The wiring systems in late model cars are nothing like those that were used just a decade ago. Like everything else, wiring has gone hi-tech digital. The new multiplex wiring systems do more with less, are smarter than the wiring systems they replace, and require a whole new approach to diagnosis and repair.

The standard electrical systems used in vehicles up until the 1990s are based on wiring technology that hasn't changed much since the days of the Ford Model A. Basically, each electrical component or system has its own individual wiring circuit. Each circuit uses insulated copper wire to carry current in a loop, from the battery to the device, then back to the battery through the ground circuit (which is usually the vehicle body). In addition, each wiring circuit has a switch, relay or control module to turn it on and off, and a fuse, circuit breaker or fusible link to protect against voltage overloads.

**WIRING COMPLEXITY**

In a vehicle with a standard electrical system, there is a separate wiring circuit for the starter, charging system, ignition system, fuel pump, fuel injectors, engine control module, sensors, exterior lights, interior lights, heater and air conditioning system, radio, horn, power windows, power seats, power door locks, you-name-it.

All this wiring adds up to a lot of weight (over 70 lbs. for the typical 1990s vintage car), and more than 2000 individual wires! Because of this, the wiring harnesses in late model vehicles have become very complex, with literally miles of wire feeding hundreds of circuits. The wiring harness looks like a gigantic tangle of multi-colored spaghetti, with bundles of wire that snake throughout every nook and cranny in the vehicle from one end to the other.

If an electrical problem occurs, troubleshooting usually requires testing individual wiring circuits with a volt meter to check for available voltage or an ohm meter to check continuity or resistance. Common electrical faults include shorts, opens, grounds, and loose or corroded connections. Such faults can prevent normal voltage and current from flowing through a circuit, or in some cases cause an overload that results in an open fuse or tripped circuit breaker.

Troubleshooting isn’t easy because the circuit has to be traced from one end to the other using the vehicle’s wiring diagrams (which can be its own manual!). And the more connections and branches there are in a wiring circuit, the more possibilities there are for trouble. Wiring connectors can corrode over time, or loosen from heat or vibration, and insulation around wires can become damaged by chaffing, vibration or abrasion.

**MULTIPLEXING**

With multiplexing, the number of individual wires and wiring circuits can be reduced up to 40% to reduce the overall complexity of the wiring system. Multiplexing allows multiple circuits to share the same wire by using digital signals and coded messages. This allows one wiring circuit to control a number of different components that are all connected to the same circuit. This eliminates the need for so many separate wires and allows wiring harnesses to be much smaller, lighter, simpler and less expensive. It also improves wiring reliability by reducing the number of wires and connections.

Fewer wires means the wiring harness can be more flexible to better withstand vibrations and movement.

Multiplexing also allows components that are connected to the same control circuit to share information and talk to each other.

*Continued on page 2*
This means the powertrain control module (PCM), antilock brake system (ABS), body control module (BCM), heating ventilation and air conditioning (HVAC) system and other onboard electronics can now share data and interact in ways that were not possible before wiring systems were multiplexed.

**HOW MULTIPLEXING WORKS**

In a multiplexed wiring system, one wiring circuit is used for command signals, feedback and data transmission. This is called the “data bus.” Separate circuits are used for power and ground, the same as a conventional wiring system. The command signals and other information that is transmitted over the data bus are sent as coded digital messages by a “gatekeeper” module, which is usually the body control module.

The gatekeeper module controls the flow of traffic in the multiplex system so the messages don't collide or become garbled. The gatekeeper module also links the components that are multiplexed together to other modules or wiring circuits in the vehicle. The gatekeeper module may also tell certain modules when to go into “sleep” mode when the ignition is turned off, and then ping them to wake them up when they are needed again. The gatekeeper is also the module that keeps track of all the addresses of each node in the multiplex wiring system (which may require a special relearn procedure or reprogramming with a scan tool if power is lost or a module is replaced).

Each message is coded in binary language with “1’s” and “0’s” that represent numbers, values or commands. The “1’s” and “0’s” are called “bits” and these add up to make chains of 8-digit “bytes.” It’s the same lingo that computers use to process information and communicate.

The speed of transmission is known as the “baud rate,” and the higher the baud rate the faster the system can communicate and process information.

To make this work, mini-control modules are needed at every “node” in a multiplexed wiring system where components are connected to the data bus. Each node is assigned its own unique numeric address so the gatekeeper module and other modules attached to the system can identify it. The address system assures messages that are sent over the common data bus are received at the correct destinations, and that data sent from any node in the system can also be identified as to its source.

When a module receives a message that has been sent to it, it deciphers the message and then acts on the information as it has been programmed to do.

For example, in a conventional wiring system, pressing the door switch to lower the power window completes the circuit to the motor inside the door that lowers the window. In a multiplex system, pressing the button on the door switch sends a command signal to the power window module. The module then completes the power circuit to the motor to lower the window. It adds an extra step, but simplifies the wiring harness because the same control circuit may also be used for all four power windows, the power door locks and adjustable outside mirrors.

Multiplexing allows the electrical system to detect faults such as a “bulb out” when a headlight, turn signal or stop light fails, to share data between control modules so the PCM can reduce engine power...
if the traction control system detects wheel spin and loss of traction, to apply counterbarking if the stability control system senses the vehicle is becoming unstable while making a steering maneuver, to increase idle speed if the HVAC system is working hard to cool down a hot interior, and so on. Multiplexing allows sensor data to be shared wherever it might be needed, and for systems that used to be totally independent to be integrated for improved safety, performance and convenience.

