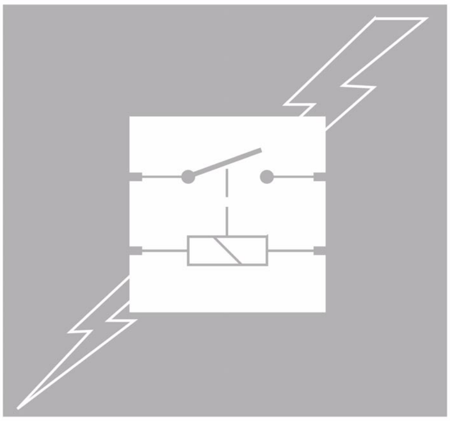
JAGUAR

TRAINING PROGRAM

JAGUAR ELECTRICAL SYSTEMS



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OBJECTIVE

The goal of the Jaguar Electrical Systems course is to provide Jaguar service technicians with information and experiences that will enable them to accurately test various electrical components and systems on Jaguar model lines.

PROGRAM CONTENT

1. INTRODUCTION
2. GENERAL INFORMATION
3. REVIEW
4. BASIC CIRCUITS & ELECTRICAL GUIDE
5. ELECTRICAL COMPONENT OPERATION
6. INTRODUCTION TO DIAGNOSIS
7. ELECTRICAL SYSTEMS TESTING

PRE-REQUISITES

The CD ROM based self-study programs that are pre-requisites for course 601 are as follows:

- Electrical for Beginners — course code 6BEG
- Advanced Electrical Components — course code 6AEC
- Advanced Circuits and Diagnostics — course code 6ACD

All three self-study course programs are included on the Electrical Systems CD from the 8 disk boxed set of Jaguar training CDs. The average time to complete each self-study program is 1.5 hours.

To receive credit, print the course completion certificate and fax it to:

Jaguar Training Administrator, FAX (201) 818–9074

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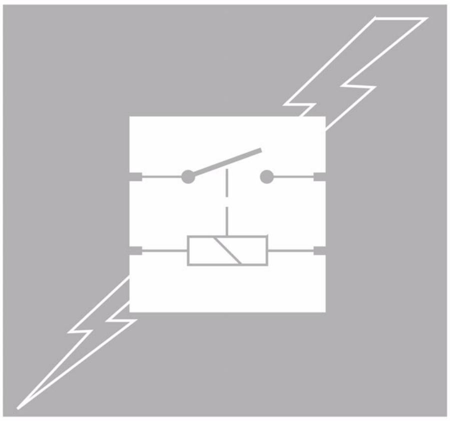

INTRODUCTION

GENERAL INFORMATION

REVIEW

BASIC CIRCUITS & ELECTRICAL GUIDE

ELECTRICAL COMPONENT OPERATION

INTRODUCTION TO DIAGNOSIS

ELECTRICAL SYSTEMS TESTING

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GENERAL INFORMATION

What this book contains

This book is divided into six sections:

- General information
- Review - Circuitry, Ohm's law, DVOM
- Basic Circuits & Electrical Guide - Build and test circuits with basic components.
- Electrical Component Operation - Advanced electric schematics, build and test circuits with advanced components.
- Introduction to Diagnosis - Logical fault finding process.
- Electrical Systems Testing - Batteries, generators, starter circuit voltage drop, identify faults, and repair procedures.

Evaluation Strategies

At the conclusion of this three day course there will be a final exam. The final exam will include one hands on test and a 20 question multiple-choice written test. A score of 100% must be achieved on the hands on portion, and 70% on the written portion to pass the course.

Safety Notice

Appropriate service methods and correct repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the safety of the person doing the work. There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the person doing the work. This course cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this course must first establish that neither personal safety or vehicle integrity is compromised from choices of methods, tools or parts.

Disconnecting the Battery

WARNING:

ALWAYS WEAR SAFTEY GLASSES AND GLOVES WHILE WORKING WITH BATTERYS.

Always stop the engine (unless otherwise instructed) before disconnecting the battery negative lead and make sure the battery positive lead is isolated (i.e. wrapped in a suitable cloth).

WARNING:

RADIO CODE SAVING DEVICES MUST NOT BE USED WHEN CONDUCTING WORK ON AIR BAG OR FUEL SYSTEMS. IT MUST BE NOTED THAT WHEN USING THESE DEVICES, THE VEHICLE ELECTRICAL SYSTEM IS STILL LIVE ALBEIT WITH A REDUCED CURRENT FLOW.

Before disconnecting the battery make sure that the radio receiver, cassette player, and compact disc player presets are recorded, and that no data is required from the Electronic Control Module/Powertrain Control Module (ECM/PCM). Disconnecting the battery will erase any fault codes and idle/drive values held in the Keep Alive Memory (KAM).

Always disconnect the battery before beginning any arc welding repair operations.

Reconnecting the Battery

WARNING:

IF THE BATTERY HAS BEEN ON BENCH CHARGE THE CELLS MAY BE GIVING OFF EXPLOSIVE HYDROGEN GAS. AVOID CREATING SPARKS. IF IN DOUBT, COVER THE VENT PLUGS OR COVERS WITH A DAMP CLOTH.

Before reconnecting the battery, make sure that all electrical systems are switched OFF to avoid causing sparks or damage to sensitive electrical equipment. Always reconnect the battery positive lead first and the negative lead last, ensuring that there is good electrical contact and the battery terminals are secure. Reset the clock to the correct time. Re-enter the radio receiver, cassette player, and compact disc player presets.

CONNECTING A BOOST BATTERY USING JUMP LEADS

WARNING:

IF THE BOOST BATTERY HAS RECENTLY BEEN CHARGED AND IS GASSING, COVER THE VENT PLUGS OR COVERS WITH A DAMP CLOTH TO REDUCE THE RISK OF EXPLOSION SHOULD ARCING OCCUR WHEN CONNECTING THE JUMP LEADS.

CAUTION:

A flat battery condition may have been caused by an electrical short circuit. If this condition exists there will be a live circuit on the vehicle even when all normal circuits are switched off. This can cause arcing when the jump leads are connected.

