Advanced Diagnostics
Multiplex Electrical Systems

This publication is intended for instructional purposes only. Always refer to the appropriate Jaguar Service publication for specific details and procedures.

WARNING: WHILE SERVICING AND TESTING VEHICLES AND VEHICLE SYSTEMS, TAKE ALL NECESSARY SAFETY PRECAUTIONS TO PREVENT THE POSSIBILITY OF BODILY INJURY OR DEATH.

Publication MXAD/98

PRINTED IN USA

Contents

Introduction

Most Jaguar Service Training courses concentrate on the technical details of a specific vehicle system; how the components function and how to determine if the system is functioning correctly. Advanced Diagnostics courses have a different focus; they concentrate on the process used to diagnose faults. They are for professionals who already have practical knowledge and experience in the systems covered by the Jaguar core courses.

We have all developed diagnostic techniques that we use on a regular basis and this course provides the opportunity to examine and further develop these techniques and share them with other technicians.

To get the most from Advanced Diagnostic training, you should practice the structured diagnostic process that will be presented and apply some critical thought to the process that you use. Time spent developing your diagnostic techniques here will be paid back as you solve problems more efficiently at the dealership. Combining the structured diagnostic process with your existing experience will result in:

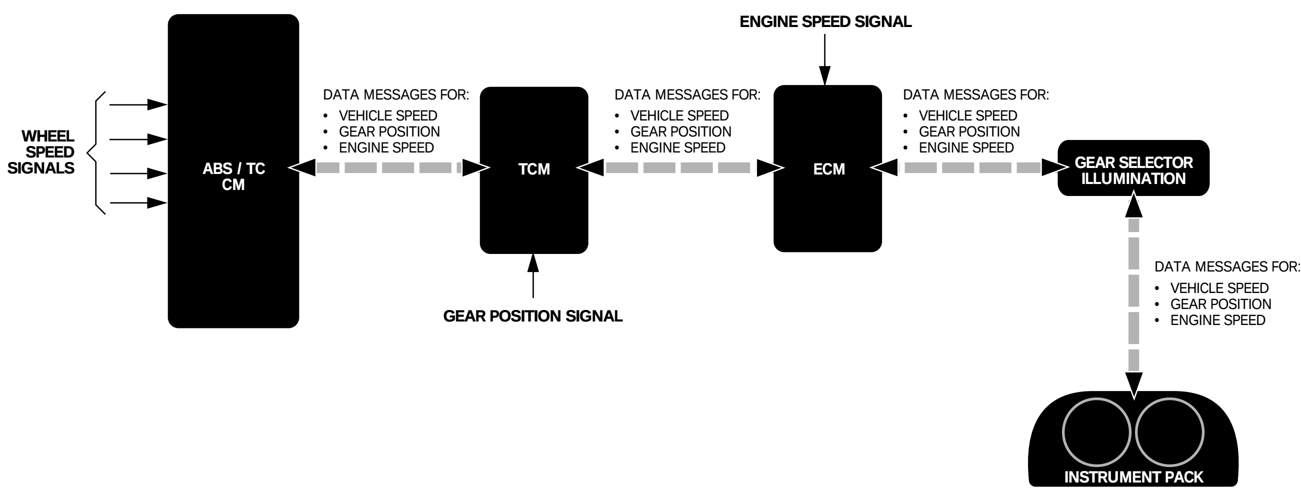
- More effective troubleshooting
- More “fixed right the first time” repairs
- More confidence in the repair

Most importantly, the enhancement of your diagnostic skills will increase customer loyalty and promote your professional image.

Introduction to Multiplexing

A multiplex circuit is an electrical circuit designed to transmit multiple signals on the same set of conductors. A single circuit (sometimes called a bus) connects a number of control modules. The modules communicate with each other by sending coded serial data messages over the shared bus. The data is available to all of the control modules on the multiplex bus. Modules connected to a multiplex circuit are often called nodes.

MULTIPLEX ELECTRICAL CIRCUIT



MXAD/1.01

Why Multiplexing?

As more functions are added to the vehicle, more sensors and wiring are needed to control them. Wiring and connectors are generally reliable, but the chances of a fault increase with each added component. In addition, it is difficult to find space in the vehicle for the connectors, wires, input devices, relays, and control modules needed for the new functions. Vehicle cost, weight, complexity, diagnostic, and repair difficulties increase with added functions.

Multiplexing — connecting control components to a single shared circuit — allows vehicle control components to communicate directly with each other to share data and function control. Multiplexing reduces the amount of wires, connections and components. In summary, multiplexing reduces vehicle weight and cost, increases functionality and improves reliability.

NOTES

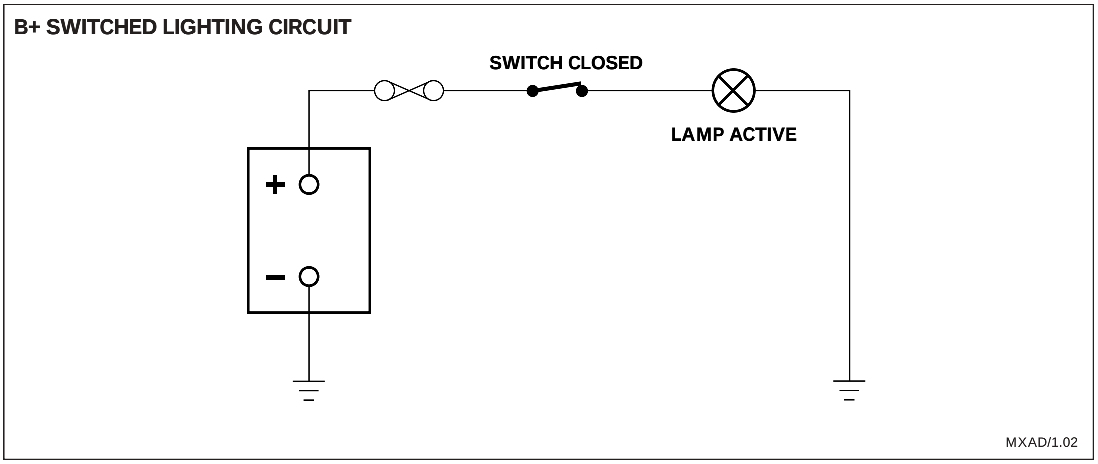
Control Circuits

The purpose of a conventional electrical or multiplex control circuit is to activate or control a function in response to an input. The input can be a driver command such as pressing a switch, an electrical input from a sensor such as wheel speed, or a signal from another control module such as engine speed.

The following circuits are examples of some inputs and outputs that control vehicle systems. The last example also illustrates that an input is often used for control of more than one function.

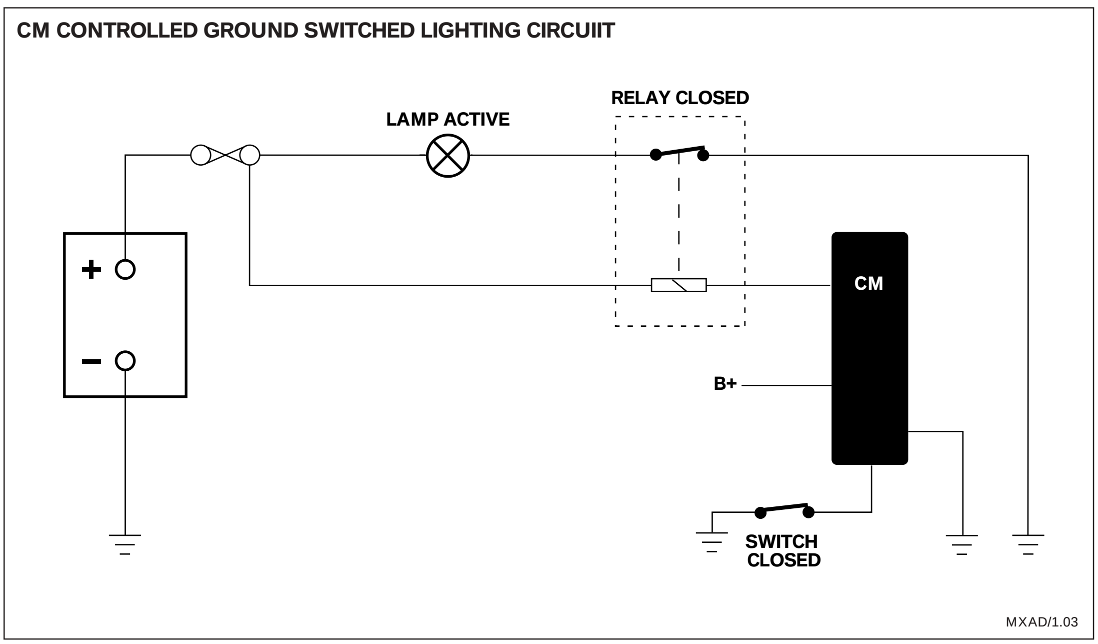
B+ switched lighting circuit

In this circuit, the input is the closing of a switch. The output is a voltage signal that results in activating the lamp.



CM controlled ground switched lighting circuit

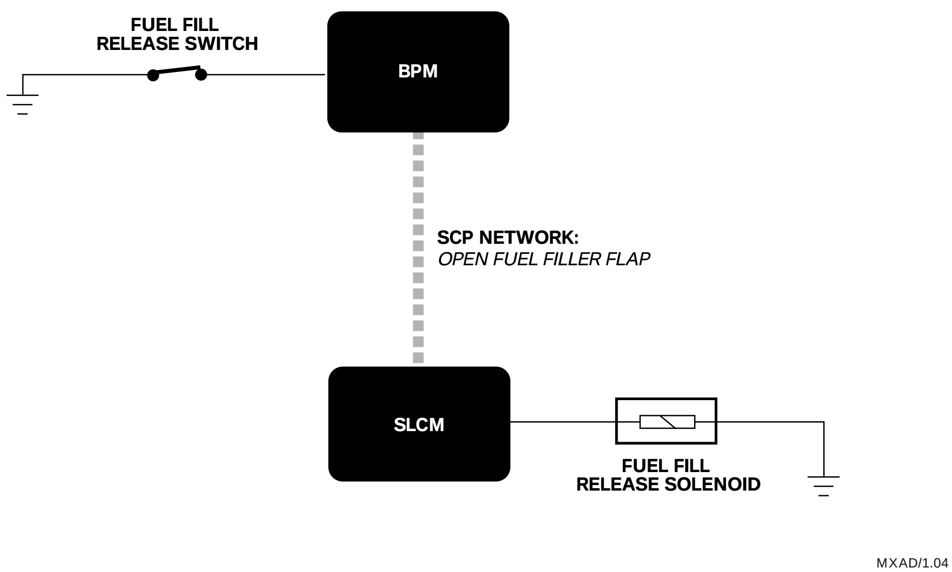
In this circuit, more than one input and output is required to activate the lamp. The first input is closing a switch that outputs a ground signal input to the CM (control module). The CM outputs a ground signal to a relay coil causing the relay contacts to close. The relay outputs (provides) the ground to activate the lamp.



Multiplex controlled fuel filler flap circuit

In this circuit, a ground input from the fuel filler release switch triggers the BPM (body processor module) to broadcast an *OPEN FUEL FILLER FLAP* data message on the SCP (standard corporate protocol) multiplex network. In response to the SCP data message, the SLCM (security and locking control module) outputs a voltage to activate the filler flap release solenoid. The fuel filler flap release solenoid, which is close to the SLCM, is "hard wired" to the fuel filler flap release solenoid. If other data on the SCP network indicates that the engine is running, the security system is armed, or the vehicle is locked, then the open fuel filler flap data message is inhibited.

MULTIPLEX CONTROLLED FUEL FILLER FLAP CIRCUIT



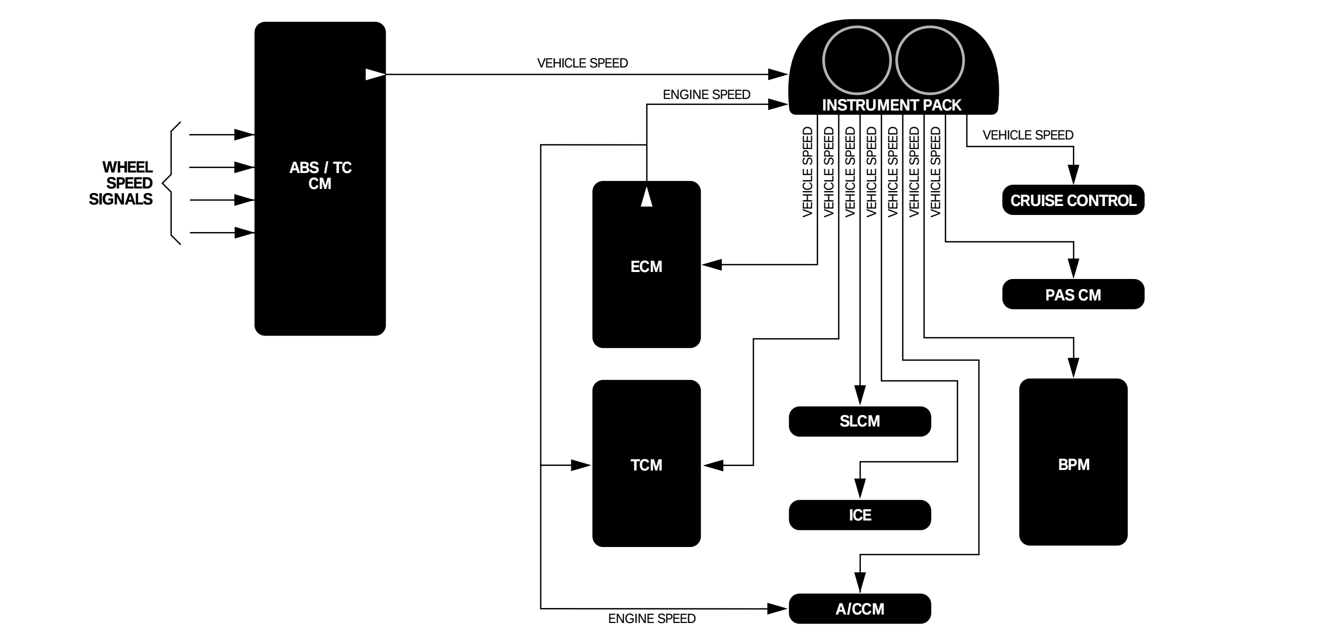
NOTES

Control Circuits (continued)

Nonmultiplexed System Signal Distribution (1995 MY Sedan Range)

This circuit shows how the ABS CM uses the inputs from four wheel speed sensors to generate a vehicle speed signal output. The ABS CM transmits one of the wheel speed sensor signals to the instrument pack to be used as the vehicle speed signal for the speedometer and for distribution to other vehicle systems.