**Multiplex Protocols**

Back in the 1980s, the Robert Bosch Corporation developed the first protocols for what would become the standards for today’s Controller Area Network or “CAN” wiring systems. These protocols define how multiplexed messages are coded and sent (number of bits, voltage levels, length of each byte, speed of transmission, etc.). Three different protocols were developed to accommodate the needs of different multiplex systems, based on the speed or baud rate of the messages.

Multiplex wiring was first used by Cadillac in 1990 for its exterior lighting system, and then by Mercedes in 1992. In 1997, Corvette incorporated multiplex wiring to tie its electronic suspension to the ABS system and PCM. Since then the use of multiplexing for various control systems and accessories has become more and more common.

**CAN Systems**

Controller Area Network (CAN) is a fancy name for what’s become the current generation of multiplex wiring. A CAN wiring system is one that ties together all the major control modules in the vehicle (PCM, BCM, ABS, etc.) and allows access via the OBD II DLC connector. CAN is now required on all 2008 and newer vehicles. Most 2007 model year cars have it, and applications extend as far back as the late 1990s on some models.

CAN vehicles have to conform to certain communications protocols (ISO 15765) that include three basic transmission speeds:

- **CAN A** is for low speed communications with a baud rate of up to 10 kilobytes per second (Kbps). This is used for low priority multiplexed devices such as power windows, seats, door locks, lights, etc.

- **CAN B** is for medium speed communications of 33 to 250 Kbps. This is used by systems that have to send and receive large amounts of data such as the electronic instrument cluster, the climate control system, certain emissions functions, the automatic transmission, keyless entry system, etc.

- **CAN C** is for high speed communications from 250 Kbps up to 1000 Kbps (1 meg). This is used by the powertrain control module, ABS/traction control/stability systems, and supplemental restraint system (air bags).

On a 2007 Cadillac XLR, for example, GM uses both a fast CAN C network that operates at 500 Kbps (which GM calls the GMLAN network), and a slower CAN A network that runs at 10 Kbps (which GM refers to as a “class 2” network). The two different CAN networks also operate at different voltages (2.5 volts for the faster one, and 7 volts for the slower one).

CAN data may be transmitted over various conductive media including single or paired copper wiring, twisted pair wiring, coaxial cable or even fiber optic cables. It’s up to the auto makers to decide what kind of wiring they want to use, but the information that passes through the wiring has to conform to the CAN protocols so it can be read with a scan tool.

*Continued on back page*
The CAN wiring network may be arranged one of three ways: in a ring or loop where each node is connected to the others in series using paired or twisted wires, in a star where each node is connected to a central master node with a single wire but do not share a direct connection with each other, or a bus configuration where each node is connected to a common bus.

Each arrangement has its own advantages. If a wire fails in a ring network, all the nodes can still talk to each other. If a wire fails in a star network, communication is lost to one node but the network stays up unless the central master node fails, in which case the whole network goes down. In a bus network, failure of any single node won’t affect the network. If the bus has dual wires, failure of a single wire will also not prevent the network from functioning.

Some cars further break down the CAN system into Local Area Networks (LAN) in much the same way computers may be arranged within a large office. Modules in the front of the vehicle may share a LAN, while those for the interior or rear of the vehicle may share another LAN.

**CAN DIAGNOSTICS**

Late model vehicles that have CAN wiring systems require a CAN-compliant scan tool for diagnostics. A CAN-compliant scan tool has the circuitry that can read the various data baud rates. Older scan tools won’t work because they were not designed to read CAN data. Consequently, upgrading to a CAN-compliant scan tool is necessary to work on newer vehicles.

If a fault occurs in the multiplex wiring in a CAN vehicle, it will set a “U” communications fault code and turn on the Malfunction Indicator Lamp (MIL). The number that follows the U-code will correspond to the type of fault.

U-codes can be set by loose or corroded wiring connectors, by open or shorted wires, or by module faults. Refer to the vehicle manufacturer’s trouble code charts for the diagnostic procedures to follow.

- Always use a backup battery or memory saver to preserve the Keep Alive Memory settings in modules if you have to disconnect or replace a battery on a CAN vehicle.
- In CAN systems, in order for data messages to be shared among different networks on the same vehicle, a special node is used that contains all of the transceivers for the different networks. These nodes are called “gateways”, and can receive a high speed message and convert it to a low speed message. A single vehicle can have several gateways to help transfer data among different networks.
- Diagnosing vehicles with a scan tool now has a twist. Your scan tool must be CAN-compliant to communicate with a CAN vehicle. For example, the Tech 2 requires what is known as a CANdi module to be inserted in the line from the scan tool to the DLC. Without this module, the Tech 2 can’t communicate with newer CAN-compliant GM vehicles. Some after market scanners are CAN-compliant, and others are not. Be careful before you buy.

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**QUESTIONS**

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**Review Questions**

**Multiplexing allows multiple circuits to share the same wiring by:**

a. Using floating ground connections  
b. Using digital signals and coded messages  
c. Using a common hot lead  
d. Using a circulating digital transducer

In multiplex wiring systems, the wiring circuit that is used for command signals is called the:

a. Node  
b. “Gatekeeper”  
c. Data Bus  
d. Command Module

**A Controller Area Network (CAN) system:**

a. Ties together all the major control modules in the vehicle  
b. Allows for three different communication speeds (CAN A, B, an C)  
c. Can transmit over various conductive media, even including fiber optic cable  
d. All of the above

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**Tech tips**

- Always use a backup battery or memory saver to preserve the Keep Alive Memory settings in modules if you have to disconnect or replace a battery on a CAN vehicle.
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