CAUTION:

While it is not recommended that the vehicle is jump started, it is recognized that this may occasionally be the only practical way to start a vehicle. In such an instance the discharged battery must be recharged immediately after jump starting to avoid permanent damage. Always make sure that the jump leads are adequate for the task. Heavy duty cables must be used. Always make sure that the boost battery is the same voltage as the vehicle battery. The batteries must be connected in parallel. Always make sure that switchable electric circuits are switched off before connecting jump leads. This reduces the risk of sparks occurring when the final connection is made.

WARNING:

MAKE SURE THAT THE ENDS OF THE JUMP LEADS DO NOT TOUCH EACH OTHER OR GROUND AGAINST THE VEHICLE BODY AT ANY TIME WHILE THE LEADS ARE ATTACHED TO THE BATTERY. A FULLY CHARGED BATTERY, IF SHORTED THROUGH JUMP LEADS, CAN DISCHARGE AT A RATE WELL ABOVE 1000 AMPS CAUSING VIOLENT ARCING AND VERY RAPID HEATING OF THE JUMP LEADS AND TERMINALS, AND CAN EVEN CAUSE THE BATTERY TO EXPLODE.

Always connect the jump leads in the following sequence:

- Boost battery positive first then vehicle battery positive.
- Boost battery negative next and then vehicle ground, at least 300 mm (12 in) from the battery terminal e.g. engine lifting bracket.

Always reduce the engine speed to idle before disconnecting the jump leads.

Before removing the jump leads from the vehicle that had the discharged battery, switch on the heater blower (high) or the heated rear window, to reduce the voltage peak when the leads are removed.

Always disconnect the jump leads in the reverse order of the connecting sequence, and take great care not to short the ends of the leads.

AIRBAGS

Always disconnect the battery and wait two minutes before working on the airbag system.

Battery Acids

Gases released during charging are explosive. Never use open flames or allow sparks near charging or recently charged batteries. Provide adequate ventilation.

Electric Shock

Electric shock can result from the use of faulty electrical equipment or from the misuse of equipment in good condition.

- Ensure that electrical equipment is maintained in good condition and tested frequently.
- Faulty equipment should be labelled and preferably removed from the work station.
- Ensure that cables, plugs and sockets are not frayed, kinked, cut, cracked or otherwise damaged.
- Ensure that electrical equipment does not come into contact with water.
- Ensure that electrical equipment is protected by the correct rated fuse.
- Never misuse electrical equipment and never use equipment which is in any way faulty. The results could be fatal.
- Ensure that the cables of mobile electrical equipment cannot get trapped and damaged, such as in a vehicle hoist.
- It is recommended that designated electrical workers are trained in basic First Aid.

In Case of Shock:

- Switch off the power supply before approaching the victim.
- If this is not possible, push or drag the victim from the source of electricity using a dry non-conductive material.
- Begin CPR if trained to do so.
- SUMMON MEDICAL ASSISTANCE.

Fire

Many of the materials found on or associated with the repair of vehicles are highly flammable. Some give off toxic or harmful fumes if burnt. Observe strict fire safety when storing and handling flammable materials or solvents, particularly near electrical equipment or welding processes. Before using electrical or welding equipment, make sure that there is no fire hazard present.

Have a suitable fire extinguisher available when using welding or heating equipment.

WARNING SYMBOLS ON VEHICLES

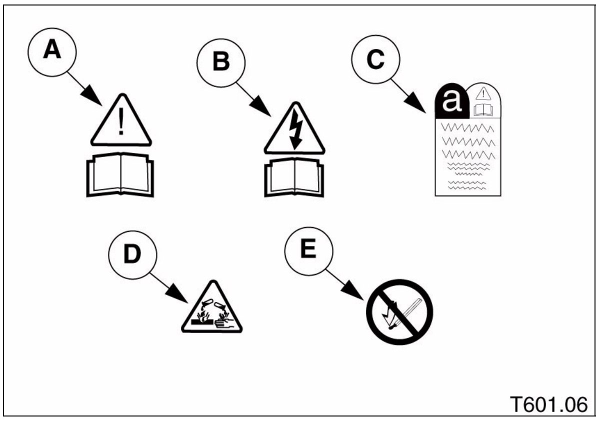

Fig. 1

Decals showing warning symbols are found on various vehicle components. These decals must not be removed. The warnings are for the attention of owners/operators and persons carrying out service or repair operations on the vehicle. The most commonly found decals are shown below together with an explanation of the warnings.

Components or assemblies displaying the warning triangle and open book symbol (**A**) advise consultation of the relevant section of the owners handbook before touching or attempting adjustments of any kind.

Components or assemblies displaying the warning triangle with the electrified arrow and open book symbol (**B**) give warning of inherent high voltages. Never touch these with the engine running or the ignition switched on.

Jaguar vehicles and replacement parts which contain asbestos are identified by this symbol (**C**).

Components or assemblies displaying this symbol (**D**) give warning that the component contains a corrosive substance.

Vehicles displaying the caution circle with a deleted lighted match symbol (**E**), caution against the use of open lights or flames within the immediate vicinity due to the pressure of highly flammable or explosive liquids or vapors.

ACRONYMS AND ABBREVIATIONS

This list is intended to cover abbreviations that are used in this course.

Alternating Current (AC)

Amperage (A) or (amp)

Cold Cranking Amps (CCA)

Current (I)

Data Link Connector (DLC)

Diagnostic Trouble Code (DTC)

Digital Volt Ohm Meter (DVOM)

Deutsche Industrie Normen (DIN)

Direct Current (DC)

Electrically Erasable Programmable Read-Only Memory (EEPROM)

Electrically Programmable Read-Only memory (EPROM)

Electromotive Force (EMF)

Engine Control Module (ECM)

Farads (F)

Generator (GEN)

Ground (GND)

Hertz (Hz)

Ignition ground (IGN GND)

International Standards Organization (ISO)

Jaguar Technical Information System (JTIS)

Keep Alive Memory (KAM)

Kilo (K)

Left-hand drive vehicle (LHD)

Light Emitting Diode (LED)

Malfunction Indicator Lamp (MIL)

Mega (M)

Meter (m)

Micro (µ)

Milli (m)

Normally Closed (NC)

Normally Open (NO)

Open Circuit Voltage (OCV)

Parameter Identification (PID)

Pedal Position Sensor (PPS)

Personal Computer (PC)

Powertrain Control Module (PCM)

Preinsulated Diamond Grip (PIDG)

Programmable Read-only Memory (PROM)