EXAMPLE OF NONMULTIPLEXED SYSTEM SIGNAL DISTRIBUTION (1995 MY SEDAN RANGE)



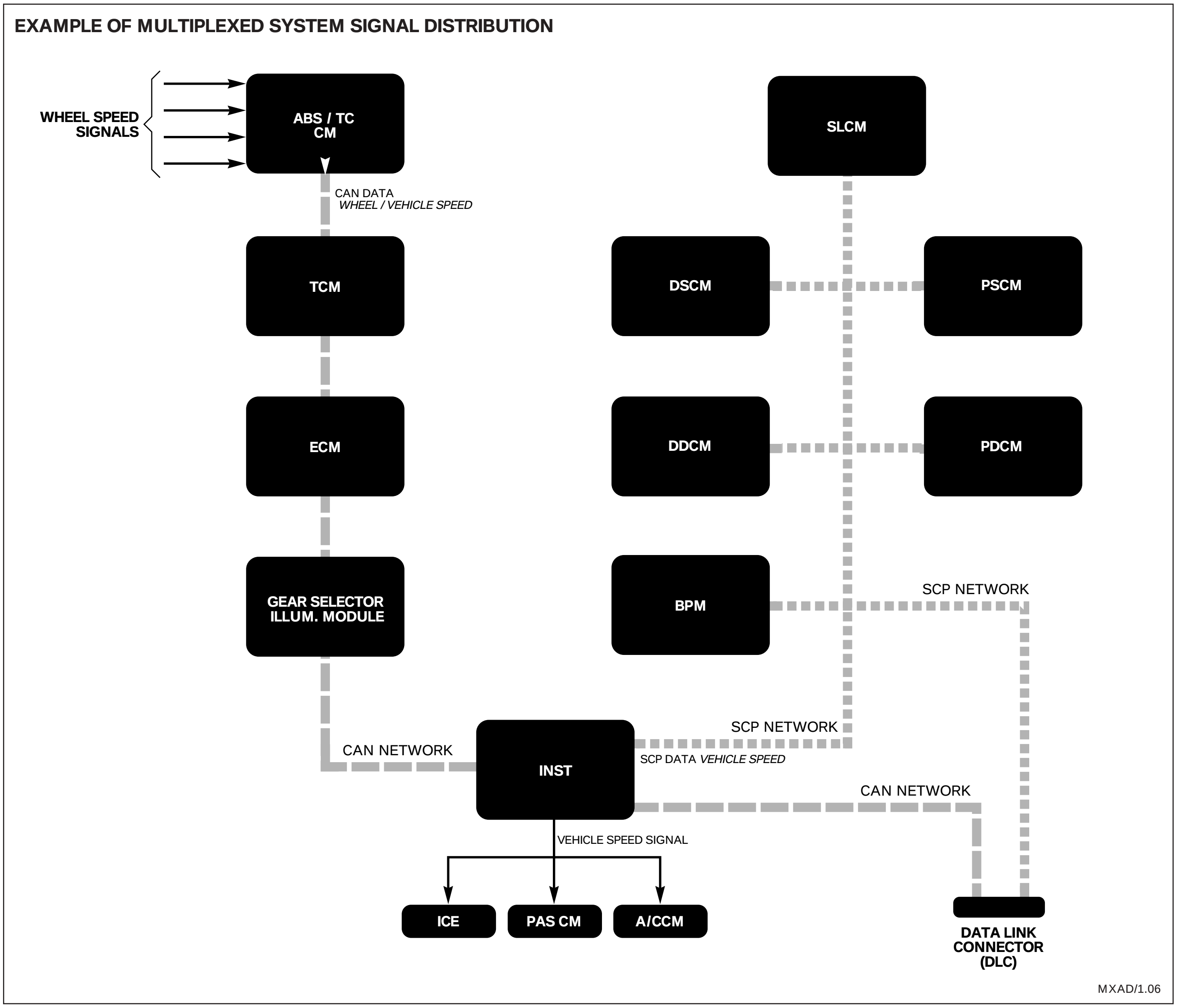
MXAD/1.05

Control Component	Function
Instrument pack (IP)	Speedometer
Transmission control module (TCM)	Transmission shift control
Radio / cassette head (ICE)	ICE volume
Air conditioning control module (A/CCM)	Climate control blower speed
Engine control module (ECM)	Engine control
Power assisted steering control module (PAS CM)	Variable assist power steering
Speed control control module (SCCM)	Cruise control
Body processor module (BPM)	Wiper speed control
Security and locking control module (SLCM)	Locking and security functions

Each of the components receives its vehicle speed input via a separate (hard-wired) circuit.

Multiplexed System Signal Distribution

The diagram on the facing page shows how the XK8 distributes the vehicle speed signal via multiplex circuits. The wheel speed signals, one from each wheel speed sensor, are used by the ABS / TC CM to provide anti-lock braking and traction control. The ABS / TC CM communicates this data on the CAN multiplex network as a message containing the speed data for each wheel plus the vehicle speed data. The TCM and ECM are connected to the CAN multiplex circuit and use the data for control of their functions. The INST (instrument pack) is also connected to the CAN network and converts the vehicle speed data portion of the message for use by the speedometer, SCP (body systems) multiplex circuit and nonmultiplexed components.



Control Component	Function
Transmission control module (TCM)	Transmission shift control
Engine control module (ECM)	Engine control, cruise control
Instrument pack (INST)	Speedometer
Body processor module (BPM)	Wiper speed, convertible top
Security and locking control module (SLCM)	Locking and security functions
Radio / cassette head (ICE)	ICE volume
Air conditioning control module (A/CCM)	Climate control blower speed
Power steering control module (PAS CM)	Variable assist power steering

All modules connected to the multiplex circuits share the same message data via the network wiring and connectors. Modules not connected to the networks receive the vehicle speed signal via separate hardwires.

NOTES

Multiplex Networks

Automotive Multiplex System Classification

Multiplex systems are classed as follows:

Class A transmits up to 10,000 bits of data per second (10 kBaud)
Class B transmits up to 125,000 bits of data per second (10 – 125 kBaud)
Class C transmits over 125,000 bits of data per second (125 kBaud)

Communication Protocols

XK8 and XJ Series Sedans use two multiplex networks consisting of two separate circuits (busses) that operate at different speeds and communicate using different protocols (languages). Some serial communications circuits are also used.

The CAN network (controller area network)

The CAN network is a high speed "real time" bus connecting the power train modules: ABS / TC CM, TCM, ECM, gear selector illumination module and INST.

The SCP network (standard corporate protocol [Ford version])

The SCP network is a slower speed bus connecting the body systems body system modules: INST, BPM, SLCM, DDCM (driver door control module), PDCM (passenger door control module), DSCM (driver seat control module) and PSCM (passenger seat control module). XJ Series Sedans have an additional module for each rear door: DRDCM (driver rear door control module), and PRDCM (passenger rear door control module).

CAN and SCP use different communications protocols (message structures). They cannot communicate data messages directly or understand each other's messages. However, both the CAN and SCP networks are connected to the INST. The INST functions as a "gateway," by translating certain data messages so that they can be understood and shared between the two networks.

Serial communications

Additional serial communications circuits allow PDU diagnosis of nonmultiplexed control modules via the DLC (data link connector). The additional serial communication links perform the same function as in previous vehicles. The links are often referred to as ISO (International Organization for Standardization) links because they conform to ISO standard 9141/2 and Society of Automotive Engineers (SAE) standard J 1978.

Communication Speed Summary

System	Class	Speed	
SCP network	B	41.6 kBaud	(41,600 bits / second)
CAN network	C	500 kBaud	(500,000 bits / second)
Serial Communications	B	10.4 kBaud	(10,400 bits / second)

NOTE: The serial communications data rate of Sedan Range Vehicles through the 1994 MY is 4.8 kBaud (4,800 bits of data a second).

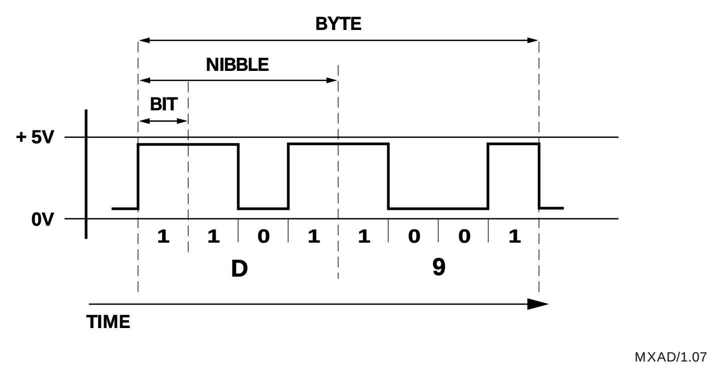
NOTES

Data Messages

Data messages are binary code values transmitted as a series of timed voltage signals on the multiplex bus. A five-volt signal is assigned a value of 1 and a zero-volt signal is assigned the value of 0. Each binary code 1 or 0 is called a bit. Four binary code data bits (called a nibble) make up one character. Eight data bits (called a byte) make up two characters.

Jaguar uses a "time divided" multiplex system that distinguishes the serial bits of binary code (1's and 0's) by the amount of time that the signal is high or low.

TYPICAL BINARY CODE DATA VOLTAGE

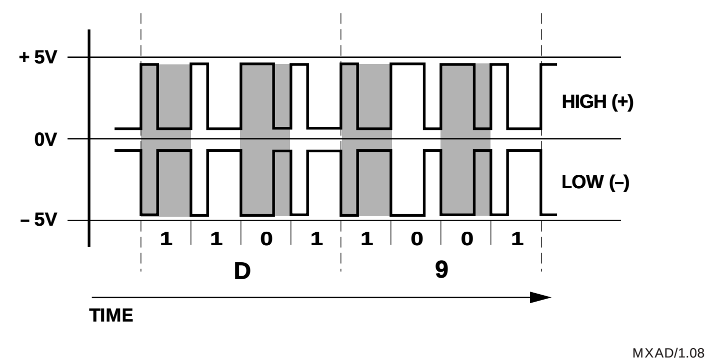


Data message transmission

The multiplex bus consists of two wires, one high (+) and the other low (–). When a module transmits a bit, it drives the voltage on one wire high and the voltage on the other wire low. The bus wires are twisted so that the opposing high and low voltages cancel any possible electromagnetic interference.

Binary code values can be converted by a decimal or hexadecimal decoding system so they can be understood as alpha or numeric characters.

TYPICAL BINARY CODE DATA VOLTAGES ON MULTIPLEX BUS



Binary	Decimal	Hexadecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7

Binary	Decimal	Hexadecimal
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

The binary code byte 11011001 translates as D9 when hexadecimal decoded or the number 139 when decimal decoded.

NOTES

Multiplex Networks (continued)

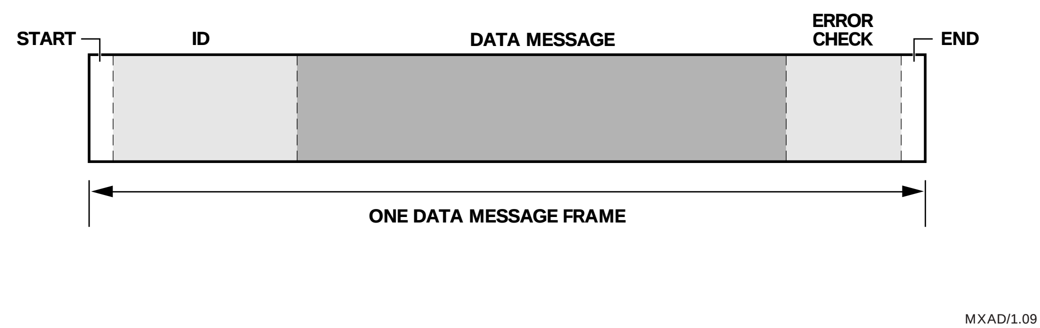
Data message frame

Data is transmitted on the bus in a data message “frame.” A frame contains a number of separate parts or fields that contain the following data:

- Start and end of the frame
- Frame identification (ID)
- Data message
- Error checking information

A complete data message frame is a serially transmitted stream of binary data 1’s and 0’s that each module can understand.

