

600 Electrical System—General

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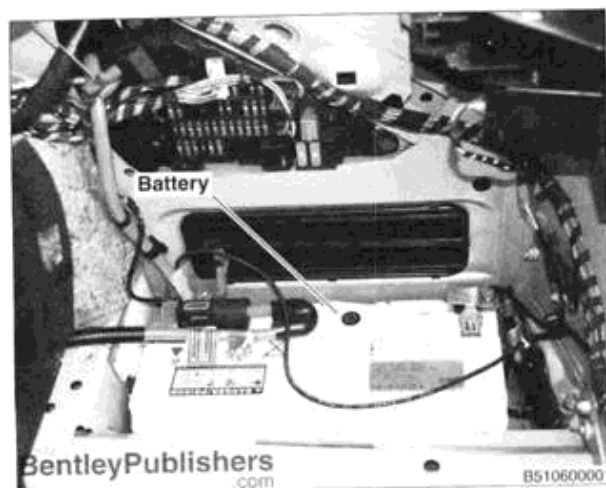
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GENERAL

This section describes the principal parts of the electrical system. Also covered here are basic electrical system troubleshooting tips.

See also:

- **121 Battery, Starter, Alternator**
- **ECL Electrical Component Locations** for common BMW acronyms as well as component location information
- **ELE Electrical Wiring Diagrams**
- **OBD On-Board Diagnostics**

Electrical overview

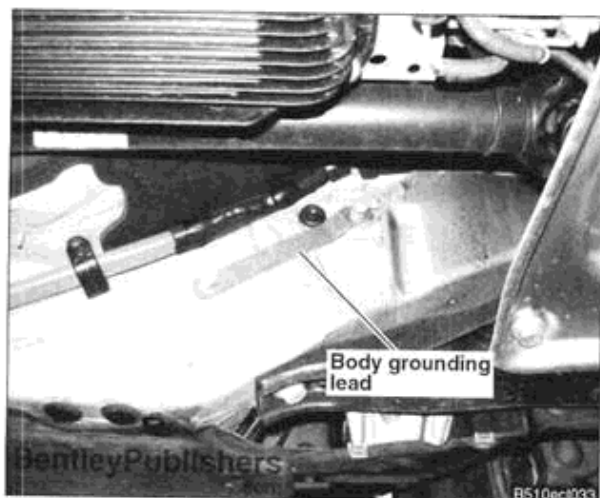
- The vehicle operates on a 12-volt direct current (DC) negative-ground system. Power is supplied by a lead-acid battery in right side of the trunk or cargo compartment.

A voltage regulator controls system voltage at approximately 12 volts. All circuits are grounded by direct or indirect connection to the negative (–) terminal of the battery.

A number of ground connections throughout the vehicle connect the wiring harness to chassis ground. These circuits are completed by the battery cable or ground strap between the body and the battery negative (–) terminal.

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Bus basics



Due to the extensive use of aluminum in 5 Series front end components, grounding leads are used to electrically bridge body components to each other.

Fuses are color coded to indicate current capacities.

Electrical components connect using one of the following:

- Heavy cables with lug-type connectors (battery, starter, alternator).
- Electrical harnesses with keyed, push-on connectors that lock into place.
- Buses with modular connectors.

Relays and control modules are mounted in various places throughout the vehicle. See **ECL Electrical Component Locations**.

Bus basics

To handle electrical complexity, 5 Series vehicles are equipped extensively with bus systems. Signals are shared digitally among electrical components on a bus, eliminating the need for separate connections for each pair of components. The use of bus communication for controls and accessories reduces wiring complexity and improves system response time.

Data transfer over a bus is similar to a telephone conference. A component on the bus transmits a stream of data (data telegrams) which other components receive at the same time. Each component is then free to use or ignore this telegram.

The benefits of the bus method of data transfer are as follows:

- As data and programs are modified and extended, only software modifications are necessary.
- Continuous verification of transmitted data leads to low error rate.
- Sensors and signal wires can be simplified or eliminated due to the transmittal of multiplexed digital data.
- Control modules transfer data at a high rate.
- Control module sizes and connector sizes are smaller.
- Bus architecture conforms to international standards. This facilitates data interchange between components of different manufacture.

Electrical test equipment

Many electrical tests described in this manual call for measuring voltage, current or resistance using a digital multimeter. A digital meter is preferred for precise measurements and for electronics work because it is generally more accurate than an analog meter (swing-needle). An analog meter may draw enough current to damage sensitive electronic components.

An LED test light is a safe, inexpensive tool that can be used to perform many simple electrical tests that would otherwise require a digital multimeter. The LED indicates when voltage is present between any two test-points in a circuit.

The integrated safety, comfort, security and handling systems on 5 Series vehicles are designed with self-diagnostic capabilities. The

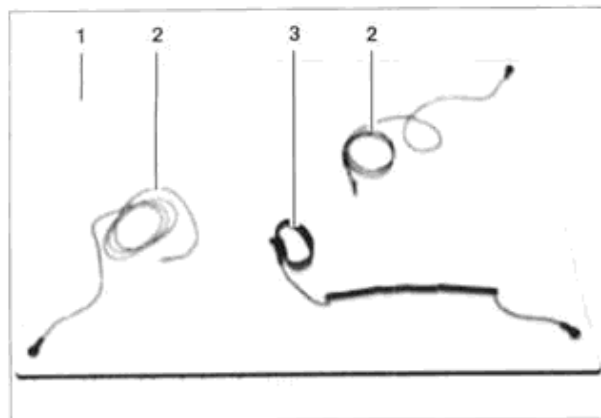
quickest way to diagnose many problems is to start with a scan tool read-out of diagnostic trouble codes (DTCs). See **Scan tool basics** in this repair group.

Static damage prevention

Electronic circuits can be easily damaged by static electricity held by the human body and vehicle electrical components. To avoid static electricity damage, take precautions to ground the static electricity before touching any internal components of a circuit.