Random Access Memory (RAM)

Read-Only Memory (ROM)

Resistance (R) or Ohms

Return (RTN)

Right-hand drive (RHD)

Signal return (SIG RTN)

Technical Service Bulletin (TSB)

Throttle Position Sensor (TPS)

Vehicle Identification Number (VIN)

Voltage (V) or (E)

Watt (W)

Worldwide Diagnostic System (WDS)

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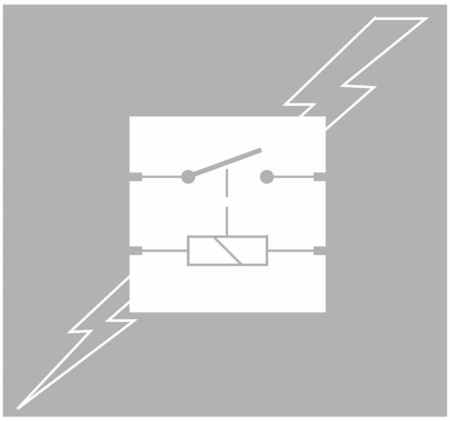

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FUNDAMENTALS OF ELECTRICITY

Voltage

Electromotive force

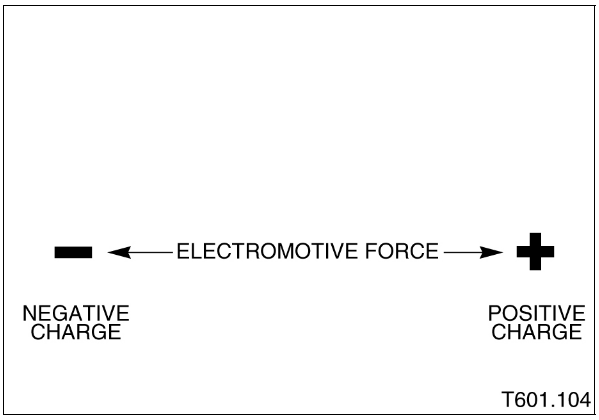


Fig. 2

Because they have the potential to perform work by causing electrons to flow through the wire, the charges at the wire ends possess potential energy. This potential difference is called Electromotive Force (EMF) and is measured in volts. Voltage is represented by the letter V.

Voltage Defined

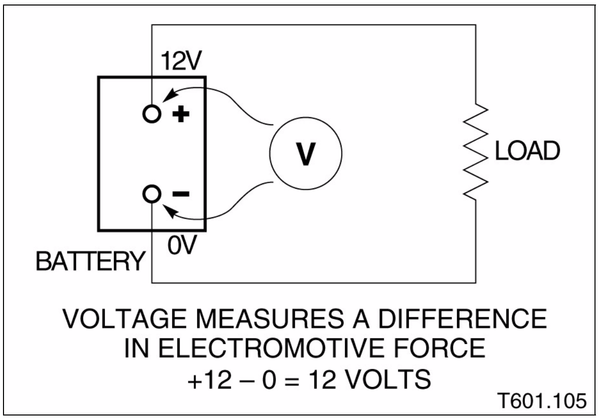


Fig. 3

Voltage is the measurement of an electromotive force in a circuit. Voltage is present in a circuit whether or not a current consuming device is connected to the source of the voltage. Voltage measurement across battery terminals is a good example.

Voltage measurement

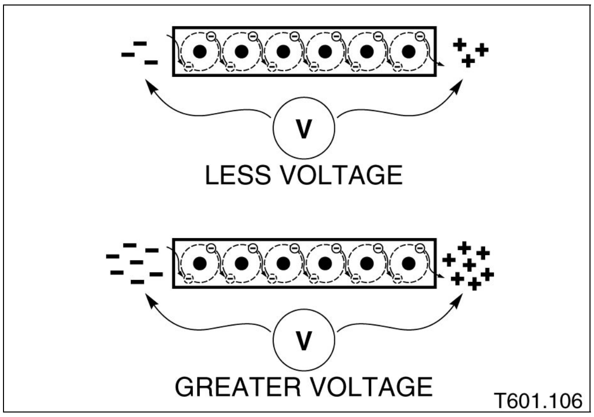


Fig. 4

Voltage is present between two points when a positive charge exists at one point and a negative charge exists at the opposite point. The greater the deficiency of electrons at the positive potential and the greater the excess of electrons at the negative potential, the greater the voltage.

AMPERAGE

Current flow

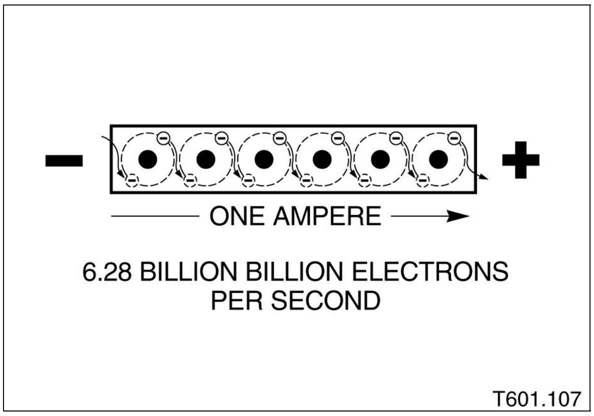


Fig. 5

The flow of electrons through a conductor is called current. It is also referred to as inductance. The rate of electric current is measured in amperes and is represented by the letter A. The electric current is one ampere when 6.28 billion billion electrons move past a given point in a conductor in one second. The Conventional Theory and the Electron Theory are two ways of describing current flow.

Conventional Theory

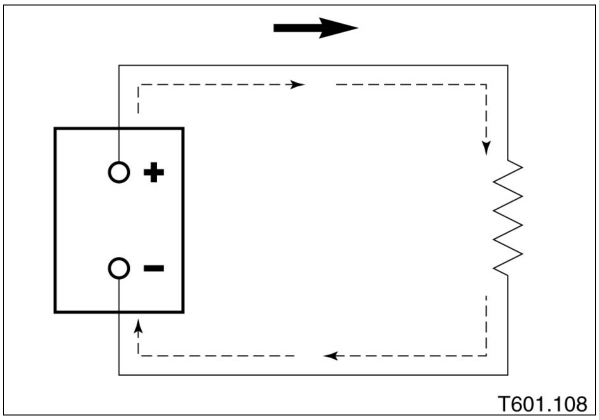


Fig. 6

In the Conventional Theory, current flows from the positive terminal of the voltage source through the circuit to the negative terminal of the voltage source.

