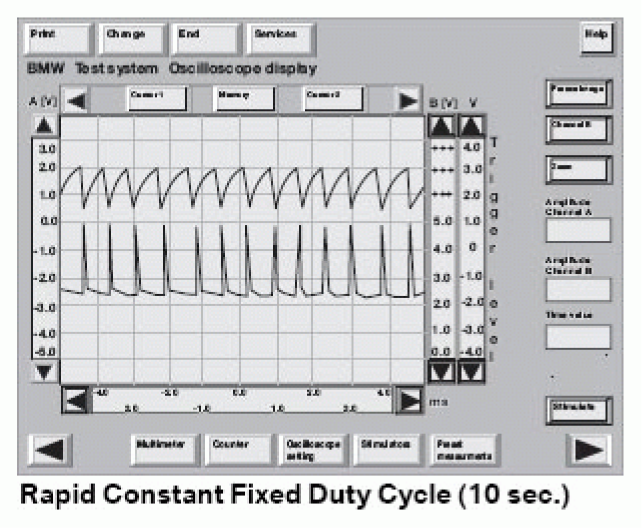


Fig. 10: Defective CAN-Bus Signals (1 Of 4)
Courtesy of BMW OF NORTH AMERICA, INC.

This example represents the output signal produced by an AGS module that is isolated from the bus. This pattern times out after 10 seconds and remains a flat line at 2.5 volts until the key is cycled and the event is repeated.

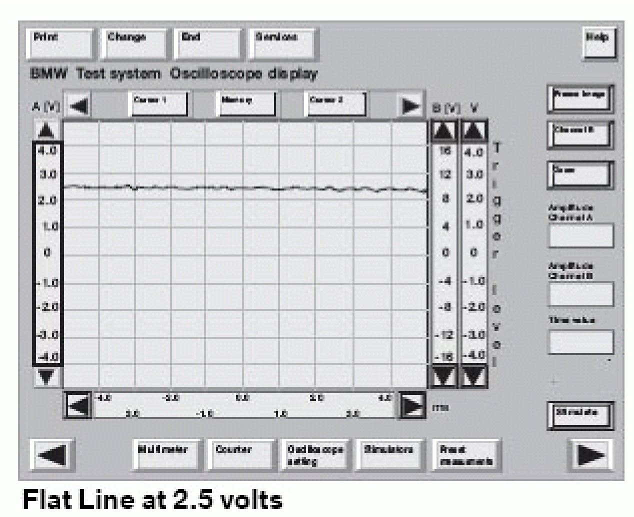


Fig. 11: Defective CAN-Bus Signals (2 Of 4)
Courtesy of BMW OF NORTH AMERICA, INC.

If a continuous flat line is present at one or both CAN lines of a particular control unit, this may indicate that the CAN is open to that particular module. The module may have timed out and is waiting for a signal from another control unit. Check the CAN-Bus at other points to see if communication is occurring else where on the bus.

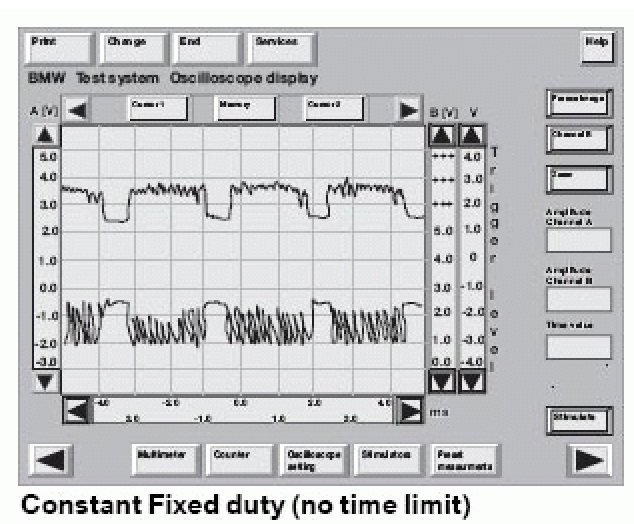
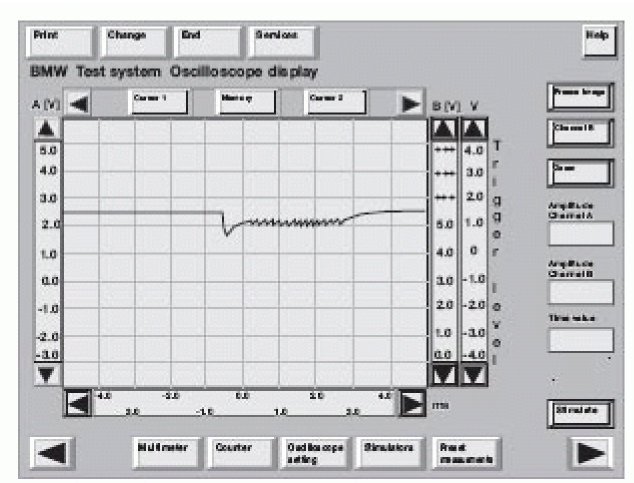


Fig. 12: Defective CAN-Bus Signals (3 Of 4)
Courtesy of BMW OF NORTH AMERICA, INC.

All of the other control units with the exception of most current AGS modules will continue to try and send information even though the control unit has already stored a "Timeout" or CAN fault. This type of signal may only be seen if a section or all of the CAN-Bus is disconnected.



CAN High shorted to CAN Low

Fig. 13: Defective CAN-Bus Signals (4 Of 4)
Courtesy of BMW OF NORTH AMERICA, INC.

If the CAN-Bus lines were to become shorted to one another then the signals would cancel each other out and effectively be a flat line.

Failure of one of the control units attached to the CAN

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

There are instances where failure of a module may paralyze or take down the entire CAN bus. This scenario would be evident by CAN faults stored in every control unit on the bus.

In order to isolate the defective control unit, the control units can be disconnected one at a time while monitoring the status of the CAN using a Voltmeter or oscilloscope. This can be further reinforced by clearing the faults of the remaining control units and then reading them again. If the disconnected control module is the defective one, the faults will only point to communication with that interrupted module and no one else.

If for example the tachometer and temperature display are plausible then communication is occurring between the EMS and IKE/KOMBI. Other indicators such as transmission range or the DSC light may give clues to the communication status with those control units.

Once the module has been replaced and coded or programmed, perform the CAN-Bus Test Module in each control unit to ensure that communication is OK.

Failure of the voltage supply to individual modules

A slowly dropping battery voltage or 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 before beginning troubleshooting on the CAN.

Interference in the CAN-Bus cables

Interference will have a similar effect to shorting or disturbing the CAN-Bus wiring. Excessive interference created by a defective alternator or aftermarket devices such as cell phones or amplifiers may induce a voltage into the CAN-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. Begin by eliminating any problems with the CAN-Bus wiring itself and verify that the generator is operating fault free. Isolate any aftermarket wiring in the vehicle and see if the fault returns.

Programming

During programming it should be noted that the module being programmed will not be communicating and therefore the other control units on the bus will store faults. These faults stored during programming should be deleted and then the fault memory should be read again to verify that they do not return. An incorrectly programmed module results in CAN faults that are not able to be cleared. Remember to always verify the correct Programmed Part Number after programming.