- Wearing an electrostatic discharge (ESD) wrist strap or working on an anti-static mat prevents static electricity damage.

1. ESD mat
2. Grounding lead
3. ESD wrist strap



Warnings and Cautions

WARNING—

- Airbags and pyrotechnic seat belt tensioners utilize explosive devices. Handle with extreme care. See warnings and cautions in **721 Airbag System (SRS)**.
- The ignition system operates at lethal voltages. If you have a weak heart or wear a pacemaker, do not expose yourself to ignition system electric currents. Take extra precautions when working on the ignition system or when servicing the engine while it is running or the key is ON. See **120 Ignition System** for additional ignition system warnings and cautions.
- Keep hands, clothing and other objects clear of the electric engine cooling fan when working on a warm engine. The fan may start at any time, even when the ignition is switched OFF.

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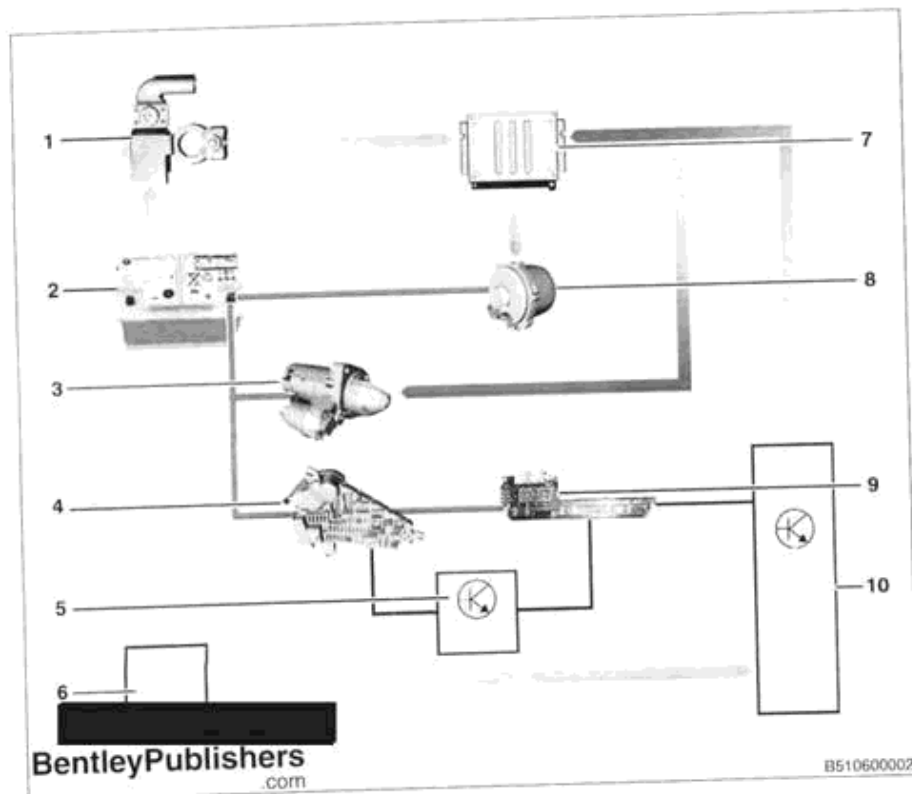
Warnings and Cautions

CAUTION—

- Do not disconnect the battery with the engine running.
- Prior to disconnecting the battery, read the battery disconnection cautions given in **001 Warnings and Cautions**.
- Switch the ignition OFF and remove the negative battery cable before removing any electrical components. Connect and disconnect electrical connectors and ignition test equipment leads only while the ignition is switched OFF.
- Relay and fuse positions are subject to change and may vary from vehicle to vehicle. If questions arise, an authorized BMW dealer is the best source for the most accurate and up-to-date information.
- Use a digital multimeter for electrical tests. Switch the multimeter to the appropriate function and range before making test connections.
- Many control modules are static sensitive. Static discharge damages them permanently. Handle the modules using static prevention equipment and techniques. See **Static damage prevention** in this repair group.
- To avoid damaging harness connectors or relay panel sockets, use jumper wires with flat-blade connectors that are the same size as the connector or relay terminals.
- Do not try to start the engine of a vehicle which has been heated above 176°F (80°C) (for example, in a paint drying booth). Allow it to cool to normal temperature.
- Disconnect the battery before doing any electric welding on the vehicle.
- Do not wash the engine while it is running, or any time the ignition is ON.
- Choose test equipment carefully. Use a digital multimeter with at least 10 M Ω input impedance or an LED test light. An analog meter (swing-needle) or a test light with a normal incandescent bulb may draw enough current to damage sensitive electronic components.
- Do not use an ohmmeter to measure resistance on solid state components such as control modules.
- Disconnect the battery before making resistance (ohm) measurements on a circuit.

VEHICLE ELECTRICAL SYSTEM (2004 - 2005)