Electron Theory

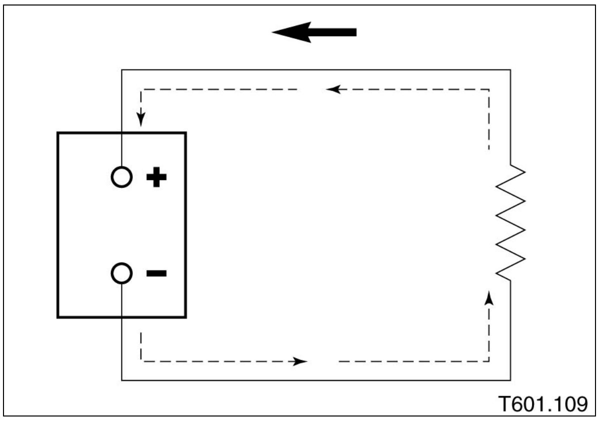


Fig. 7

In the Electron Theory, current flows from the negative terminal of the voltage source through the circuit to the positive terminal of the voltage source.

OHMS

Resistance

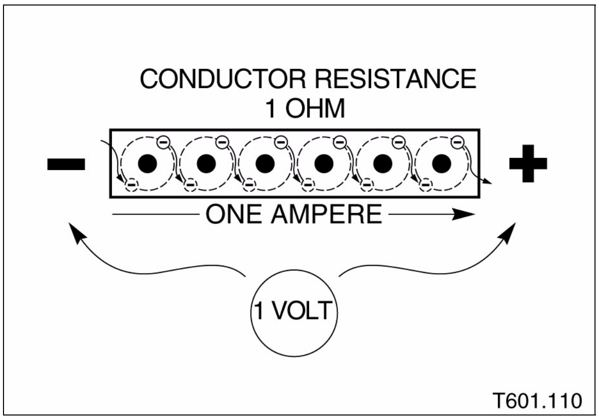


Fig. 8

All electrical conductors offer some measure of resistance to current flow. Resistance is measured in Ohms. One Ohm is defined as the resistance that will allow one ampere to flow when the potential is one volt. Resistance results primarily from two factors: electron movement and electron/atom collisions.

Electron movement

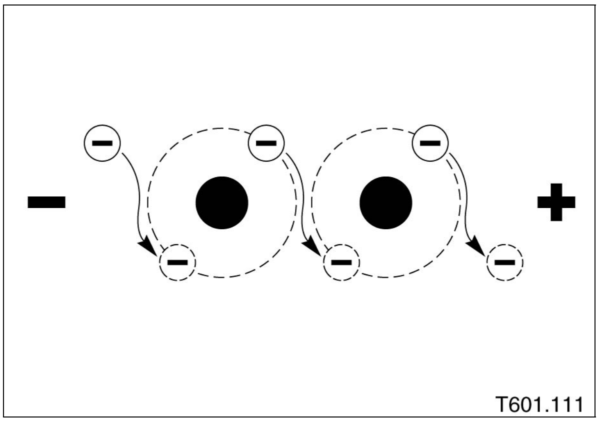


Fig. 9

The first factor is that atoms resist the loss of electrons due to the attraction of unlike charges.

Electron / atom collisions

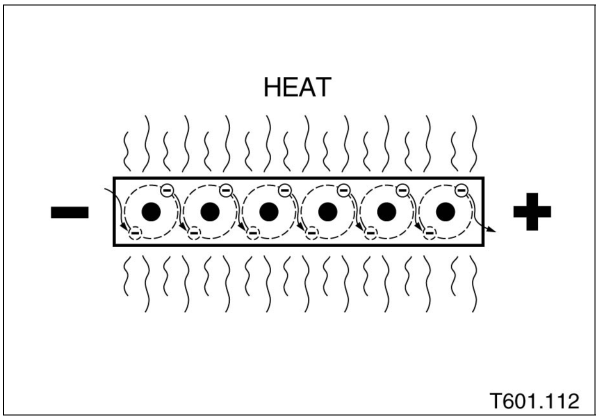


Fig. 10

The second factor involves the many billions of collisions between electrons and atoms as electrons move through the conductor. The collisions create resistance and cause heat to appear in the conductor. Mass, type of material, temperature and condition of the material determine the resistance of a conductor. All electrical components have resistance.

PROPERTIES OF CONDUCTORS, INSULATORS AND SEMICONDUCTORS

Conductors

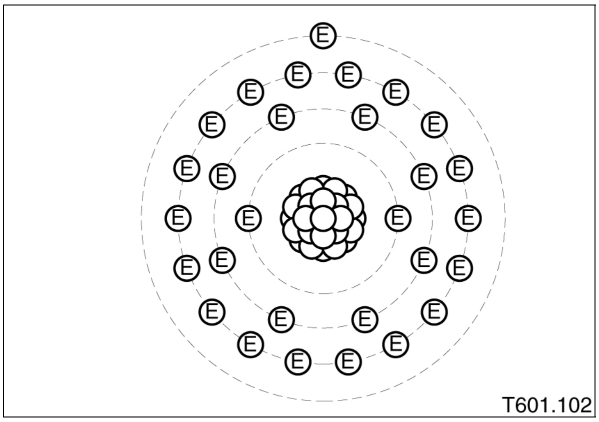


Fig. 11

Elements that form good paths for the movement of electrons are called conductors. Most metals are conductors, with the best being copper, iron and aluminum. Copper is an excellent conductor of electricity because a copper atom has only one electron in its outer orbit. Elements that have less than four electrons in their outer orbit are conductors of electricity because the electrons are free to leave the atom.