TYPICAL DATA MESSAGE “FRAME”



Multiplex messages are communicated one at a time over the network bus. A bus can be compared to a single lane road and each data message frame to a vehicle. The capacity of the road is much greater than the maximum traffic at any one time so there is little possibility of one message frame colliding with another. In addition, each module constantly watches the network message traffic by monitoring the voltages on the bus. A module will not begin a communication until the bus is clear. If two modules attempt communication at the same instant, a method of “arbitration” assures that the message frame with the highest priority will always be communicated first. The module with the lower priority message frame will stop transmitting and try again when the bus is clear. Only one message frame will be transmitted on the bus at a time.

NOTES

SCP (Standard Corporate Protocol [Ford Version]) Network

The SCP bus is two standard 0.5 mm (0.020 in.) copper wires twisted together with 40 twists per meter (approximately one twist per inch). One wire in the bus is designated as SCP high (+) and the other is designated as SCP low (–). The network is wired as a "star" circuit. Bus integrity is maintained by using the vehicle speed data message as a "keep alive" signal. If a module does not receive the "keep alive" message, the module assumes a fault and takes itself off line.

SCP Data Message Frames

Each SCP data message frame is a complete message unit communicating only the data for one action. Messages on the bus are available to all of the modules connected to the bus but are only "used" by a module if required. There are three general types of SCP data messages:

Cyclical messages

Cyclical messages are transmitted on the bus at specified intervals. *VEHICLE SPEED, ENGINE RUNNING* and *CHARGING OK* are examples of three separate cyclical messages that are transmitted by the INST at least every 150 ms.

Event messages

Event messages are sent once, or for a specified number of times, when something happens. *KEY IN IGNITION* is a message sent by the BPM. The message is transmitted when the key is put into the ignition switch. When the key is withdrawn from the switch, *KEY NOT IN IGNITION* is sent by the BPM. Event messages are often used to "toggle" a function ON and OFF through other modules.

Request messages

Request messages ask for a specific piece of data. An example of a request message is *REQUEST KEY-IN STATUS* sent by the SLCM, DDCM or PDCM. The BPM then responds with a key status message – either *KEY IN IGNITION* or *KEY NOT IN IGNITION.*

Refer to the applicable Electrical Guide Appendix for individual module messages.

SCP cannot communicate directly with CAN. However, the INST converts specific message data allowing communication between networks.

NOTE: All modules have fail safe default modes in case of a network failure.

NOTES

SCP (Standard Corporate Protocol [Ford Version]) Network (continued)

XK8 SCP modules

The following control modules communicate directly through the SCP network:

- Major instrument pack (INST)
- Body processor module (BPM)
- Security and locking control module (SLCM)
- Driver door control module (DDCM)
- Passenger door control module (PDCM)
- Driver seat control module (DSCM)
- Passenger seat control module (PSCM)

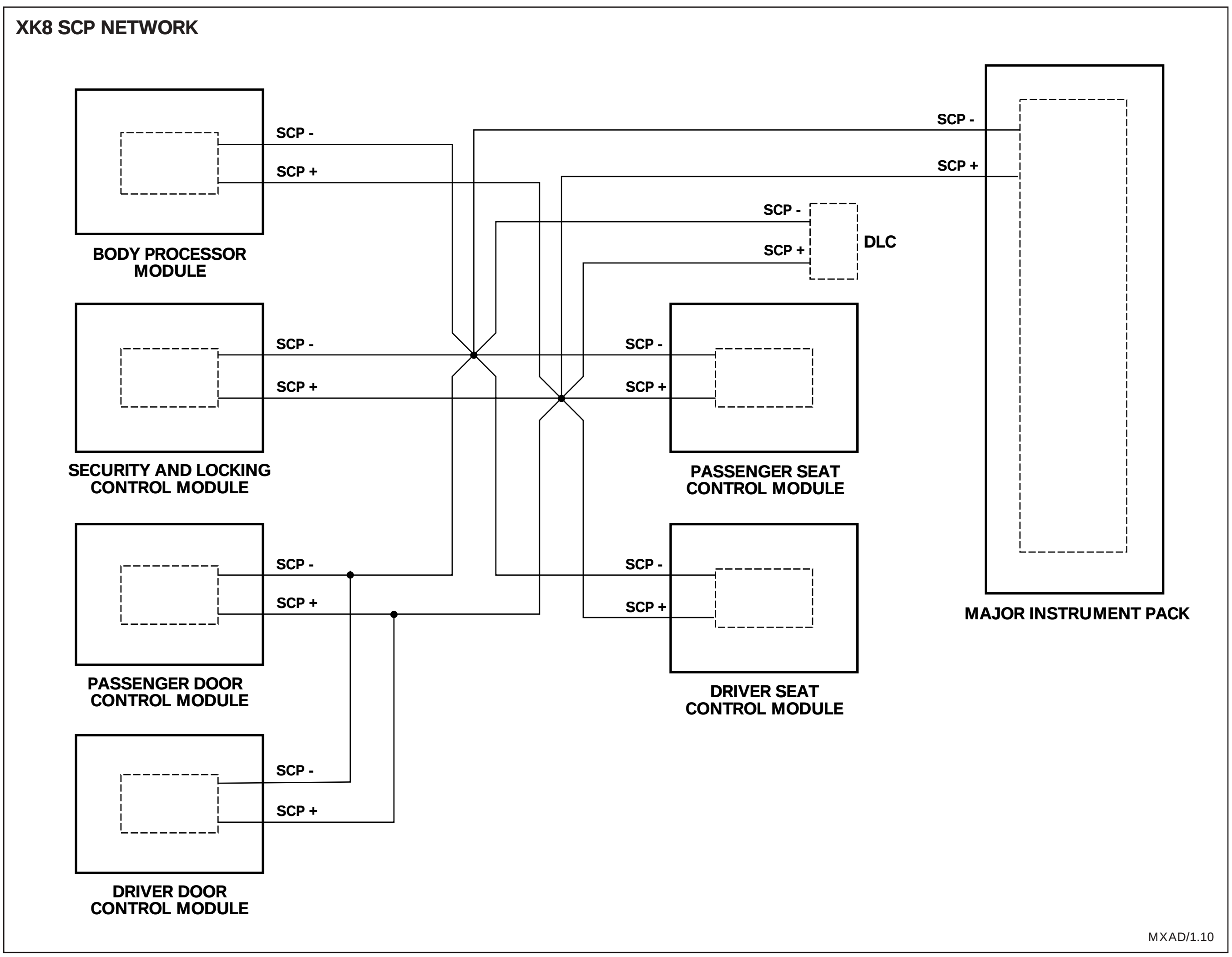
The network is also connected to the DLC (data link connector) for diagnostics.

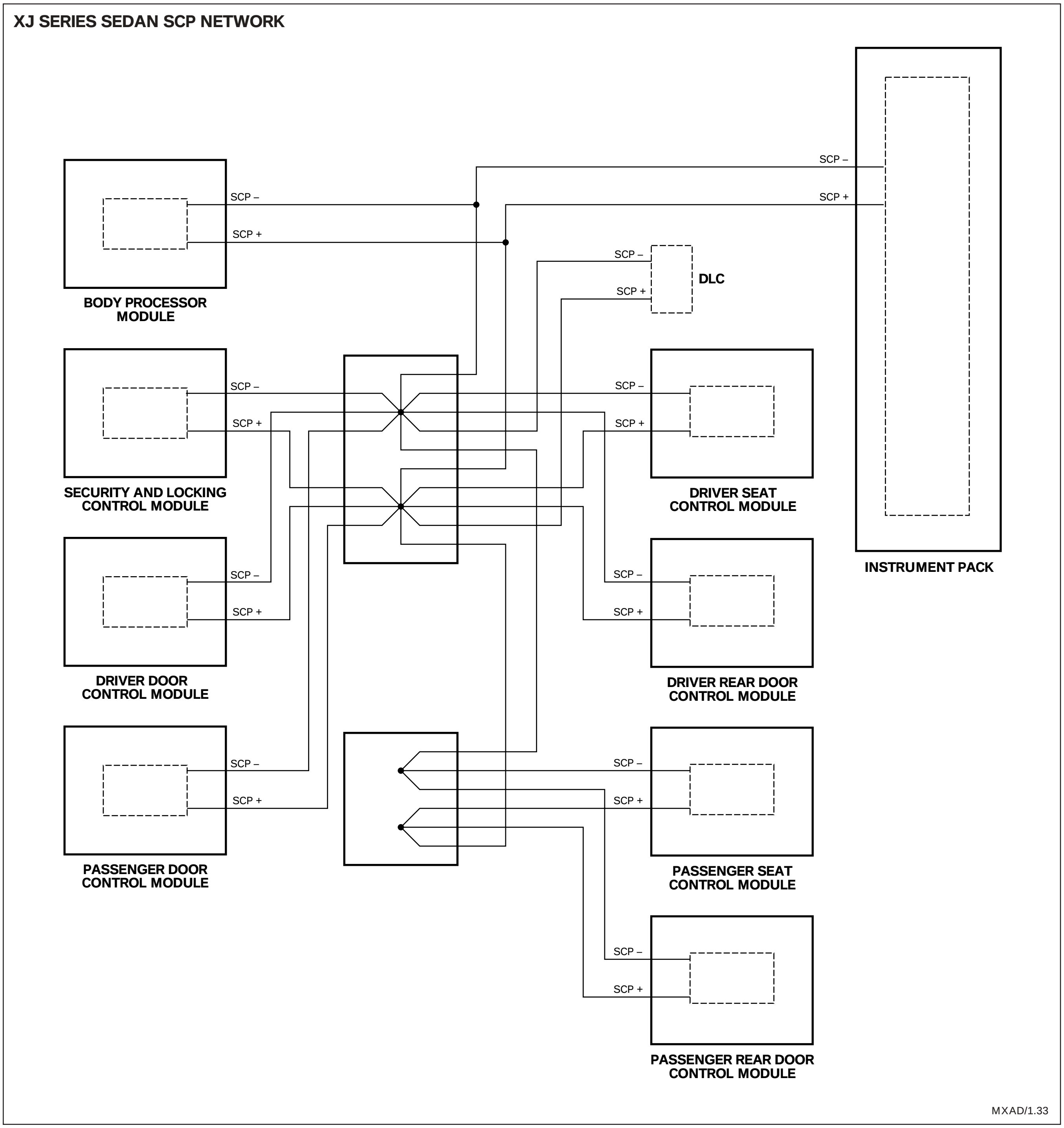
XJ Series Sedan SCP modules

The following control modules communicate directly through the SCP network:

- Instrument pack (INST)
- Body processor module (BPM)
- Security and locking control module (SLCM)
- Driver door control module (DDCM)
- Passenger door control module (PDCM)
- Driver seat control module (DSCM)
- Driver rear door control module (DRDCM)
- Passenger seat control module (PSCM)
- Passenger rear door control module (PRDCM)

The network is also connected to the DLC (data link connector) for diagnostics.




XJ SERIES SEDAN SCP NETWORK
SCP –
SCP +
BODY PROCESSOR MODULE
SECURITY AND LOCKING CONTROL MODULE
DRIVER DOOR CONTROL MODULE
PASSENGER DOOR CONTROL MODULE
DLC
DRIVER SEAT CONTROL MODULE
DRIVER REAR DOOR CONTROL MODULE
PASSENGER SEAT CONTROL MODULE
PASSENGER REAR DOOR CONTROL MODULE
INSTRUMENT PACK
MXAD/1.33

NOTES

CAN (Controller Area Network)

The CAN bus is two standard 0.5 mm (0.020 in.) copper wires twisted together with 40 twists per meter (approximately one twist per inch). One wire in the bus is designated as CAN high (+) and the other is designated as CAN low (–).

CAN is called "real time" communication because its speed allows extremely fast response time for controlling time critical operations.

XK8 and XJ Series Sedan CAN modules

The following control modules communicate directly through the CAN network:

- Anti-lock braking / traction control module (ABS / TC CM)
- Transmission control module (TCM)
- Engine control module (ECM)
- Gear selector illumination module (does not transmit – used only for gear selector position lights)
- Instrument pack (INST)

The CAN network is also connected to the DLC (data link connector) for diagnostics.

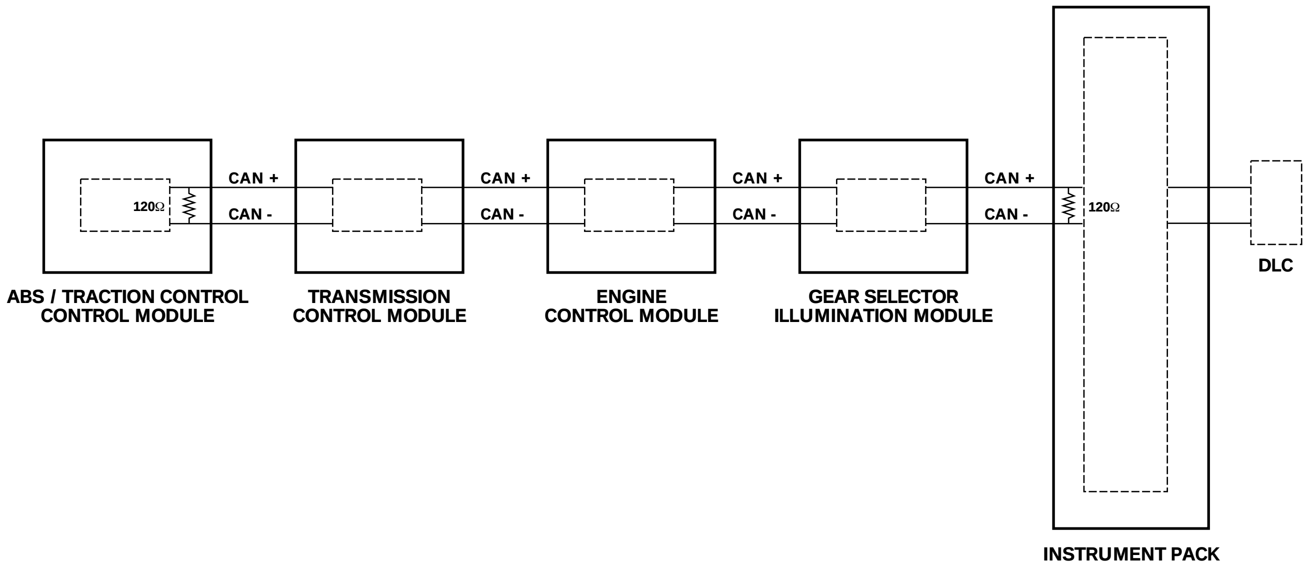
Refer to the applicable Electrical Guide Appendix for individual module messages

CAN is unable to communicate directly with SCP. However, the INST converts specific message data allowing communication between networks.