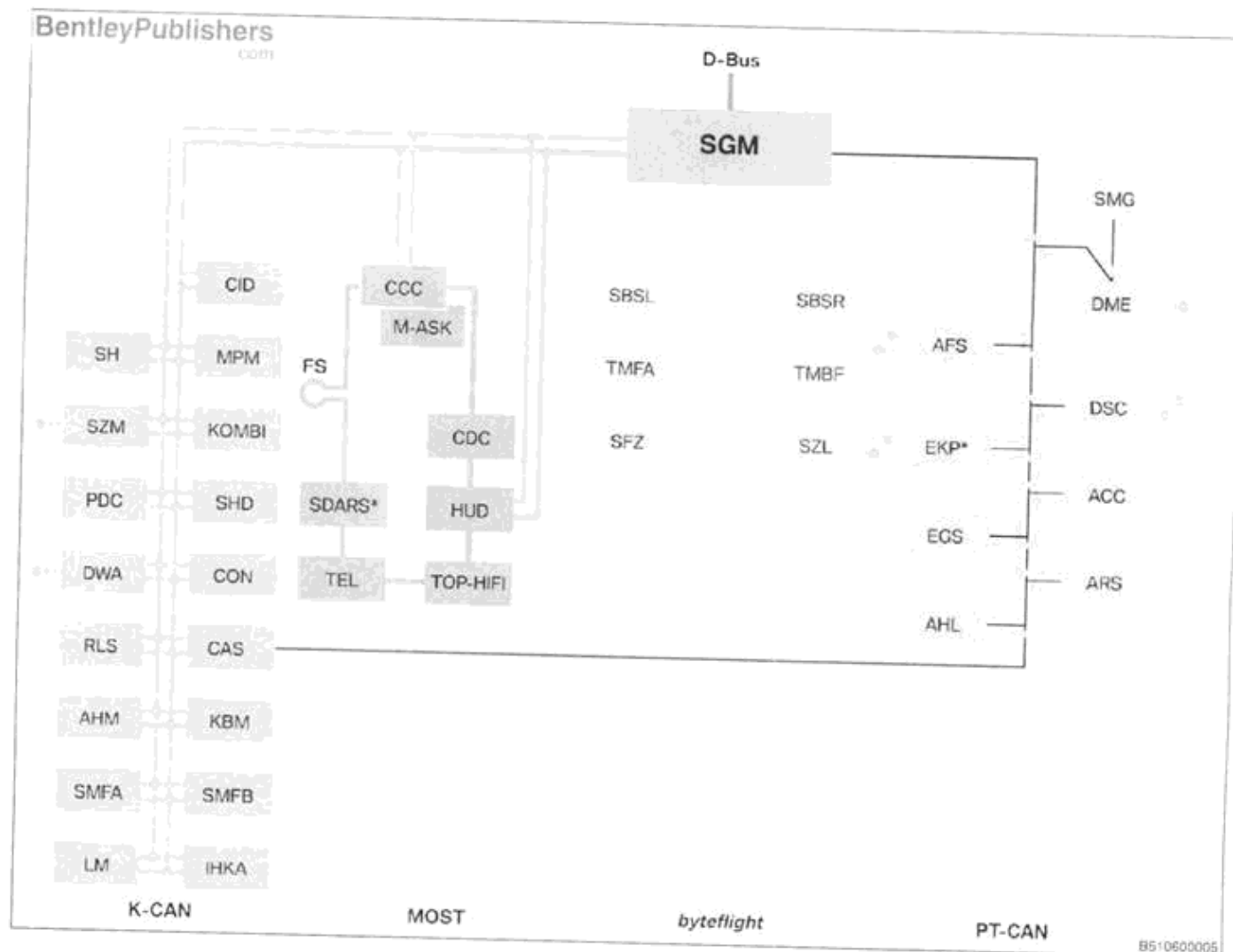
Power supply (2004 - 2005)



1. Intelligent battery sensor (IBS)
 - Monitors battery state of charge, state of health.
 - See **121 Battery, Starter, Alternator** for additional information.
2. Battery.
3. Starter.
4. Rear power distribution and fuse panel (A46).
 - Houses terminal 30g relay for electric load cut-off function.
 - See **ECL Electrical Component Locations** for fuse and relay positions.
5. Micro-power module (MPM).
 - In trunk, underneath spare tire.
 - Houses bistable (latching) relay for electric load cut-off function.
 - Switches power supply to audio and communications equipment.
6. Ignition and starter switch (ZAS).
7. Engine control module (ECM).
8. Alternator.
9. Front fuse and relay panel (A41).
 - See **ECL Electrical Component Locations** for fuse and relay positions.
10. Car access system (CAS), version 1.
 - Underneath left side dashboard.
 - See **121 Battery, Starter, Alternator** for replacement procedure.

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Bus systems (2004 - 2006)



Bus systems (2004 - 2006)

ACC Active cruise control
AFS Active steering
AHL Adaptive headlights
AHM Hazard warning
ARS Acceleration sensor
CAS Car access system
CCC Car communications computer
CDC CD changer
CID Central information display
CON iDrive controller
DME Engine control module (ECM)
DSC Dynamic stability control module
DWA anti-theft alarm

EGS Automatic transmission control module
EKP Fuel pump control module
FS MOST direct access
IHKA Automatic climate control
KBM Body basic module
KOMBI Instrument cluster
LM Light module
M-ASK Multi-audio system controller
MPM Micro-power module
PDC Park distance control
RLS Rain and light sensor
SBSL B-pillar satellite crash sensor, left
SBSR B-pillar satellite crash sensor, right

SDARS Satellite radio
SFZ Center satellite crash sensor
SGM Safety and gateway module
SH Seat heater
SHD Sunroof module
SMBF Passenger seat module
SMG Sequential manual gearbox
SMFA Driver seat module
SZL Steering column switch cluster
SZM Center console switch center
TMBF Passenger door module
TMFA Driver door module
TEL Telematics control module
TOP-HIFI Amplifier

Bus functions and types (2004 - 2005)**Main buses**

Main bus systems exchange data between control modules throughout the vehicle.

D-bus (diagnostic -bus) connects SGM to diagnostic plug (OBD plug).

K-CAN (body CAN) connects the instrument cluster, central information display (CID) and iDrive controller.

MOST (media oriented systems transport fiber optic bus) connects satellite radio, telephone and top HiFi system.

byetflight (fiber optic bus) connects satellite crash sensors, door modules and driver airbag to SGM (primary airbag module).

PT-CAN (powertrain CAN) links fuel injection, powertrain and traction control modules. The change from CAN-bus (twisted pair of wires) is that PT-CAN has three wires, with the third wire used as the wake-up line for associated modules.