Insulators

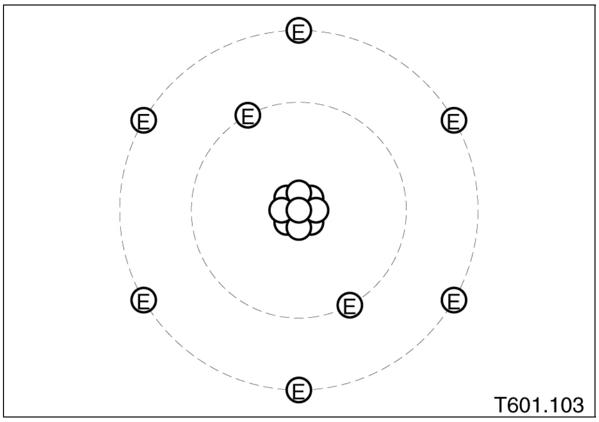


Fig. 12

Elements that strongly oppose the movement of electrons are called insulators. Elements that have more than four electrons in their outer orbit are insulators because the electrons are not free to leave the atom and thus block current flow. The best insulators have eight electrons in their outer orbit. Rubber, most plastics and glass are good insulators.

SEMICONDUCTORS

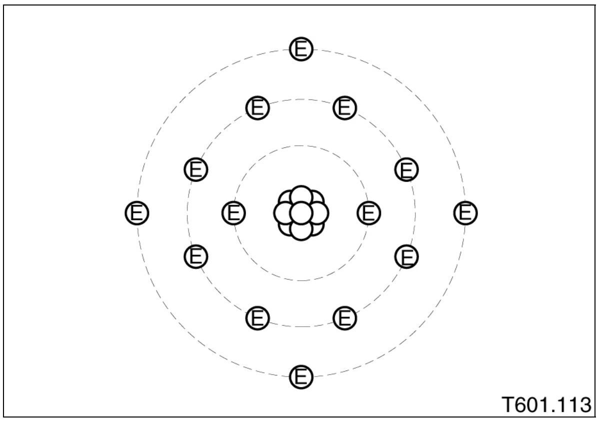


Fig. 13

Elements that are in a class between conductors and insulators are called semiconductors. Elements that have exactly four electrons in their outer orbit are semiconductors. Silicone and germanium are the two most commonly used semiconductors.

DIGITAL VOLT OHM METER (DVOM)

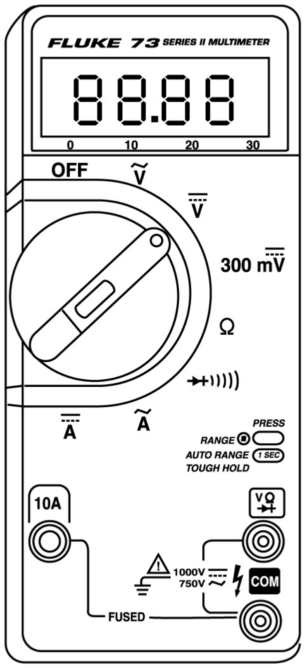


Fig. 14

Since electronic circuits can be damaged by using analog meters and equipment for circuit testing, only a Digital Volt Ohm Meter (DVOM) should be used. Analog meters draw too much power from the device they are testing to be used in circuits with sensitive digital components. DVOMs on the other hand are classified as high impedance. High impedance means that DVOMs use electronics, as opposed to a magnetic field, to take their readings. The DVOM will not damage or place any additional loads on the circuit being tested and is easy to read.

DVOM FUNCTIONS

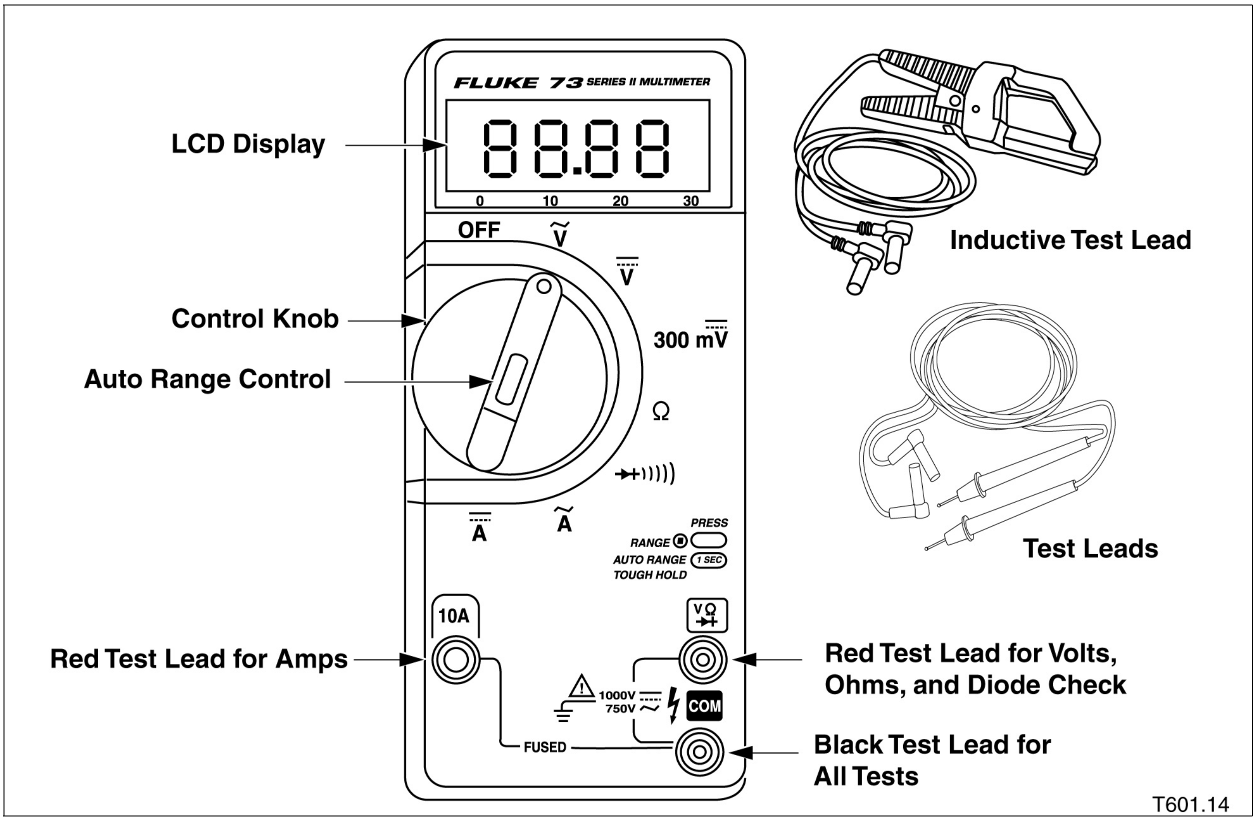


Fig. 15

Liquid Crystal Display (LCD)

The LCD display is where the test results are displayed.