NOTE: All modules have fail safe default modes in case of a network failure.

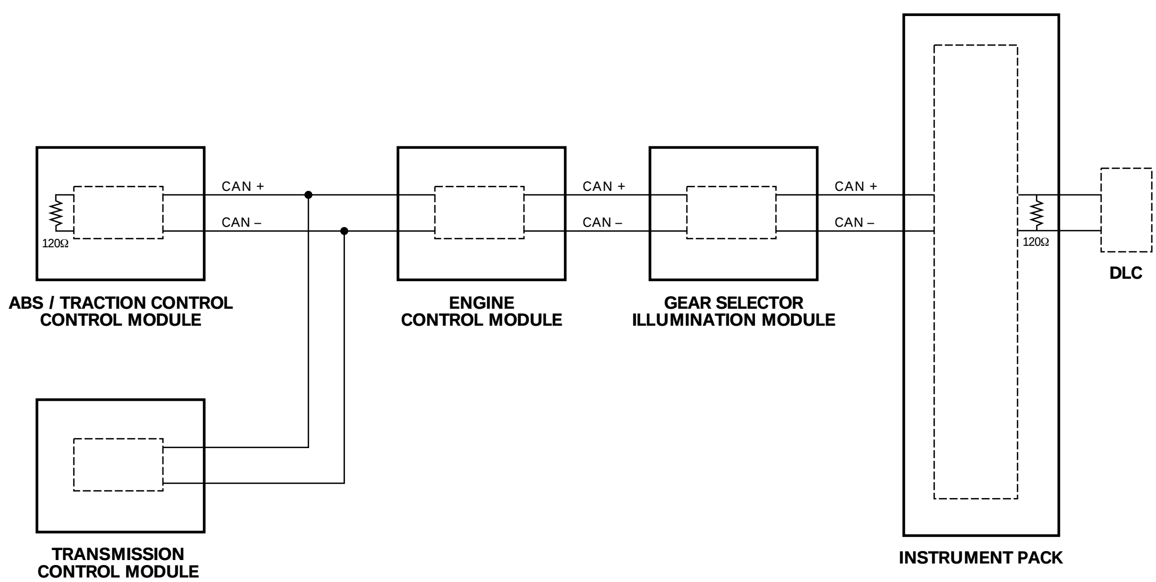
NOTES

NORMALLY ASPIRATED VEHICLE CAN NETWORK



MXAD/1.11

SUPERCHARGED VEHICLE CAN NETWORK



MXAD/1.31

NOTES

CAN (Controller Area Network) (continued)

CAN Data Message Frames

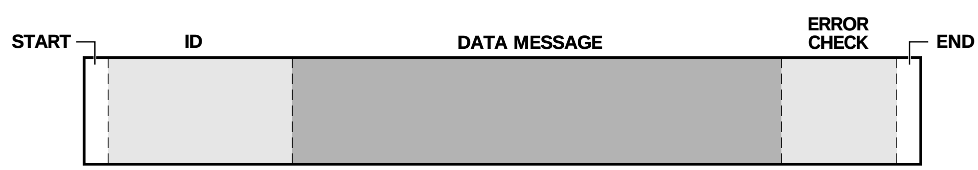
CAN data message frames generally contain more data than SCP message frames. CAN message frames are transmitted at intervals of from 4 to 20 ms depending on the message. The data is available to all modules but is only "used" by those modules that require it.

Each CAN module transmits three types of data message frames.

- Token data message frames (cyclical transmission) — The token message tells the network that the module is "alive."
- Diagnostic data message frames (request transmission) — The diagnostic message is a response to a PDU request for specific diagnostic information.
- Vehicle operation data message frames (cyclical transmission) — The vehicle operation message contains the vehicle operational information from the module.

Modules transmit more than one vehicle operation data frame because the amount of data from the module exceeds the capacity of a single data frame. The ID (identification) field of each CAN message frame not only identifies the transmitting module, it also identifies the type of data and its precise location within the frame's data message field.

TYPICAL CAN DATA MESSAGE FRAME



MXAD/1.12

Examples of vehicle operation data messages:

The ABS / TC CM transmits three separate vehicle operation data message frames. One message frame contains the data required for traction control and automatic stability control functions, vehicle speed, and distance traveled. Another message contains vehicle speed, distance traveled, traction control and automatic stability control status. The remaining frame contains the individual wheel speed data

The number of separate data frames a module transmits depends on the module design and the amount of data that needs to be transmitted.

The following separate vehicle operation message frames are cyclically communicated on the CAN bus:

- ABS Data
- ABS Data
- ABS Data
- TCM Data
- TCM Data
- ECM Data
- ECM Data
- ECM Data
- INST Data

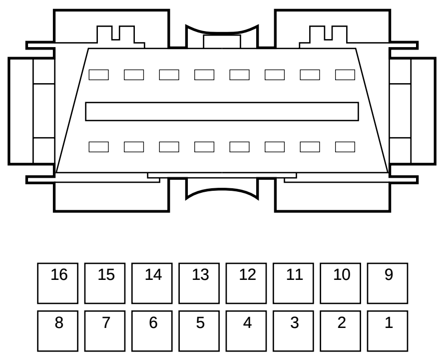
In addition, one token message is transmitted by each module and each module responds to PDU interrogation with its diagnostic message.

Data Link Connector (DLC)

Both the CAN and SCP busses are directly connected to the DLC. PDU / MPA contains hardware and software that allows it to function as a "node," an additional module added to networks. The software and hardware supports direct communications between PDU / MPA and the networks for diagnostics and module programming. In addition, PDU / MPA communicates via the DLC with nonmultiplexed modules using ISO 9141/2 standard serial data communications links.

Generic scan tools access the legislated OBD II DTCs and freeze frame information in the ECM via DLC pins 7 and 15.

DATA LINK CONNECTOR



Data Link Connector Pin Out Information

XJ Series Sedan

Pin	Description
CC6-1	Ignition position II switched ground
CC6-2	SCP high (+)
CC6-3	Not used
CC6-4	Power ground
CC6-5	Logic ground
CC6-6	CAN high (+)
CC6-7	ECM OBD II DTC, A/CCM, KTM, Airbag / SRS SPS serial data
CC6-8	Ignition position I switched ground
CC6-9	Ignition switched B+
CC6-10	SCP low (–)
CC6-11	Not used
CC6-12	ECM programming
CC6-13	ECM programming
CC6-14	CAN low (–)
CC6-15	ECM OBD II DTC, A/CCM
CC6-16	B+ supply

XK8

Pin	Description
FC53-1	Ignition position II switched ground
FC53-2	SCP high (+)
FC53-3	Airbag / SRS serial data
FC53-4	Power ground
FC53-5	Logic ground
FC53-6	CAN high (+)
FC53-7	ECM OBD II DTC, A/CCM, KTM, serial data
FC53-8	Ignition position I switched ground
FC53-9	Ignition switched B+
FC53-10	SCP low (–)
FC53-11	Not used
FC53-12	ECM programming
FC53-13	ECM programming
FC53-14	CAN low (–)
FC53-15	ECM OBD II DTC, A/CCM
FC53-16	B+ supply

NOTES

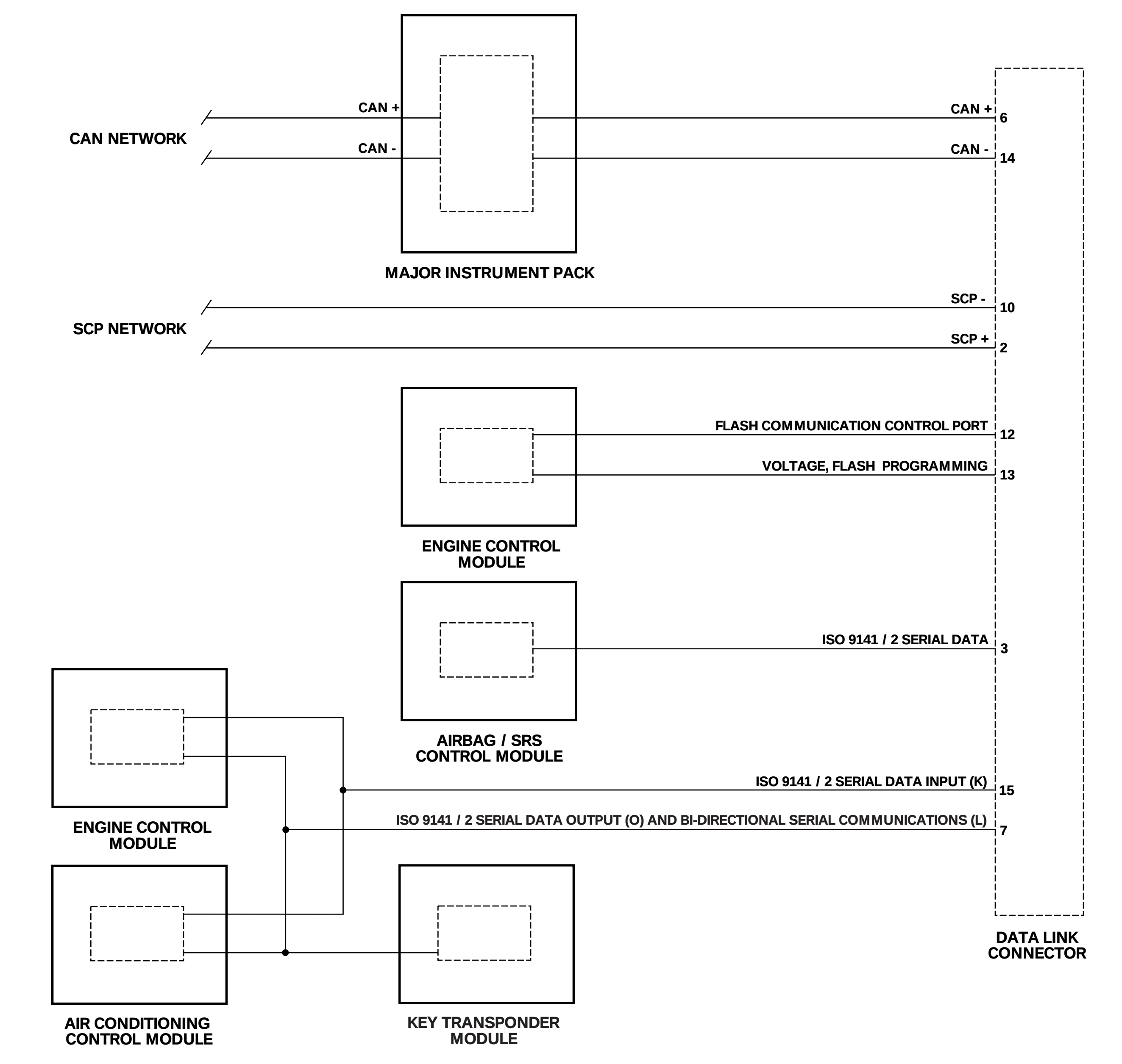
Data Link Connector (DLC) (continued)