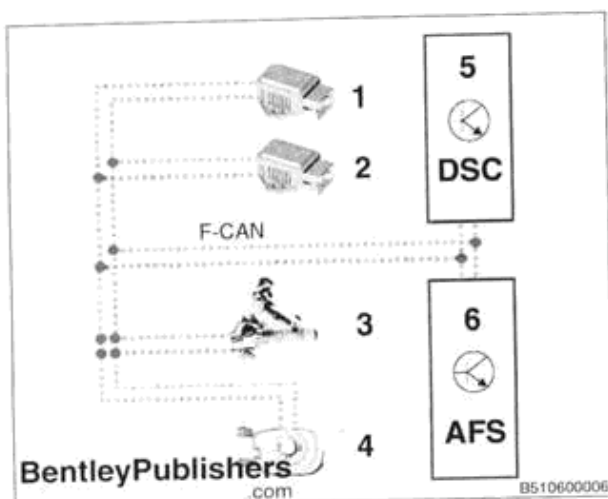
Sub-buses

Sub-bus systems exchange relatively small quantities of data within one system.

LIN-bus (local interconnect network), a bidirectional single-wire bus system, includes a main controller and several server units. The 5 Series LIN-bus connects control modules with blower motor, tire pressure monitoring wheel housing antennas and door modules.

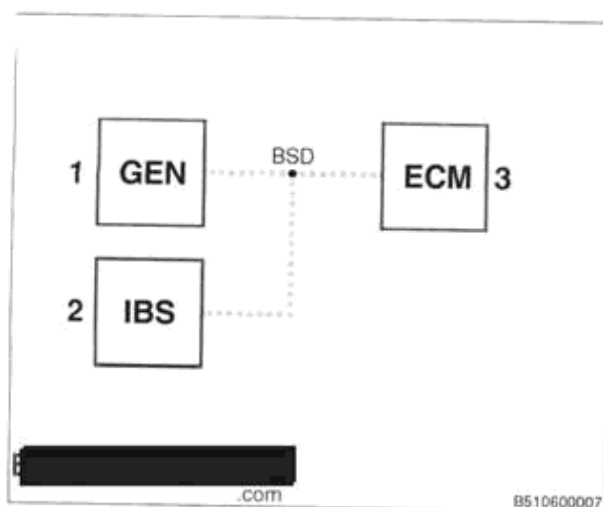
◀ **F-CAN** (chassis CAN) enables fast data transfer among components in DSC and active steering.

1. DSC acceleration sensor 1
2. DSC acceleration sensor 2
3. Active steering actuator
4. Steering column switch center (SZL)
5. DSC control module
6. Active steering control module



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Bus functions and types (2004 - 2005)



◀ **BSD** (bit-serial data interface) connects intelligent battery sensor (IBS) with alternator and engine control module (ECM).

1. Alternator
2. Intelligent battery sensor (IBS)
3. Engine control module (ECM)

Table a summarizes bus structure and data speeds.

Table a. Bus system parameters

Bus system	Data rate	Structure
BSD	9.6 kBd	Linear, single wire
byteflight	10 MBd	Star, fiber optic
D-bus	10.5 - 115 kBd	Linear, single wire
DWA-bus	9.6 kBd	Linear, single wire
F-CAN	100 kBd	Linear, 2-wire
K-bus seats	9.6 kBd	Linear, single wire
K-CAN	100 kBd	Linear, 2-wire
LIN-bus adaptive headlights	19.2 kBd	Linear, single wire
LIN-bus doors	19.2 kBd	Linear, single wire
LIN-bus IHKA	9.6 kBd	Linear, single wire
LIN-bus tire pressure monitor	9.6 kBd	Linear, single wire
MOST	22.5 Mbd	Ring, fiber optic
PT-CAN	500 kBd	Linear, 2-wire

VEHICLE ELECTRICAL SYSTEM (2006 - 2007)

System overview (2006 - 2007)

Beginning with 09 / 2005 production (2006 model year), 5 Series electrical system was modified as follows:

System network:

- byteflight bus eliminated.
- Body-gateway module (KGM) mounted in front fuse and relay panel behind glove compartment.
- Door module functions transferred to KGM.

Energy management: Micro-power module (MPM) eliminated. MPM function, including bistable relay, integrated in KGM.

Comfort access (optional):

- Keyless access.
- Electronic outer door handle modules (TAGE)

Car access system (CAS), version 2:

- Start / stop button.
- Key slot.
- Electric steering column lock (ELV).

Expanded diagnostic functions:

- Monitoring of control modules to detect authorized bus system wake-up.
- Monitoring of control modules to detect sleep mode preventer (control unit that prevents bus system from switching to sleep mode).

Steering column switch cluster (SZL): New connection to PT-CAN.

Passive safety: Airbag control system changed from advanced safety electronics (ASE) to advanced crash and safety management (ACSM).

Audio systems: MP3 function in radio module.

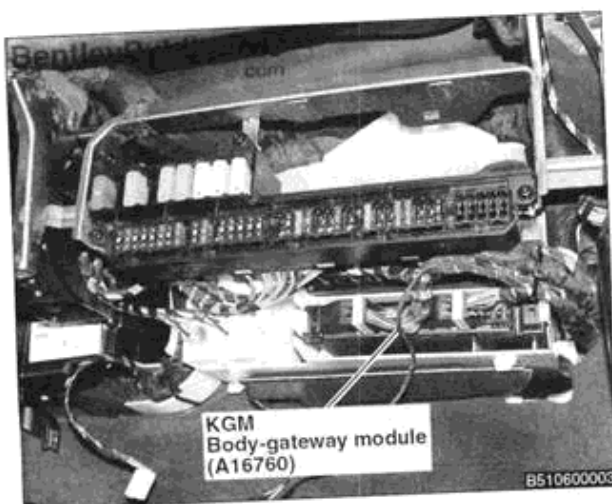
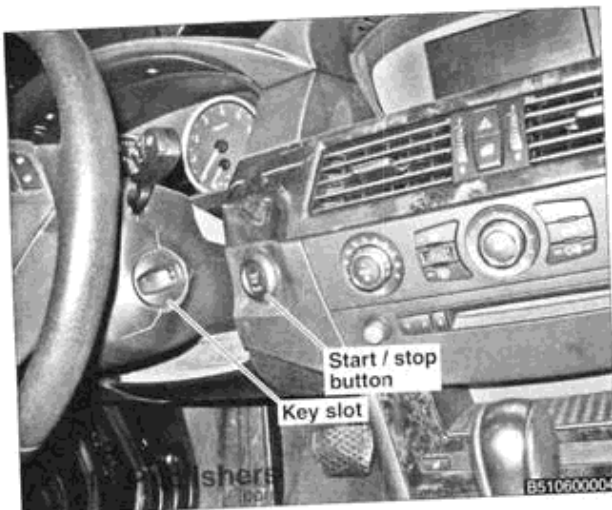
Bus system (2006 - 2007)