Control Knob

Use the control knob to select the various electrical measurement types.

Auto Range Control

The DVOM defaults to auto range every time it is turned ON. Pressing the auto range control button in the center of the control knob turns the auto range function OFF. Once the function is turned OFF, the desired range can be selected by repeatedly pressing the auto range button. The decimal point will move to indicate the selected range.

Amperage Test Lead Port

The red test lead is installed in this port to test amperage.

Common Test Port

The black test lead is installed in this port for all tests.

Volt, Ohm, Diode Test Port

The red test lead is installed in this port to test volts, ohms, and to perform the diode test.

Test Leads

The test leads attach to the appropriate port on the tool. They are used to test voltage, amperage, and resistance of a component or circuit.

Inductive Pickup

Inductive pickup is used to measure current in a circuit without breaking the circuit open.

DVOM SETTINGS AND OUTPUT

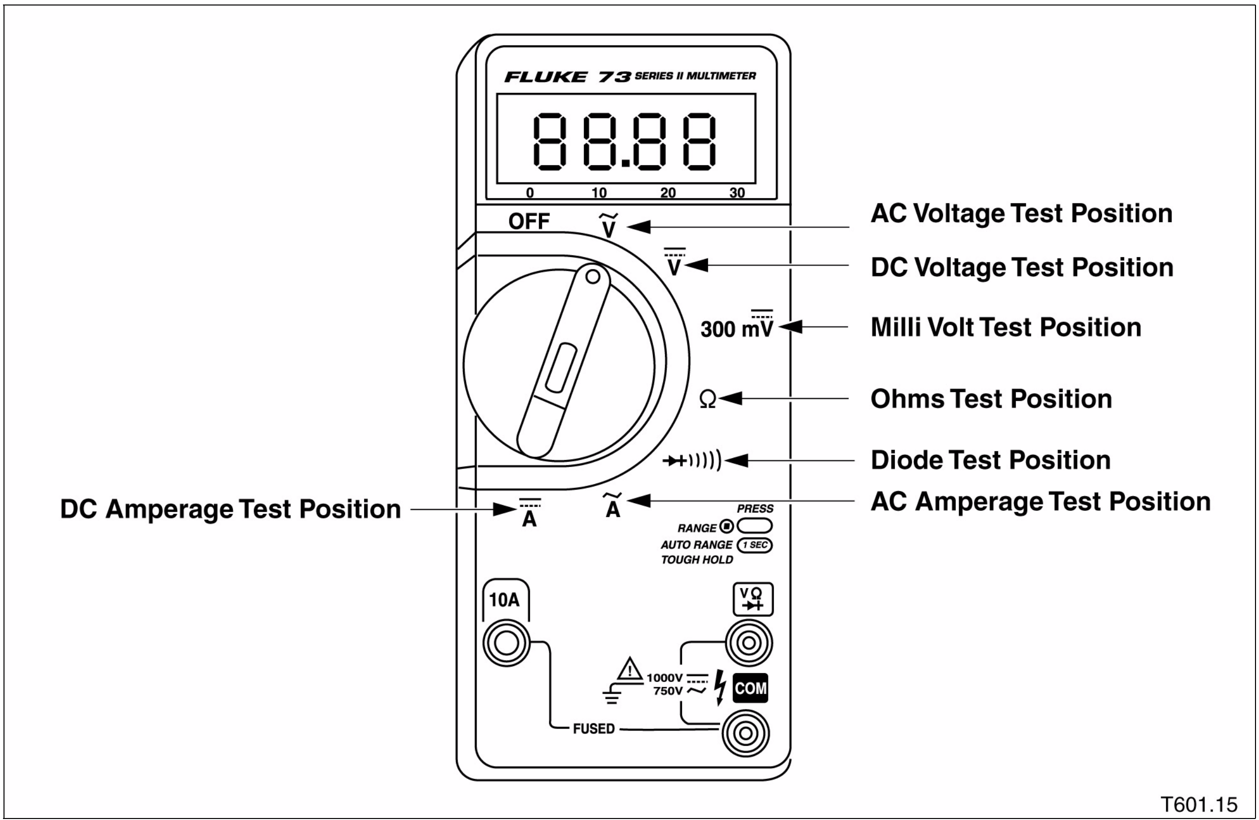


Fig. 16

AC Voltage

Select the AC voltage test position to measure available AC voltage. An example of this would be to measure the voltage at Crankshaft Position (CKP) sensor.

DC Voltage

Select the DC voltage test position to measure available DC voltage. An example of this would be to measure the voltage of the vehicle's battery.

Milli Volt

Select this test position to measure thousandths of a volt. An example of this would be to measure minute electronic circuits.

Ohms

Select this test position to measure resistance. An example of this would be to measure the resistance of a wire from one point in the vehicle to another.

Diode Test

Select this test position to test diodes.

AC Amperage

Select this test position to measure the amount of current flowing in an AC circuit.

DC Amperage

Select this test position to measure the amount of current flowing in a DC circuit. An example of this would be to measure vehicle current to a component or load.

ELECTRICAL UNITS

Table 1

Electrical Units			
Base Unit	Symbol	SI Unit	Symbol
Electric current	I	Ampere	A
Electric potential	U	Volt	V
Electric resistance	R	Ohm	
Quantity of electricity	Q	Ampere hour	Ah
Electric capacitance	C	Farad	F
Time	T	Second	S
Power	P	Watt	W

The electrical units and the symbols used to represent them are shown above.

ELECTRICAL QUANTITIES

Table 2

Electric Quantities		
Quantity	Prefix	Prefix Symbol
1,000,000,000 (billion[millard])	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

Electrical values are often very large or very small.

Electrical values are indicated by metric numbers.

The metric measurements used are Mega, Kilo, Milli, and Micro.

Mega (M) means one million. For example, a circuit with one million ohms of resistance can be written as 1,000,000 Ohms. If the decimal is moved to the left, the value can be written as 1 Megohm, or 1 M.

Kilo (K) stands for one thousand. A circuit with twelve thousand volts can be written as 12,000 volts. Or, with the decimal moved three spaces to the left, it can be written as 12 Kilovolts, or 12 Kv.