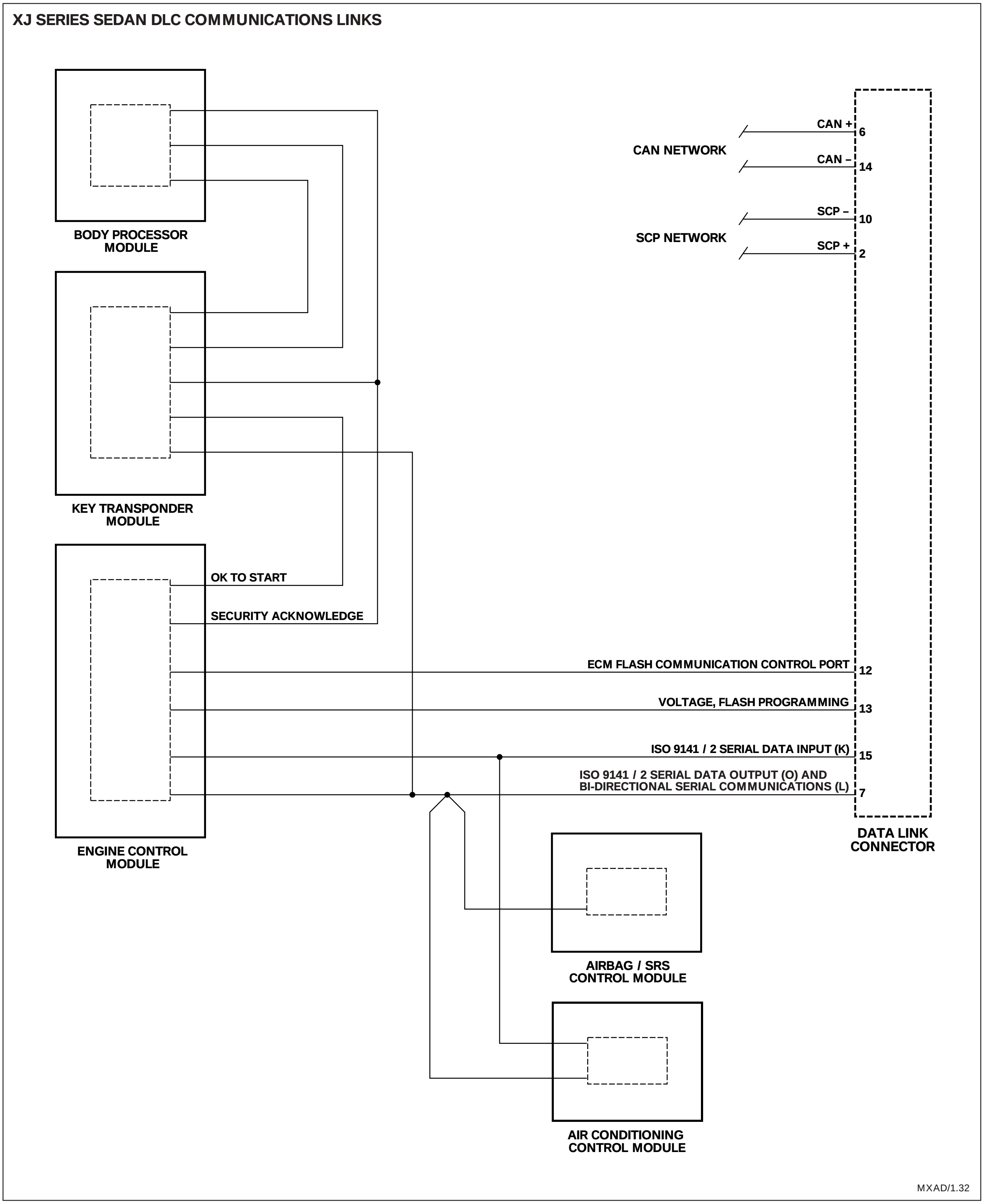
The ISO 9141/2 communications links connect the following components to the DLC:

- ECM — Scan tool legislated OBD II DTC / freeze frame connection (this link is also used by PDU / MPA for OBD II DTCs and freeze frame data)
- ECM — Module “flash” programming
- A/CCM — PDU diagnostics and programming for pollen / particle filters
- Airbag / SRS CM — PDU diagnostics
- KTM — PDU diagnostics and programming

NOTE: Generic scan tools communicate only with the ECM for OBD II DTCs and legislated freeze frame data

XK8 DLC COMMUNICATIONS LINKS




XJ SERIES SEDAN DLC COMMUNICATIONS LINKS
BODY PROCESSOR MODULE
KEY TRANSPONDER MODULE
ENGINE CONTROL MODULE
OK TO START
SECURITY ACKNOWLEDGE
CAN NETWORK
CAN +
6
CAN –
14
SCP NETWORK
SCP –
10
SCP +
2
ECM FLASH COMMUNICATION CONTROL PORT
12
VOLTAGE, FLASH PROGRAMMING
13
ISO 9141 / 2 SERIAL DATA INPUT (K)
15
ISO 9141 / 2 SERIAL DATA OUTPUT (O) AND BI-DIRECTIONAL SERIAL COMMUNICATIONS (L)
7
DATA LINK CONNECTOR
AIRBAG / SRS CONTROL MODULE
AIR CONDITIONING CONTROL MODULE
MXAD/1.32

Multiplex System Diagnostics

Overview

By following the Jaguar five-step Diagnostic Strategy, outlined on the facing page, and applying knowledge of the Jaguar multiplexing systems, a multiplex controlled circuit fault can often be easier to diagnose than a fault in a more conventionally controlled circuit.

A number of methods are available to test for problems that may occur. The test methods chosen depend on the vehicle symptoms, the physical layout of the circuits, and the accessibility of test points.

Testing a multiplex problem

PDU / MPA functions as a diagnostic aid and a DVOM. Each time PDU / MPA runs a multiplex component diagnostic routine it automatically tests multiplex circuit integrity to determine if the circuit is capable of communicating a data message. PDU will most often help you to pinpoint the cause of the failure. Because PDU diagnostics are software driven, its efficiency in any diagnostic mode depends on the design of the software that it uses. Most PDU diagnostic modes are excellent. However, a technician with knowledge of the system being tested, an Electrical Guide and a DVOM, can often diagnose a problem as efficiently as the PDU diagnostic function.

Multiplex symptoms analysis

Any action controlled through a multiplex system requires the following:

- An input to a module on the multiplex system
- A data message transmitted by a module on the multiplex system
- A data message received by a module on the multiplex system
- An output to a function

The symptoms of a particular multiplex failure cannot always be accurately predicted. Symptoms that may seem unrelated to the failure can occur depending on the state of the modules and the data being transmitted at the time of the failure. It is important to concentrate on the primary failure symptoms to help isolate the fault. Carefully observe the symptoms while performing functional tests. If the symptoms appear to change while testing, perform a “hard reset” of the control modules. A “hard reset” clears any “false” symptoms that might result from testing. Also, perform a “hard reset” after a repair is completed. Then, perform functional tests of the original failed function to verify the repair. Finally, perform a functional test of related functions, looking for any remaining symptoms.

Hard Reset Instructions

A “hard reset” restores the control modules to their default conditions assuring that network communications are synchronized.

Sedan vehicles

- Disconnect the negative cable of the battery for at least 60 seconds
- Reconnect the Battery negative cable

XK8 vehicles

- Open one window fully or open a door
- Disconnect the negative cable of the battery for at least 60 seconds
- Reconnect the Battery negative cable
- Reset the window position memory for the passenger and driver door windows

NOTES

Diagnostic Strategy

Problem diagnosis can be time consuming and sometimes frustrating. However, the job will be easier if you apply a logical approach to the task, called a Diagnostic Strategy. The following outlines a Diagnostic Strategy that will help ensure that none of the information necessary for accurate diagnosis is overlooked.

1 Verify the complaint.

Check the accuracy and detail of information on the repair order.

Confirm the complaint.

Gather information about the complaint. Identify all of the symptoms – what is working and what isn't, check for MILs, warning lights and driver information display messages.

Look for additional symptoms.

2 Analyze the system(s) and identify probable causes.

Determine what controls the faulty function.

Determine if the failure is in the multiplex network or if an input / output to the network failed.

Determine the data messages that control the function and establish which modules transmit and which modules use the messages.

Determine if any of the messages are required for other functions.

Perform functional tests to eliminate probable causes.

3 Inspect, test and pinpoint the fault.

Visually inspect the vehicle and look for obvious faults first.

Test the circuits and components using PDU / MPA or a DVOM as appropriate. Start with the circuits or components that are the most likely cause and the easiest to test.

Be aware that intermittent faults or symptoms may require recreating the fault conditions while testing: hot condition, cold condition, or "wiggle" test.

4 Perform the repair.

Follow the recommended service procedures.

To avoid a repeat failure, ensure that wiring, connectors, and grounds are in good condition before fitting new components.

Replace defective components.

NOTE: After the repair, perform a "hard reset" of the control modules. Refer to page 20.

5 Evaluate the results.

Verify that the customer complaint is resolved and that all of the original symptoms have disappeared.

Confirm that no new conditions were created by performing operational tests of any other systems that are related to the complaint or that were disturbed during the repair.

Three rules for diagnosing multiplex related failures

- Before checking for related faults and symptoms, always "hard reset" the control modules to restore them to their default conditions.
- Always determine if the failure is within the multiplex network or if it is a failed input or output connected to the network before doing further diagnosis.
- For multiplex network failures, use a DVOM to pin point the fault (PDU / MPA only checks the multiplex circuit wiring). For input or output failures, use PDU / MPA for diagnosis.

NOTES

SCP Network Troubleshooting

PDU / MPA SCP Network Diagnostics

When PDU / MPA is used for diagnostics, it automatically tests network integrity and communications before running specific diagnostic routines.

Network integrity and communications tests

PDU / MPA tests the CAN and SCP networks separately, indicating the status while testing. CAN is tested first followed by SCP. Test procedures for CAN and SCP follow similar routines. Each network is tested with the ignition OFF, then with the ignition ON. Each module is tested in a sequence that may vary depending on the diagnostic software version. Watch the PDU screen during testing. If PDU / MPA fails the network, the communications problem is with the last module shown on the PDU screen.

With the ignition OFF, PDU / MPA transmits a "request for identification" message to the first module. If module response is correct, the next module on the network is tested. If module response is missing or incorrect, the test is failed and PDU / MPA terminates diagnostics directing the user to an appropriate specific test routine. When all modules have passed, PDU / MPA switches the ignition ON and PDU / MPA transmits a vehicle speed signal to the ECM. The ECM transmits a CAN vehicle speed message, which is also the module "wake up" call. Each module should respond with an "I'm awake" message. If PDU / MPA does not recognize an "I'm awake" message from each module, the test is failed and PDU / MPA terminates diagnostics directing the user to an appropriate specific test routine. Because the INST translates the CAN message and transmits it to the SCP modules, the same procedure is used for the SCP network test. When all tests are passed, PDU / MPA begins the user specified diagnostic routines.

NOTE: If only SCP high (+) or low (–) is functioning, the system will pass part one of the test and PDU lists the modules that failed to respond.

SCP Network Failure Modes

The PDU / MPA diagnostic routine tests the network wiring but will not pinpoint an individual module failure. If a network failure is established by PDU / MPA, then pinpoint the fault by using the following information and a DVOM.

An open circuit or a short circuit in an SCP high (+) OR an SCP low (–) wire will not stop communication. Data will still be communicated over the remaining wire using the chassis as ground. However, some data errors may occur.

An open circuit in both the SCP high (+) AND the SCP low (–) wires will stop communication at the open circuit. Modules on either side of the open circuit will continue to communicate with modules on the same side, but no data will cross the open circuit.

SCP modules will communicate only when the SCP high (+) and the SCP (–) circuits are in an acceptable electrical state. The following shows communication possibilities depending on the electrical state of each wire.

Wire	Condition	Communication
SCP high (+) OR SCP low (–)	open circuit	YES (if other SCP circuit is functioning)
SCP high (+) OR SCP low (–)	short circuit to ground	YES (if other SCP circuit is functioning)
SCP high (+) OR SCP low (–)	short circuit to B+ voltage	YES (if other SCP circuit is functioning)
SCP high (+) AND SCP low (–)	short circuit to ground	NO
SCP high (+)	short circuit to SCP low (–)	YES (unless one is also short circuit to ground)

SCP Network Communications Functional Check

The following procedure confirms that data message communication is possible between all of the control modules connected to the SCP bus without using PDU / MPA.

– With the doors and windows closed, lock the vehicle using the key.

– Using the key, unlock the vehicle and hold the key in the unlocked position (global open).

  XK8: If both doors unlock, all windows open, and if equipped, the convertible top opens, data messages were communicated between the DDCM, PDCM, BPM and SLCM.

  XJ Series Sedan: If all doors unlock and all windows open, data messages were communicated between the DDCM, DRDCM, PDCM, PRDCM, BPM and SLCM (XJ Series Sedan).

– Switch the ignition to position II, set and recall a seat memory position. Open and close the driver door while watching the door ajar INST warning.

  If the seat memory works, data messages were communicated between DDCM, BPM and DSCM.

  If the door ajar warning is active with the door open and becomes inactive with the door closed, a data message was communicated between the DDCM and the INST.

SCP Network Integrity Check without PDU / MPA

– Disconnect the INST and all of the other SCP control modules from the network.

– Connect one control module to the network. With a DVOM, measure the voltage between DLC pin 2 (SCP high[+]) and chassis ground. Then, measure the voltage between DLC pin 10 (SCP low [–]) and chassis ground. The measured values should be as shown below.

– Disconnect the control module.

– Repeat the test with the remaining modules, in turn, until all of the modules and the entire network have been tested.

SCP Control Module Voltage Values (approximate)

	XJ Series Sedan		XK8	
Module Connected	**Pin 2 (SCP +) to ground**	**Pin 10 (SCP –) to ground**	**Pin 2 (SCP +) to ground**	**Pin 10 (SCP –) to ground**
INST	0.0 V	5.0 V	0.0 V	5.0 V
BPM	0.0 V	5.0 V	0.0 V	5.0 V
SLCM	0.0 V	5.0 V	0.0 V	5.0 V
PDCM	0.0 V	1.7 V	0.0 V	1.7 V
PRDCM	0.0 V	1.7 V	N/A	N/A
DDCM	2.7 V	1.7 V	0.0 V	1.7 V
DRDCM	2.7 V	1.7 V	N/A	N/A
PSCM	0.0 V	1.7 V	0.0 V	1.7 V
DDCM	0.0 V	1.7 V	0.0 V	1.7 V

NOTE: If a function is activated during testing, the DVOM should show a varying frequency reading on both the SCP high (+) and SCP low (–) lines as the module attempts to communicate.