The 2004 - 2005 bus system is modified as follows:

Body-gateway module (KGM) performs the gateway interconnect function for the following buses:

- Diagnostic-bus (D-bus)
- PT-CAN (powertrain CAN)
- K-CAN (body CAN)
- LIN-bus (local interconnect network)

Data transmission rates and data telegram structure vary among different buses. KGM is responsible for buffering data telegrams and forwarding them according to priority.



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Bus system (2006 - 2007)

KGM is the interface to the diagnostic-bus for the purpose of diagnosing or programming control units connected to the bus system.

The KGM additionally features a link to LIN-bus for the purpose of reading information from the driver's door switch cluster.

Main airbag control module functions are transferred to the advanced crash and safety management (ACSM) control module, above center tunnel, connected to sensors and airbags via K-CAN.

Comfort access components, including the control module, door handle modules (TAGE) and electric steering column lock (ELV) interconnect via K-CAN.

VEHICLE ELECTRICAL SYSTEM (2008 - 2010)

Electrical system (2008 - 2010)

Beginning with 03 / 2007 production (2008 model year) new electrical features are either standard or optional on 5 Series:

S-CAN (sensor CAN), a new bus system based on PT-CAN, transmits data at the same speed as PT-CAN and uses PT-CAN protocol.

D-CAN (diagnostics-CAN), also a new bus, is connected to KGM.

Car access system (CAS), version 3 with electronic immobilizer 3 or 4 (EWS 3 or EWS 4), depending on the engine. With EWS 4, engine electronics are connected to CAS by an additional data connection. The data connection is redundant to PT-CAN and uses K-bus protocol.

Rain / light sensor connected by LIN-bus to wiper and lights systems.

Welcome light.

Daytime driving light with corona rings.

Adaptive headlights with turn-off light.

Turn signal LED and additional rear side-marker lights standard.

Diagnostics-CAN on body-gateway module (KGM).

Lane departure warning (TLC) generates a vibration warning in the steering wheel when the driver accidentally changes lane, prompting the driver to counter-steer.

Active cruise control with stop and go function makes it easier to drive in heavy traffic. The system supports repeated pulling away and braking in slow traffic queues.

Longitudinal dynamics management (LDM) is used, among other things, for active cruise control stop and go function.

Long and short range radar are for active cruise control with stop and go function.

- ◀ **Gear selector switch (GWS)** control module replaces automatic transmission mechanical gear shift.
- ◀ **Center console switch cluster (SZM)** consists of two columns of buttons on two sides of center dashboard ashtray.



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Power management basics

POWER MANAGEMENT

Power management basics

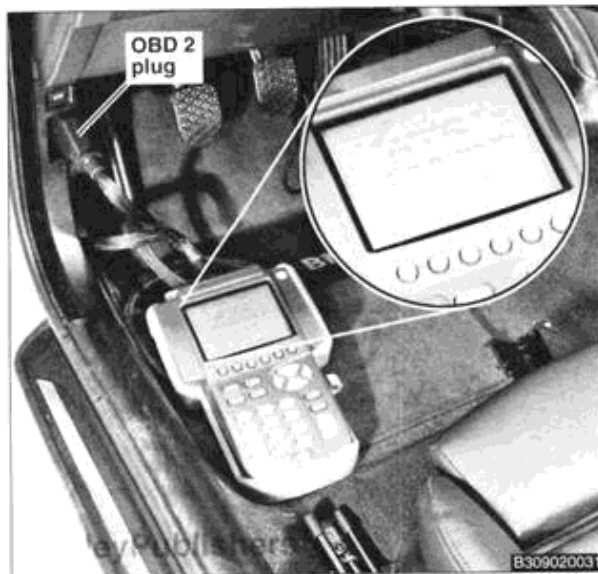
Power management strategies in 5 Series vehicles are designed to monitor battery power, minimize power loss (dead battery) and diagnose battery state of charge problems. Intelligent battery sensor (IBS) data is continuously monitored and evaluated for this purpose.

During vehicle operation, engine mechanical energy is converted by the alternator into electrical energy and made available to *electric* loads in the vehicle. Most electric loads receive power primarily via switched terminal 30g and terminal 30g_f relays. Certain electric loads are supplied unswitched battery power directly by terminal 30 or terminal R. *Example:* Anti-theft alarm system is active when the vehicle is parked and engine is shut OFF. Therefore anti-theft power is from an unswitched terminal.

The power management portion of the engine control module (ECM) operating program is able to:

- Regulate idle speed and charging voltage while the engine is running.
- Regulate power consumption of electric loads with relatively high power demands, or switch OFF those loads if power is needed elsewhere.
- Switch OFF electric loads when engine is stationary either as a timed function (via CAS and terminal 30g relay) or in response to electrical faults (via ECM and terminal 30g_f relay).
- Generate and store fault codes to help with vehicle or battery diagnosis.

Additional information on IBS is in **121 Battery, Starter, Alternator**.