Milli (m) means one thousandth. A circuit with 0.015 amperes of current can be written as 0.015, or by moving the decimal three places to the right, it can be written as 15 Milliamperes, or 15 mA.

Micro (µ) means one millionth. For explanation purposes, assume that there is a circuit with 0.000015 amperes. By moving the decimal six places to the right, this can now be written as 15 microamperes, or 15 µa.

CIRCUIT ANALYSIS WITH A DVOM

Ammeter

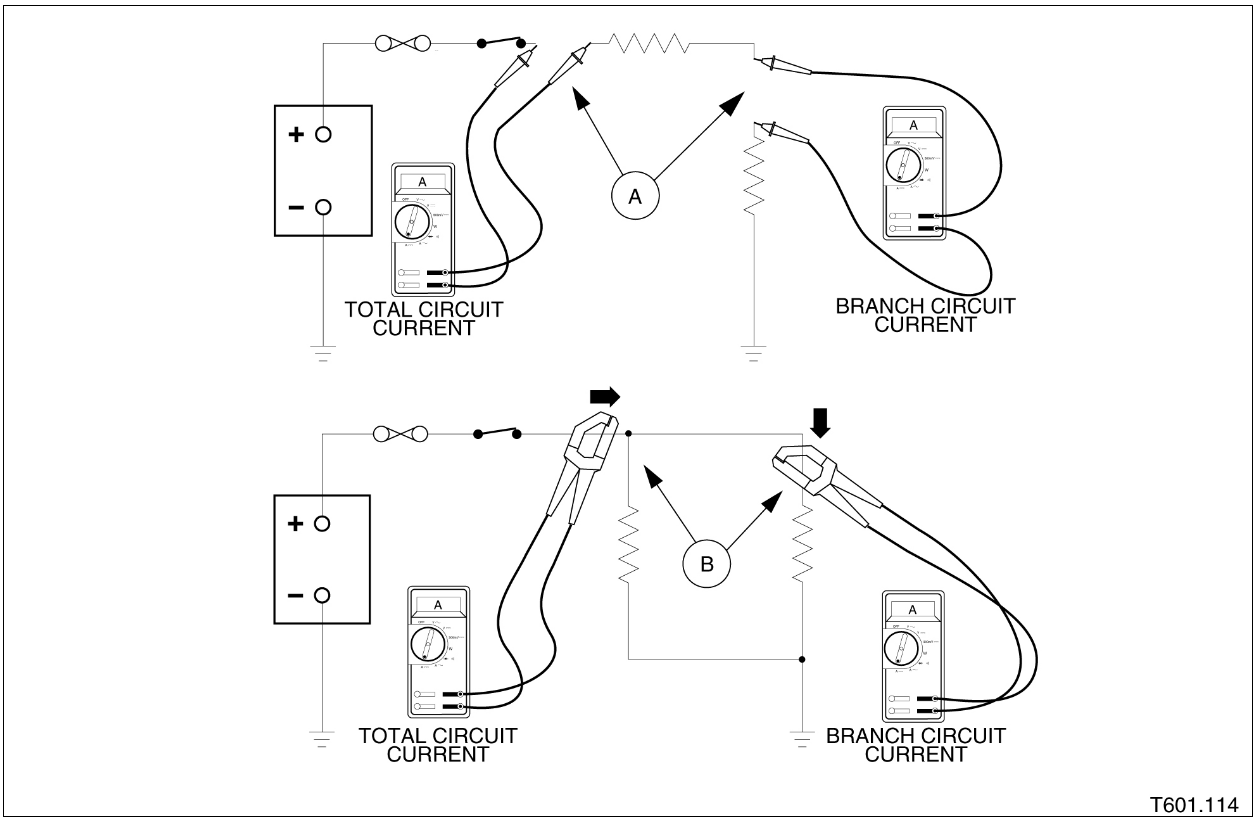


Fig. 17

An ammeter measures current flow in a circuit. Conventional meters were connected into the circuit in series (A) to accomplish measurement. Some meters employ a clamp-on current probe (B) that fits around the circuit wire and senses the strength of the induced magnetic field when current flows. The direction arrow on the probe must be observed to obtain an accurate reading. Depending on the placement of the current probe, total circuit or branch circuit current can be measured.