NOTES

CAN Network Troubleshooting

CAN PDU / MPA Network Diagnostics

PDU / MPA automatically tests the network integrity and communications before running specific diagnostic routines. First, PDU / MPA establishes communication with the vehicle via the DLC and begins its automatic test sequence. Once network integrity and communications are both confirmed, PDU / MPA begins the specific diagnostic routine. If the network communications and integrity test is failed, PDU directs the user to an appropriate test from the CAN network menu. For a more detailed explanation of the network and communications tests, refer to PDU / MPA SCP Network Diagnostics on page 22.

CAN Network Failure Modes

The PDU / MPA diagnostic routine tests the network wiring but will not pin point an individual module failure. If a network failure is established using PDU / MPA, then pin point the fault using the following information and a DVOM.

An open circuit in both the CAN high (+) AND the CAN low (–) wires will stop communications at the open circuit. Modules on either side of the open circuit will continue to communicate with modules on the same side of the open circuit but no data will be cross the open circuit. Modules will continue to operate by substituting default values for the missing data.

CAN modules will communicate only when the CAN high (+) and CAN low (–) are in an acceptable electrical state. The following shows communication possibilities depending on the electrical state of each wire. If all communication is lost on the CAN bus, the modules will continue to function but will substitute default values for any missing data.

Wire	Condition	Communication
CAN high (+)	open circuit	NO
CAN high (+)	short circuit to ground	NO
CAN high (+)	short circuit to B+ voltage	NO
CAN high (+)	short circuit to CAN low (–)	NO
CAN low (–)	open circuit	YES (if CAN high (+) is functioning)
CAN low (–)	short circuit to ground	YES (if CAN high (+) is functioning)
CAN low (–)	short circuit to B+ voltage	NO

NOTES

CAN Network Communications Functional Check

The following procedure confirms that data message communication is possible between all of the control modules connected to the CAN bus without using PDU / MPA.

– Switch the ignition ON to position II and observe the MILs

– Switch the ignition OFF and disconnect the battery negative cable.

  Disconnect the ABS / TC CM.

  Reconnect the battery negative cable and switch the ignition to position II.

  The following warnings should activate:

  XK8 with traction control and XJ Series Sedan

  MILs: ABS; BRAKE; AMBER

  LEDs: TRAC switch

  Message center display: TRACTION CONTROL FAILURE; STABILITY CONTROL FAILURE

  XK8 without traction control

  MILs: ABS; BRAKE

  LEDs: ASC switch

  Switch the ignition OFF and disconnect the battery negative cable.

  Reconnect the ABS / TC CM.

  Reconnect the battery negative cable and switch the ignition to position II.

  If the MILs, LEDs, and message center display are inactive, the CAN network is communicating from one end to the other (ABS / TC CM to INST).

– Start the engine and apply the parking brake and foot brake. Move the gear selector through all of the gear positions.

  If the gear selector indicator lights operate correctly, the CAN network is communicating from the TCM to the gear selector module.

CAN Network Integrity Check without PDU / MPA

– With the ignition switched OFF, connect a DVOM between DLC pin 6 (CAN high [+]) and DLC pin 14 (CAN low [–]). A reading of 60 Ω indicates a good CAN bus:

  < 60 Ω indicates a short circuit on the bus

  > 60 Ω indicates high resistance on the bus

– Disconnect the DVOM from the DLC and switch to the voltage scale.

– Switch the ignition ON to position II.

– Connect the DVOM between DLC pin 6 (CAN high [+]) and ground. The measured value should be 2.7 V (approx.).

– Connect the DVOM between DLC pin 14 (CAN low [–]) and ground. The measured value should be 2.5 V (approx.).

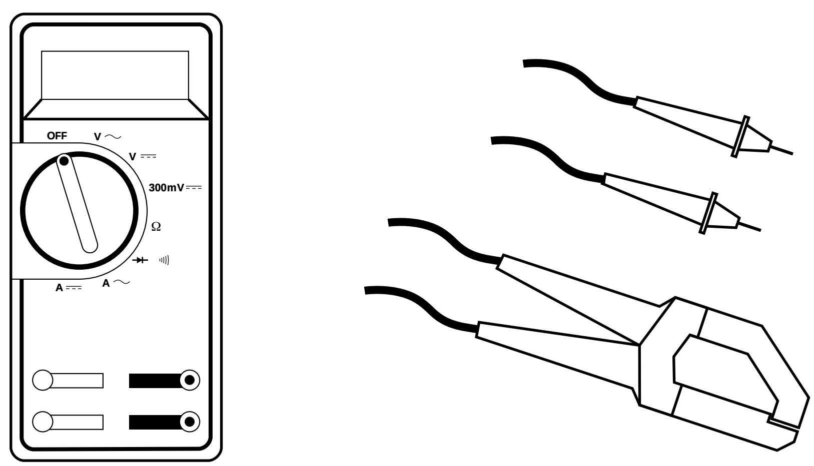
NOTES

Testing Equipment

Because sensitive electronic circuits can be damaged by using analog (dial type) meters, test lights and many types of circuit testers, only digital multimeters (DVOM) should be used. Analog meters require too much power to be used in circuits with sensitive digital components. DVOMs require very little power. In addition, DVOMs are more accurate, enabling precise value measurement. By using a DVOM with a combination digital / analog display or a MIN / MAX mode, it can be determined if the measured value is increasing or decreasing during the test.

PDU has digital multimeter capabilities and can be used for circuit analysis.

DIGITAL MULTIMETER (DVOM) WITH LEADS AND CURRENT PROBE



MXAD/1.15

Electrical Units and Quantities

The international engineering and scientific communities have adopted standards for quantities and units in order to do away with the confusion caused by converting between the various measurement systems used by individual countries. The ISO (International Organization for Standardization) published the standards in their documents ISO 31 and ISO 1000. The units used in this standardized measurement system are known as SI (Systéme International) units.

Selected Units

Base unit	Symbol	SI unit	Symbol
Electric current	I	Ampere	A
Electric potential	E	Volt	V
Electric conductance	G	Siemens	S
Electric resistance	R	Ohm	Ω
Quantity of electricity	Q	Ampere hour	A h
Electric capacitance	C	Farad	F
Time	t	second	s
Power	P	Watt	W

Multiples or decimal fractions of SI units are shown by prefixes or prefix symbols before the name of the unit. Refer to the following chart.

Selected Quantities

Quantity	Prefix	Symbol
1,000,000,000 (billion)	giga	G
1,000,000 (million)	mega	M
1,000 (thousand)	kilo	k
100 (hundred)	hecto	h
10 (ten)	deka	da
0.1 (tenth)	deci	d
0.01 (hundredth)	centi	c
0.001 (thousandth)	milli	m
0.000001 (millionth)	micro	μ

Examples: 2,000,000 Ohms (two million Ohms) is written as 2 MΩ (two mega-Ohms)
6/1,000 Volt (six-thousandths of a Volt) is written as 6 mV (six milli-Volts)

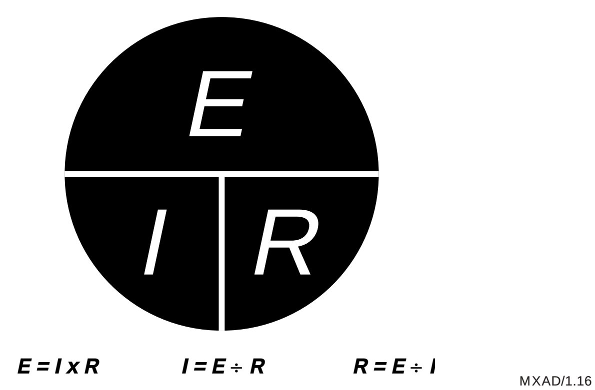
Rules Governing Electrical Circuits

Ohm's Law describes the relationship between voltage and resistance in solid and liquid conductors: Electrical potential *(E)* is equal to the electrical current *(I)* multiplied by the electrical resistance *(R)*. The formula is written as *E = I x R [E (volts) = I (amperes) x R (ohms)].*

Ohm's Law can be useful during diagnoses to help determine the effect of voltage, current flow or resistance in a circuit. If two values are known, the third value can easily be calculated.

The diagram at the right is designed to simplify the use of Ohm's Law. The horizontal line indicates that two values should be divided; the vertical line indicates that two values should be multiplied. To use the formula, substitute the known or measured values for their symbols, cover the unknown value with your thumb and multiply or divide, as indicated, to find the missing value.

DIAGRAM FOR USING OHM'S LAW



For example, if the electrical potential *(E)* and the current *(I)* are known, but the resistance *(R)* is not, divide the electrical potential *(E)* by the electrical current *(I)* to find the electrical resistance *(R)*: *R (ohms) = E (volts) ÷ I (amperes).*

Electrical resistance depends on the dimensions, material and temperature of the conductor. Resistance in metal conductors generally increases with the length and temperature of the conductor. Conductors with larger cross sectional areas have less resistance than conductors with smaller cross sectional areas.

Electrical Power

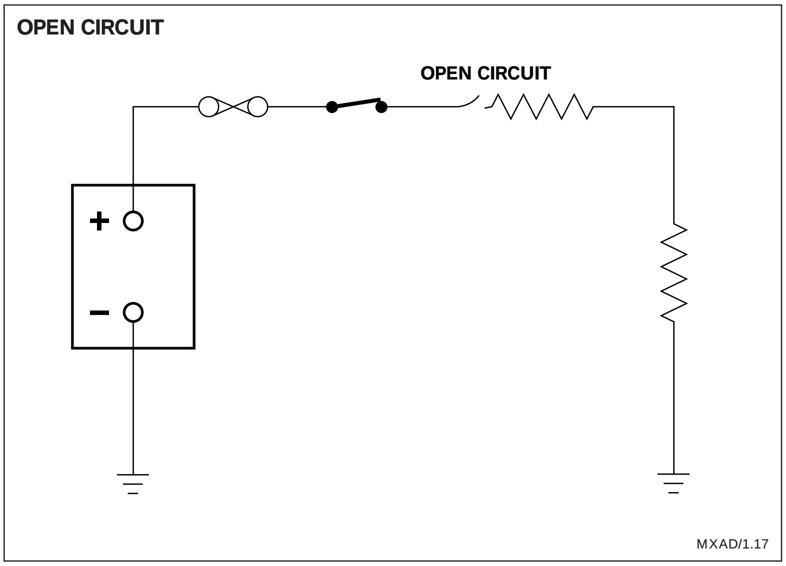
Electrical power is expressed in watts: *W (watts) = E (volts) x I (amperes).*

Energy Conversions

1 Watt = 0.0013 HP   1 kW = 1.341 HP   1 HP = 745.7 Watts

Basic Electrical Circuit Faults

Electrical circuit faults can be categorized as follows:



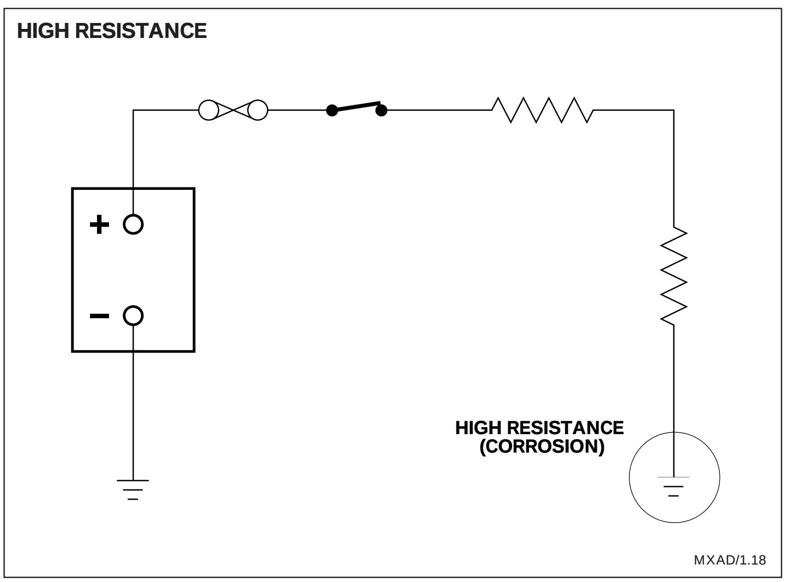
Open Circuit

An open circuit is a break in the path of current flow. If the circuit is powered, a voltage potential will be present in the portion of the circuit that is still connected to the power source.

With parallel circuits, an open circuit in one branch will stop operation in that branch, but the other branches will continue to operate.

An ohmmeter test can determine an open circuit (infinite resistance [∞ Ω]).

A voltmeter can also be used to determine an open circuit. By measuring the available voltage at various points or the voltage drop between two points, it is possible to determine the location of the open circuit.



High Resistance

A high resistance circuit is a circuit with more resistance than specified. High resistance reduces the amount of power (current x voltage) available for components connected to the circuit.

High resistance can be caused by loose, dirty or corroded connections. Broken strands of conductor within a wire's insulation or at a connector will also increase circuit resistance.

When diagnosing a circuit for high resistance, disturb the connections as little as possible until the area of high resistance has been found. Disturbing connections may clean any corrosion or dirt, temporarily correcting the problem and making diagnosis difficult.

An ohmmeter test on an unpowered circuit can determine high resistance.

An available voltage or voltage drop test on a powered circuit can also determine areas of high resistance.

NOTES

Short Circuit to Ground

A short circuit to ground occurs when the circuit is grounded or partially grounded where not designed. If the short circuit is located after the load, circuit control may be lost causing operation when it is not wanted.