CODING, PROGRAMMING, ADAPTATION

Scan tool basics

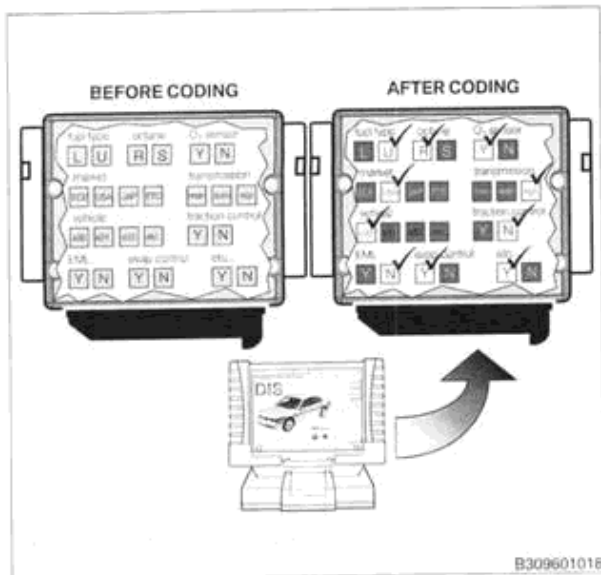
- The scan tool, shown here connected to the OBD 2 plug, is an electronic device used for the following:
- Displaying vehicle data such as engine, engine management and transmission versions
 - Viewing and clearing fault codes (diagnostic trouble codes or DTCs)
 - Coding and programming new control modules and other electronic equipment
 - Clearing and resetting adaptations

Coding

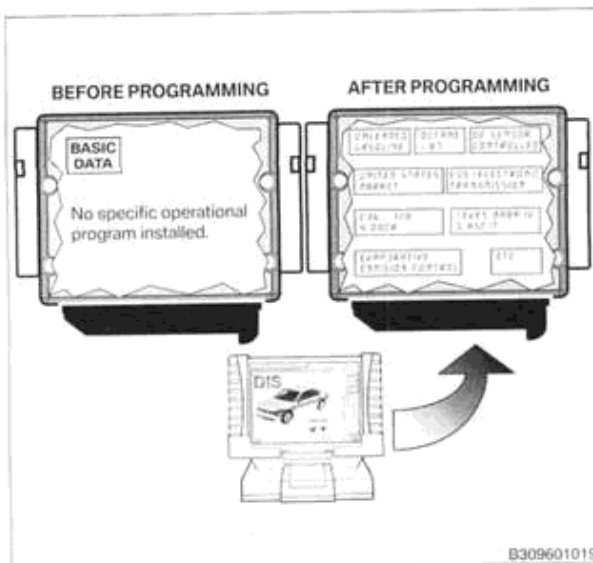
- The procedure of assigning one labeled group of data to the operating program of a control module or component is referred to as coding. A codable control module has a basic operating program already installed along with several variations of operating data. The coding process allows a specific set of operating data to be assigned to the basic operating program of that module or component to match a specific application.

Here are some types of operating requirements:

- Nominal values of device input signals (0.25 - 2.5 volts, 5 - 25 watts, etc.)
- Type of device input signal (PWM, square wave, analog)
- Operational parameters (device activation or deactivation time)
- Market specific operations (oxygen sensors, fuel type, emission standards)
- Country specific regulations (USA, Canada, Japan, UK, EU)
- Powertrain configurations (manual transmission, automatic transmission, TLEV, ULEV, SULEV, Diesel)



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Programming

- Programming loads application and system-specific operating instructions (program) into a coded module. Programming is also a means of updating data and operating instructions previously installed in a control module.

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Adaptation

Adaptation

The engine control model (ECM), automatic transmission control module (EGS), dynamic stability control (DSC) module and other modules and components in the vehicle are adaptive. The software in each module learns from use and becomes adapted to other accompanying modules.

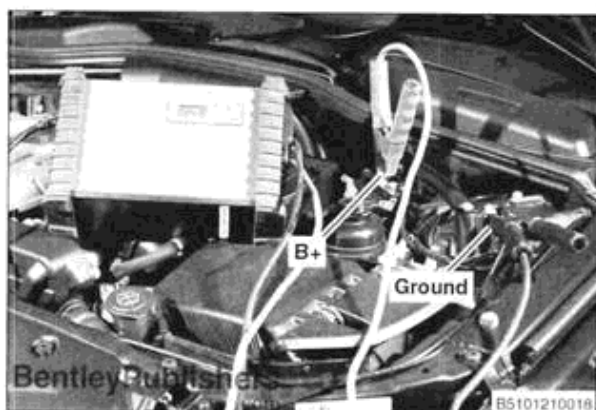
When installing a new module or component, be sure to use the scan tool to clear old adaptations in order to allow the components to readapt.

Coding and programming procedure

- Before starting the coding and programming procedure, use a vehicle power supply to maintain correct voltage throughout the electrical system. See **121 Battery, Starter, Alternator**.

For the most up-to-date data and program information, make sure the scan tool has the current version of CIP (coding, individualization and programming) installed.

Connect BMW scan tool or equivalent to OBD II plug under dashboard. See **Scan tool basics** in this repair group. In addition to BMW scan tools, there are a number of aftermarket tools available. See **Tools** in **020 Maintenance**.



ELECTRICAL TROUBLESHOOTING

Four things are required for current to flow in any electrical circuit:

- Voltage source.
- Wires or connections to transport voltage.
- Load or device that uses electricity.
- Connection to ground.

Most problems can be found using a digital multimeter (volt / ohm / ammeter) to check the following:

- Voltage supply.
- Breaks in the wiring (infinite resistance / no continuity).
- A path to ground that completes the circuit.

Electric current is logical in its flow, always moving from the voltage source toward ground. Electrical faults can usually be located through a process of elimination. When troubleshooting a complex circuit, separate the circuit into smaller parts. General tests outlined below may be helpful in finding electrical problems. The information is most helpful when used with wiring diagrams.