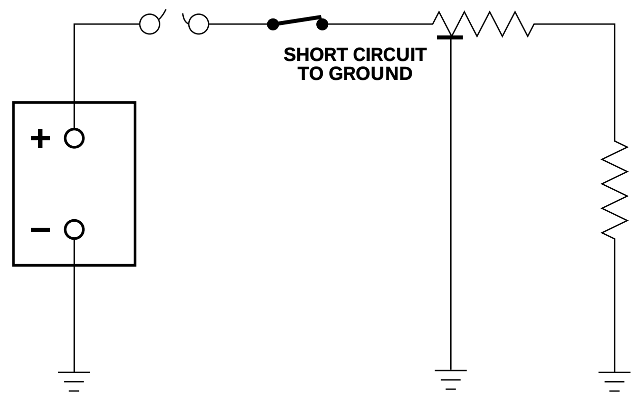
To diagnose a short circuit to ground in a fused circuit, substitute a voltmeter for the fuse. Systematically disconnecting circuit components until the voltmeter reads 0 V will identify the area of the short circuit.

Short Circuit to Voltage

A short circuit to voltage occurs when insulation failure causes a conductor to contact the voltage of another circuit. The circuit (or circuits) will operate improperly.

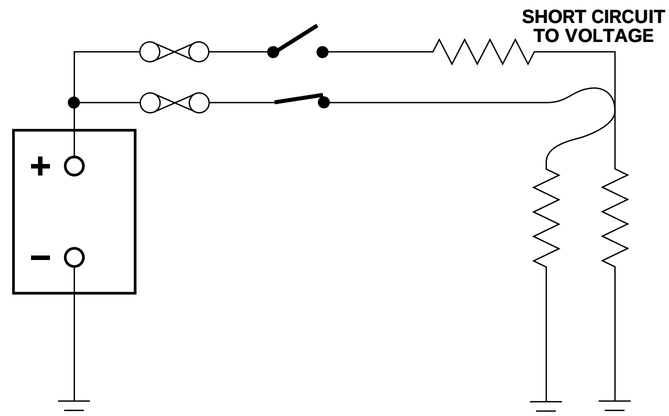
Carefully observe the symptoms and related symptoms and refer to the Electrical Guide to understand the circuits involved. Remove fuses until the circuit is isolated, and then measure resistance and voltage as appropriate to find the problem area.

SHORT CIRCUIT TO GROUND



MXAD/1.19

SHORT CIRCUIT TO VOLTAGE

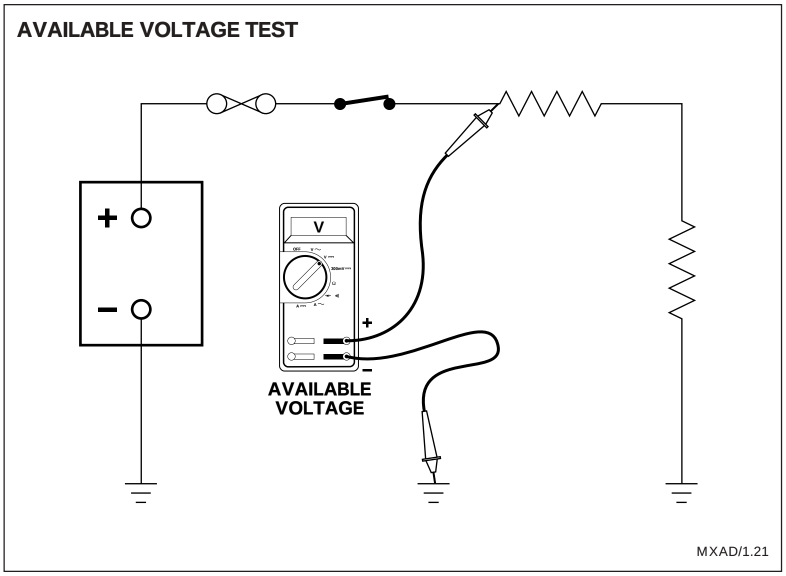


MXAD/1.20

NOTES

Voltmeter Tests

Voltmeter tests are useful because they measure the voltage potential in the circuit during its operational state.



Available Voltage Test

Tests for power supply availability, open circuits, short circuits.

Measures the AMOUNT of voltage available at that point of the circuit. The circuit must be powered (active).

Should show circuit operating voltage (usually B+ voltage).

Voltage Drop Test

Tests for circuit resistance under load.

Measures the DIFFERENCE in voltage between two points in the circuit. The circuit must be powered (active).

Generally, voltage drops should not exceed the following values:

Wire or cable	200 mV	Ground connection	100 mV
Switch	300 mV	Connector	50 mV

NOTE: The voltage reading depends on the portion of the circuit being tested. The lower the voltage reading, the lower the resistance.

High current circuits such as the starter motor circuit have greater voltage drops.

The relationship between voltage, resistance and current flow, as expressed by Ohm's Law, shows that even a small amount of resistance can have a great affect on the electrical power available in the circuit.

Example: A 12 V starting system drawing 200 Amps will develop 2400 Watts of power (Volts x Amps = Watts). The starter motor will develop 3.22 HP (746 Watts = 1 HP).

A resistance of 0.01 Ω in the starter cable will drop the voltage available at the starter by 2 V (Amps x Ohms = Volts). The 2 V drop caused by the resistance results in only 2000 Watts (83%) of starting power. The starter will develop only 2.68 HP.

Small amounts of resistance are difficult to determine without expensive equipment. In addition, battery power must be disconnected from the circuit to measure resistance. Voltage drop measurements indicate circuit resistance without disconnecting power or disturbing the circuit.

NOTES

Voltage Drop Test: Ground Side

Tests for ground circuit high resistance or open circuit.

Measures the DIFFERENCE in voltage between a point in the circuit and ground. The circuit must be powered (active).

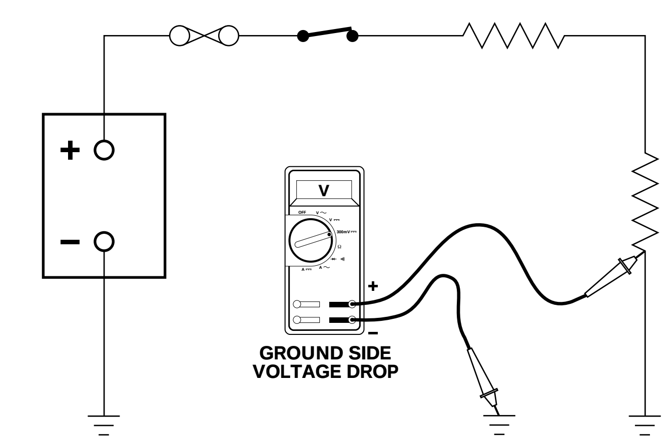
Voltage Drop Test: Switch or Connector

Tests for component high resistance, open circuit, switch function.

Measures the DIFFERENCE in voltage across a switch or connector. The circuit must be powered (active).

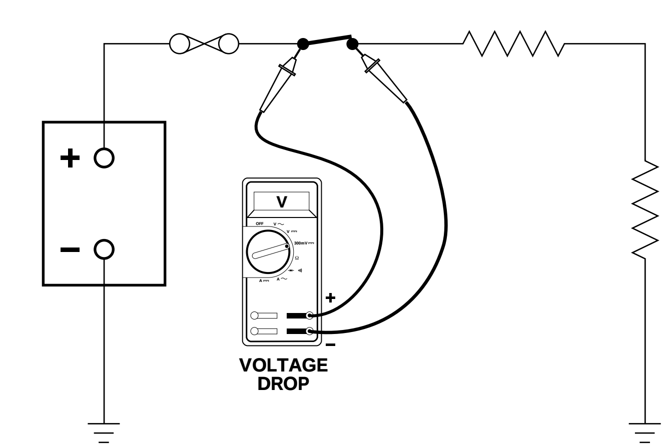
NOTES

VOLTAGE DROP TEST: GROUND SIDE



MXAD/1.22

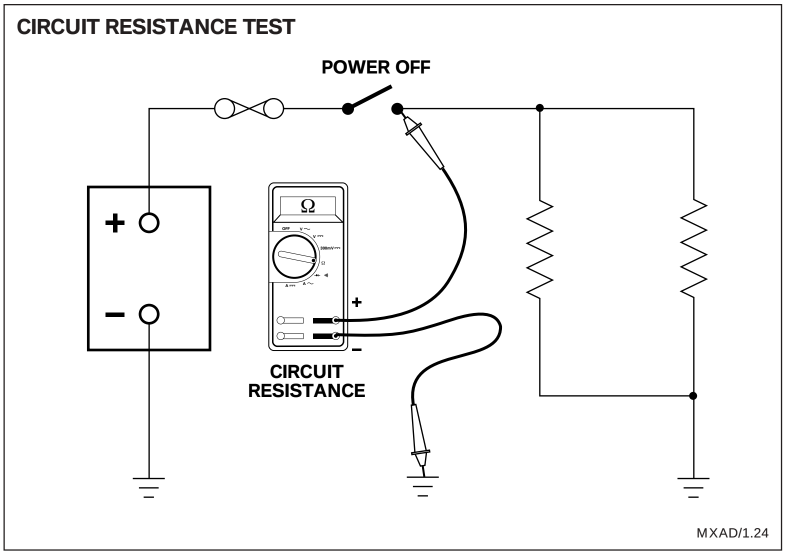
VOLTAGE DROP TEST: SWITCH



MXAD/1.23

Ohmmeter Tests

NOTE: Battery power MUST be disconnected from circuits when measuring resistance. The meter provides a small amount of power to measure the circuit resistance.



Circuit Resistance Test

Tests for circuit resistance, open circuit, short circuit.

Measures circuit resistance between the probes. The circuit must be unpowered.

The tested value should equal the specified circuit resistance.

NOTE: When checking a parallel circuit, the total circuit resistance will be less than the value of the lowest resistance load in the circuit.

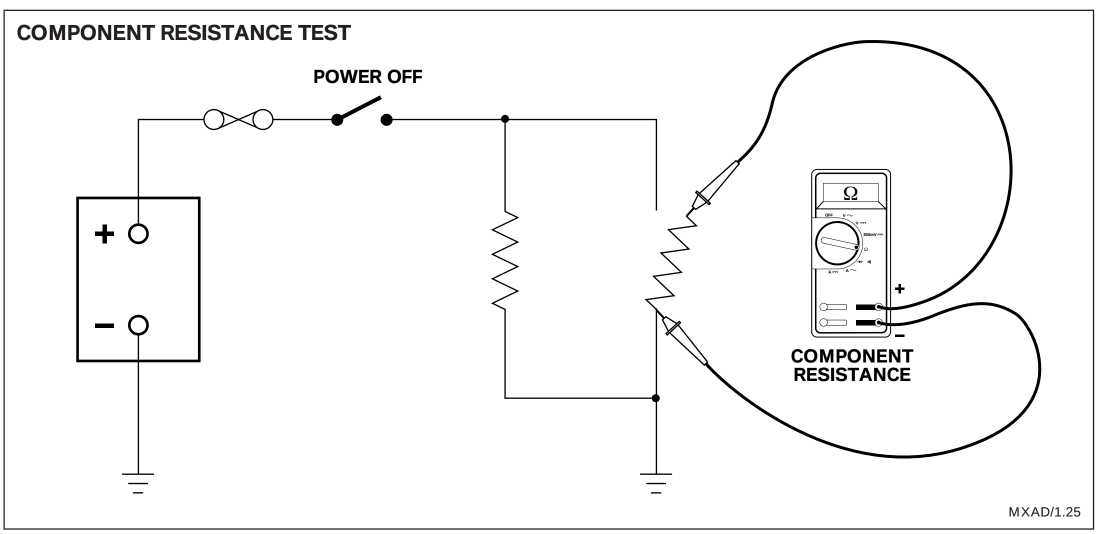
Component Resistance Test

Tests for component resistance, open circuit, short circuit.

Measures individual component resistance. The circuit must be unpowered.

The tested value should equal the specified component resistance.

NOTE: Disconnect components in parallel circuits when measuring resistance. If connected, the total circuit resistance will be less than the value of the lowest resistance load in the circuit.



”Wiggle” Test

Tests for intermittent circuit faults

The “wiggle” test is important to help identify circuit problems caused by intermittent failures in the wiring, connectors or grounds. With the meter connected, “wiggle” the suspect wires or connectors and look for differences in the meter reading indicating changes in resistance or voltage.

Professional Electrical Practices

When testing electrical circuits it is important to access the circuits carefully to avoid damaging insulation, conductors, contacts or components. Measurements should be performed carefully. Ensure that the tester is connected to the correct pins. If measurements are not consistent with the expected values, always double check that the tester is correctly connected.

✓ **Periodically calibrate test equipment** and check the resistance of the test leads and adapters to assure that measurements are accurate.

✓ **Use the correct testing adapters** when performing measurements. Using incorrect adapters or probing connectors may damage the plating on the contacts, causing corrosion and increased resistance.

✗ **Circuit powered or self-powered test lights or circuit testers** may cause damage to sensitive components. The best rule is to use only a high impedance digital multimeter when measuring any electrical circuit in the vehicle.

✗ **Back probing sealed electrical connectors** will damage the seal allowing moisture or other contaminants to enter the connector causing corrosion.

✗ **Piercing the insulation of conductors** when performing measurements will damage the conductor, increase the conductor resistance, and allow moisture or other contaminants to enter the connector causing corrosion.

NOTES

Circuit Failure Testing

NOTE: The circuit examples in the following pages are simplified and show the fuse supply voltage as a direct battery voltage. Many vehicle circuits utilize ignition switched voltage or other strategies to control the fuse supply voltage. Before attempting to test a circuit on a vehicle always refer to the appropriate Electrical Guide to verify its construction.

Consumer / Function Doesn't Work; Power Fuse Open Circuits

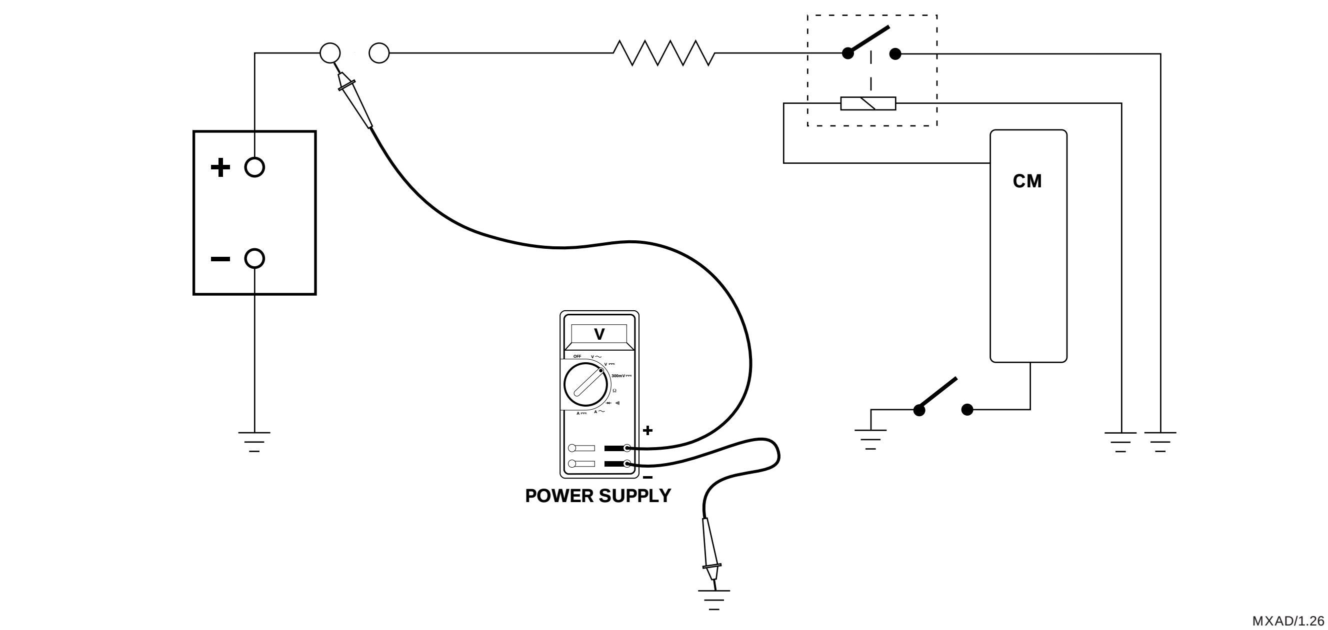
The problem MUST be related to excessive current draw. Excessive current draw is caused by the following:

- A short circuit to ground in the power supply after the fuse or a short circuit in the consumer
- A mechanical problem in the consumer or its drives

Testing strategy depends on the circuit and how easy it is to access its parts. The following example is based on the circuit illustrated.

– **Switch everything OFF; check for available voltage at the B+ side of the fuse.**

AVAILABLE VOLTAGE TEST

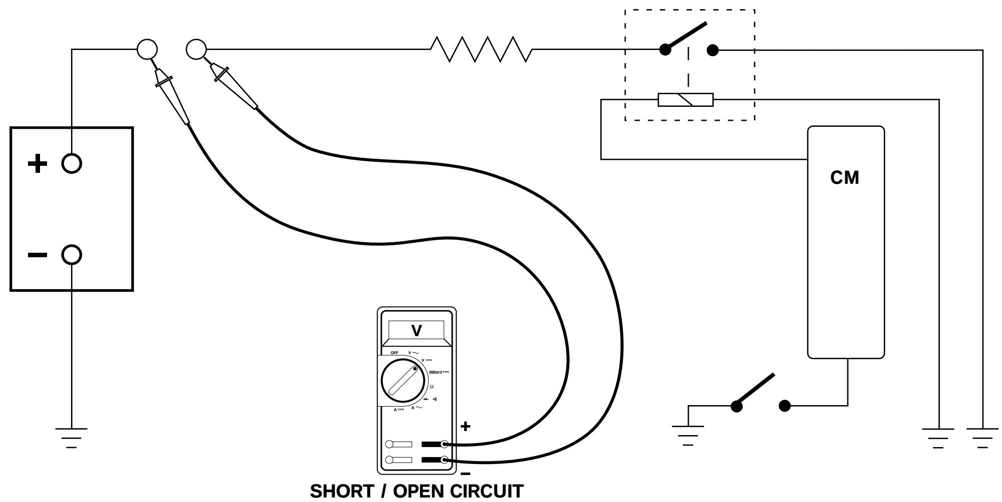


If there is no voltage or low voltage, the power supply is insufficient. (ALWAYS CHECK THE POWER SUPPLY).

NOTES

– **Connect the voltmeter across the fuse.**

SHORT CIRCUIT / OPEN CIRCUIT TEST



MXAD/1.27

If there is a voltage reading, there is a short circuit before the circuit control components.

– **Switch the circuit ON.**

If there is no voltage reading, there is an open circuit or a fault in the circuit control components.

If there is a voltage reading, there is a short circuit after the circuit control components.

NOTES

Circuit Failure Testing (continued)

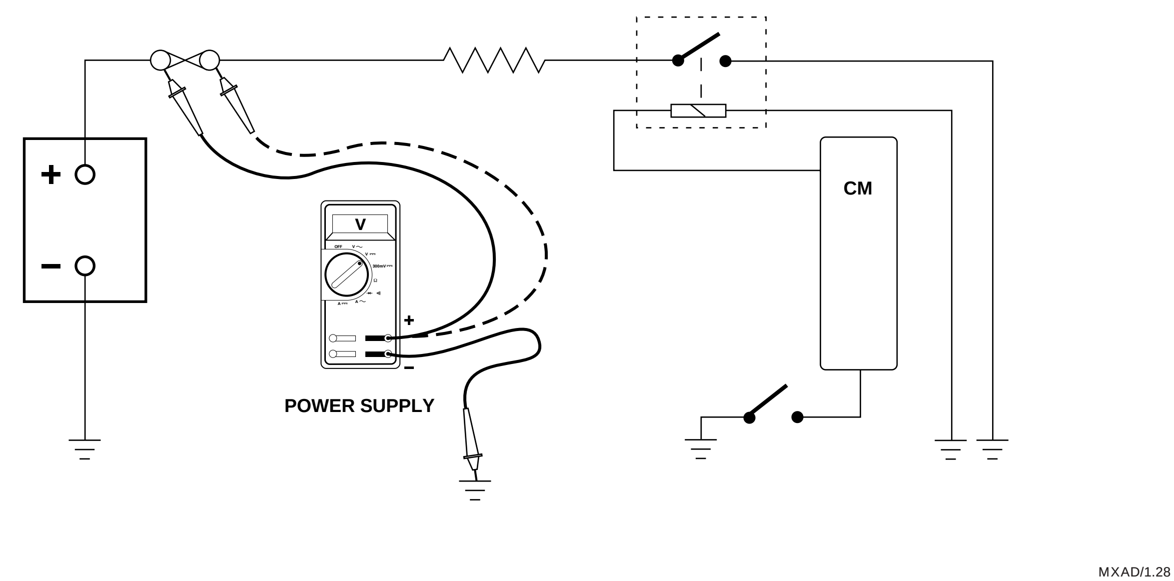
Consumer / Function Doesn't Work; Power Fuse is OK

The problem MUST be caused by the following:

- No power supply to the consumer, open circuit in the consumer power supply circuit or in the consumer.
- No ground or a fault in the circuit control components.

Testing strategy depends on circuit construction and how easy it is to access convenient testing points. The following example is based on the circuit illustrated.

AVAILABLE VOLTAGE TEST



– **Switch everything OFF; check for available voltage at the B+ side of the fuse.**

If there is no voltage or low voltage, the power supply is insufficient. (ALWAYS CHECK THE POWER SUPPLY).

– **Check for voltage at the other side of the fuse.**

If there is no voltage or insufficient voltage, there is an open circuit or high resistance in the fuse or fuse box.

– **Check for voltage at the consumer or at a convenient point close to the consumer.**

If there is no voltage or insufficient voltage, there is an open circuit between the fuse box and the point tested.

If the voltage is OK, the circuit is OK to that point.

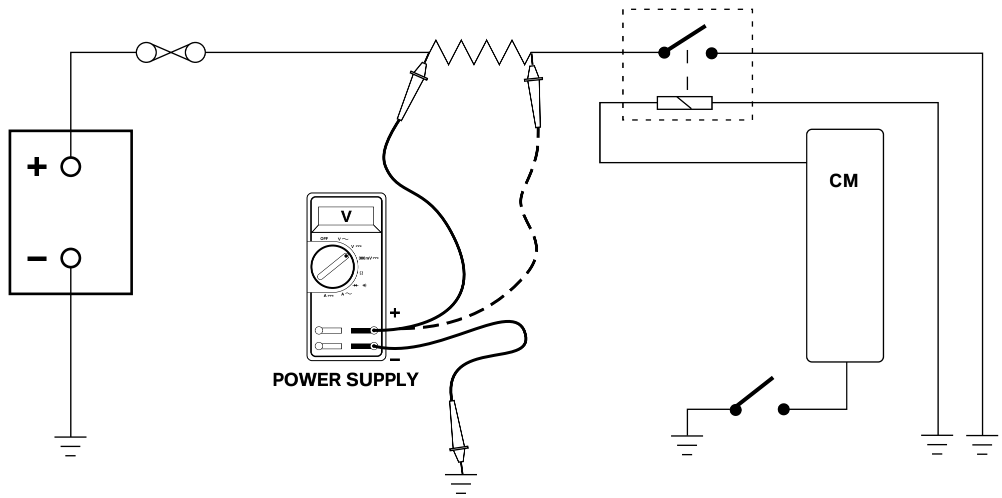
Refer to the Electrical Guide and split-half test the suspected section of the circuit, narrowing down to the fault area.

NOTES

– Check the voltage at the ground side of the consumer.

If the voltage is OK, the consumer is probably OK.

AVAILABLE VOLTAGE TEST

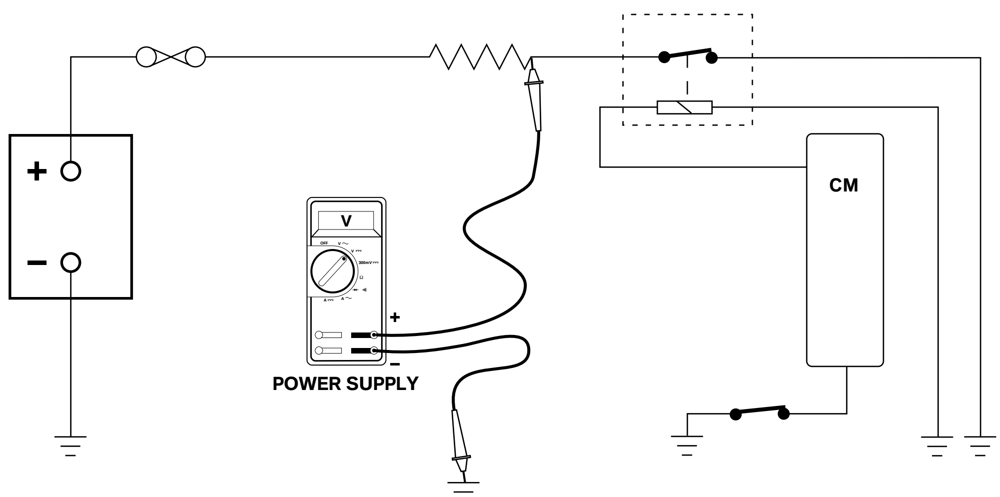


MXAD/1.29

– Switch the circuit ON.

If there is no change in the available voltage reading at the ground side of the consumer, there is a control circuit failure or an open ground circuit.

AVAILABLE VOLTAGE TEST



MXAD/1.30

Circuit Failure Testing (continued)

Consumer / Function Operates Intermittently

Because the failure is not always present, intermittent failures can be the most difficult to diagnose. If the system is electronically controlled and its control module is capable of storing DTCs, extract any DTCs as a guide to diagnosis.

It is also vital to gather the following information about any intermittent failure:

- When does the function fail?
- Are any other functions affected?
- Were any other functions in operation at the time of failure?
- Is the failure related to a vibration or bump occurrence?
- Does the failure occur at any specific temperature, time of day, engine or transmission operating condition?

Try to recreate the failure by operating the vehicle under the conditions reported. If the failure can be recreated, follow the general diagnostic procedures.

If the failure cannot be recreated, apply the reported failure conditions to the symptoms in order to determine the probable causes of the failure. Then, carefully examine each of the probable causes. Start with the circuit areas or system components that are the most probable causes of the failure and thoroughly test each one. Apply the “wiggle” test while following the general diagnostic procedures.

NOTES