Be sure to analyze the problem. Use wiring diagrams to determine the most likely cause. Get an understanding of how the circuit works by following the circuit from ground back to the power source.

When making test connections at connectors and components, use care to avoid spreading or damaging the connectors or terminals. Some tests may require jumper wires to bypass components or connections in the wiring harness. When connecting jumper wires, use blade connectors at the wire ends that match the size of the terminal being tested. The small internal contacts are easily spread apart, and this can cause intermittent or faulty connections that can lead to more problems.

Voltage and voltage drop

Wires, connectors, and switches that carry current are designed with very low resistance so that current flows with a minimum loss of voltage. A voltage drop is caused by higher than normal resistance in a circuit. This additional resistance actually decreases or stops the flow of current. Excessive voltage drop can be noticed by problems ranging from dim headlights to sluggish wipers. Some common sources of voltage drops are corroded or dirty switches, dirty or corroded connections or contacts, and loose or corroded ground wires and ground connections.

A voltage drop test is a good test to perform if current is flowing through the circuit but the circuit is not operating correctly. A voltage drop test helps pinpoint a corroded ground strap or a faulty switch. Normally, there should be less than 1 volt drop across most wires or closed switches. Voltage drop across a connector or short cable varies but should not exceed 0.3 volt.

A voltage drop test is generally more accurate than a simple resistance check because the resistances involved are often too small to measure with most ohmmeters. For example, a resistance as small as $0.02\ \Omega$ results in a 3 volt drop in a typical 150 amp starter circuit. ($150\text{ amps} \times 0.02\ \Omega = 3\text{ volts}$).

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Voltage and voltage drop

Keep in mind that voltage with ignition key ON and voltage with engine running are not the same. With ignition ON and engine OFF, fully charged battery voltage is approximately 12.6 volts. With engine running (charging voltage), normal voltage is approximately 14.0 volts. Measure voltage at battery with ignition ON and then with engine running to get exact measurements.

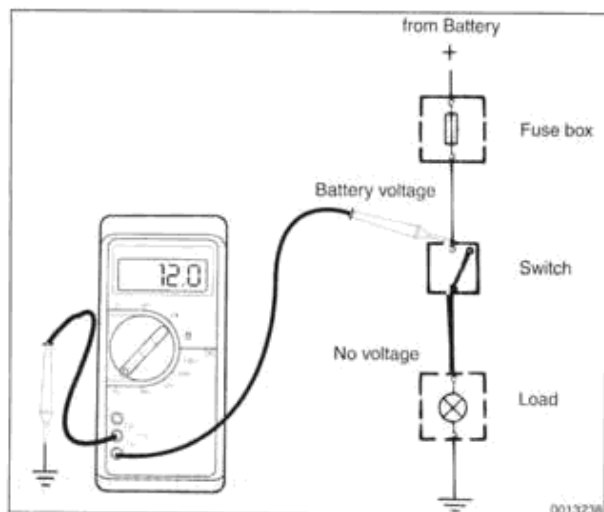
Voltage, measuring

- Connect digital multimeter negative lead to a reliable ground point on vehicle.

NOTE —

- The negative (-) battery terminal is always a good ground point.

- Connect digital multimeter positive lead to point in circuit you wish to measure.
- Check that voltage reading does not deviate more than 1 volt from voltage at battery. If voltage drop is more than this, check for a corroded connector or loose ground wire.

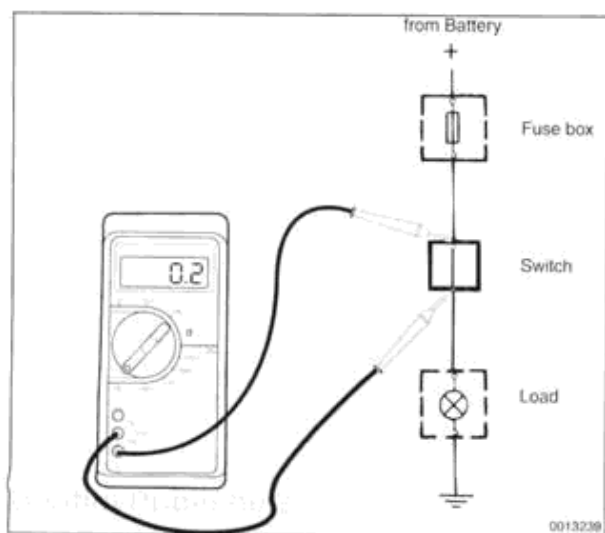


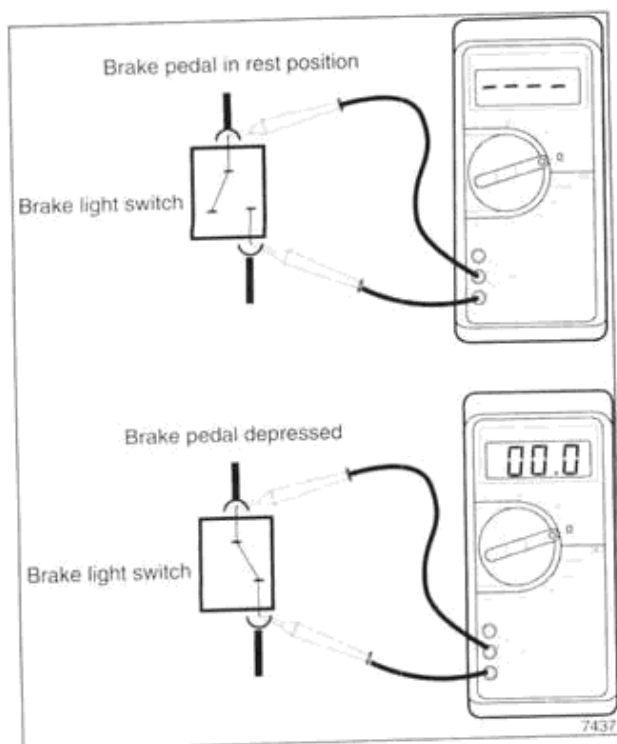
Voltage drop, testing

Check voltage drop only when there is a load on the circuit, such as when operating the starter motor or turning on the headlights. Use a digital multimeter to ensure accurate readings.

- Connect digital multimeter positive lead to positive (+) battery terminal or a positive power supply close to battery source.

- Connect digital multimeter negative lead to other end of cable or switch being tested.
- With power switched ON and circuit working, meter shows voltage drop (difference between two points). This value should not exceed 1 volt.
- Maximum voltage drop in an automotive circuit, as recommended by the Society of Automotive Engineers (SAE), is as follows:
 - 0 volt for small wire connections
 - 0.1 volt for high current connections
 - 0.2 volt for high current cables
 - 0.3 volt for switch or solenoid contacts
- On longer wires or cables, the drop may be slightly higher. In any case, a voltage drop of more than 1.0 volt usually indicates a problem.





Continuity, checking

Use continuity test to check a circuit or switch. Because most automotive circuits are designed to have little or no resistance, a circuit or part of a circuit can be easily checked for faults using an ohmmeter. An open circuit or a circuit with high resistance does not allow current to flow. A circuit with little or no resistance allows current to flow easily.

When checking continuity, switch ignition OFF. On circuits that are powered at all times, disconnect battery. Using the appropriate wiring diagram, test circuit for faulty connections, wires, switches, relays and engine sensors by checking for continuity.

Example: Test brake light switch for continuity:

- With brake pedal in rest position (switch open) there is no continuity (infinite Ω).
- With pedal depressed (switch closed) there is continuity (0 Ω).

Short circuits, testing

Short circuits are exactly what the name implies. Current in the circuit takes a shorter path than it was designed to take. The most common short that causes problems is a short to ground where the insulation on a positive (+) wire wears away and the metal wire is exposed. When the wire rubs against a metal part of the vehicle or other ground source, the circuit is shorted to ground. If the exposed wire is live (positive battery voltage), a fuse blows or the circuit may be damaged.

Short circuits vary in nature and are often difficult to locate. They can be found using a logical approach based on knowledge of the current path.

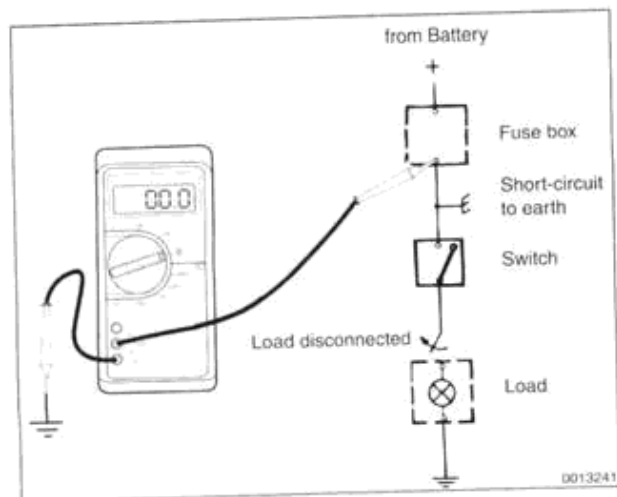
Use a digital multimeter to locate short circuits.

CAUTION—

- In circuits protected with high rating fuses (25 amp and greater), wires or circuit components may be damaged before the fuse blows. Check for wiring damage before replacing fuses of this rating. Also, check for correct fuse rating.

Testing with ohmmeter

- Remove blown fuse from circuit and disconnect cables from battery. Disconnect harness connector from circuit load or consumer.
- Using an ohmmeter, connect one test lead to load side of fuse terminal (terminal leading to circuit) and other test lead to ground.
- If there is continuity to ground, there is a short to ground.



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Short circuits, testing

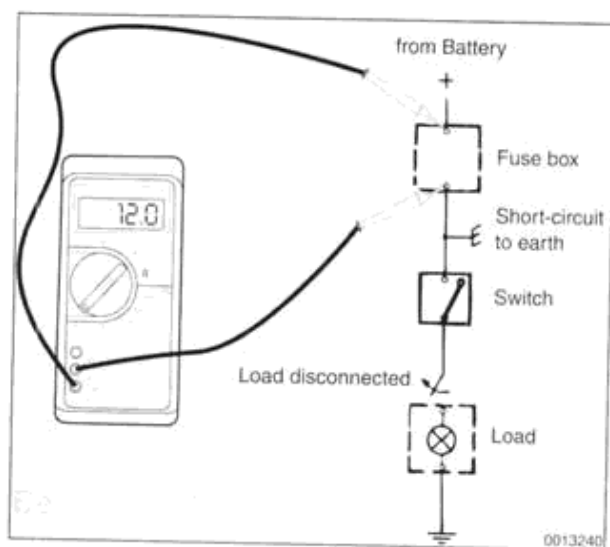
- If there is no continuity, work from wire harness nearest to fuse and relay panel and move or wiggle wires while observing meter. Continue to move down harness until meter displays a reading. This is the location of the short to ground.
- Visually inspect wire harness at this point for any faults. If no faults are visible, carefully slice open harness cover or wire insulation for further inspection. Repair any faults found.

Testing with voltmeter

- Remove blown fuse from circuit. Disconnect harness connector from circuit load or consumer.

NOTE —

- Most fuses power more than one consumer. Be sure all consumers are disconnected when checking for a short circuit.



- Using a digital multimeter, connect test leads across fuse terminals. Make sure power is present in circuit. If necessary switch ignition ON.
- If voltage is present at voltmeter, there is a short to ground.
- If voltage is not present, work from wire harness nearest to fuse and relay panel and move or wiggle wires while observing meter. Continue to move down harness until meter displays a reading. This is the location of the short to ground.

Visually inspect wire harness at this point for any faults. If no faults are visible, carefully slice open harness cover or wire insulation for further inspection. Repair any faults found.