VOLTMETER

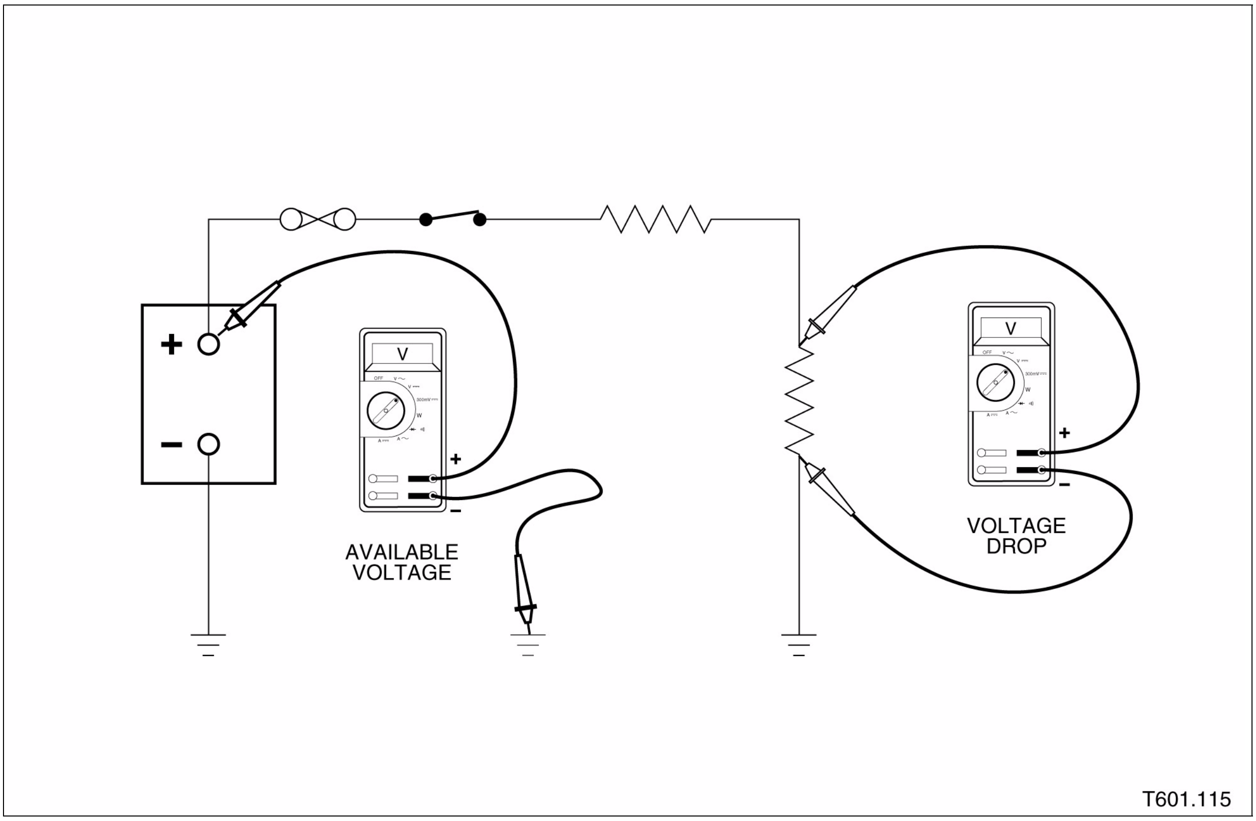


Fig. 18

A voltmeter measures the difference in voltage between two points in a circuit. It uses two leads (positive [+] and negative [-]) to connect to the circuit. It is connected in parallel with the current path. The positive lead should be connected closest to the power source (negative ground automotive circuit) in the circuit. The voltmeter can be used to measure voltage at any point in the circuit. The voltmeter can also be used to measure the voltage drop of components or between components such as connectors and terminals. This measurement is particularly useful for determining the condition of connections as a higher than expected voltage drop will indicate a poor connection.

OHMMETER

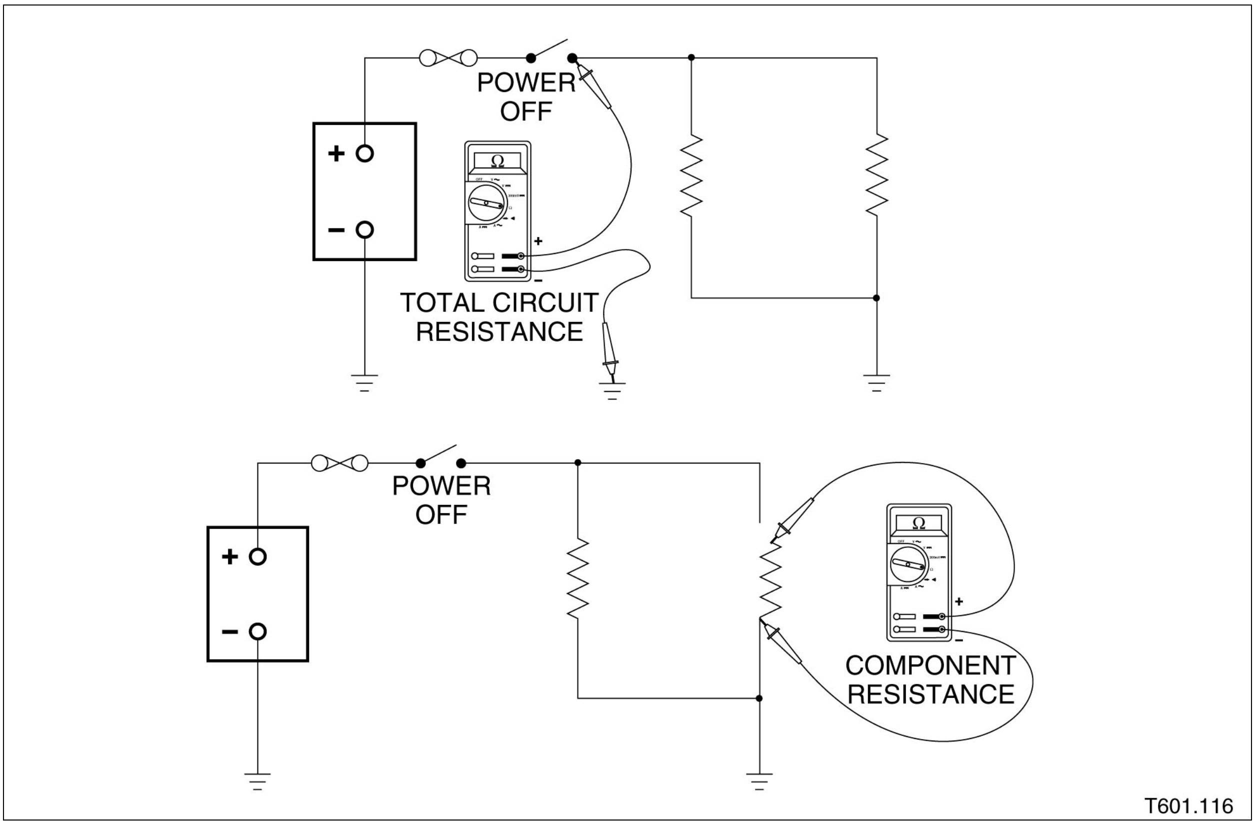


Fig. 19

An ohmmeter measures the resistance in a circuit or component. The ohmmeter uses two leads (positive [+] and negative [-]) to connect to the circuit or component. The ohmmeter has its own battery and must be connected in place of the power source to operate properly. The resistance of an entire circuit can be measured. Parts of the circuit and individual components can also be measured after disconnection from the remainder of the circuit.

OHM'S LAW

Ohm's Law (Volts)

I = E ÷ R
(AMPERES = VOLTS ÷ OHMS)
R = E ÷ I
(OHMS = VOLTS ÷ AMPERES)
E = I x R
(VOLTS = AMPERES x OHMS)

T601.117

Fig. 20

Ohm's Law states that voltage (E = electromotive force), amperage (I = impedance) and resistance (R = Ohms) are related. This relationship can be described in three ways:

One volt (E) in a circuit with a resistance of one Ohm (R) will cause a current of one ampere (I).

If resistance (R) remains the same, a change in voltage (E) will cause a similar change in current (I).

If voltage (E) remains the same, a change in resistance (R) will cause an opposite change in current (I).

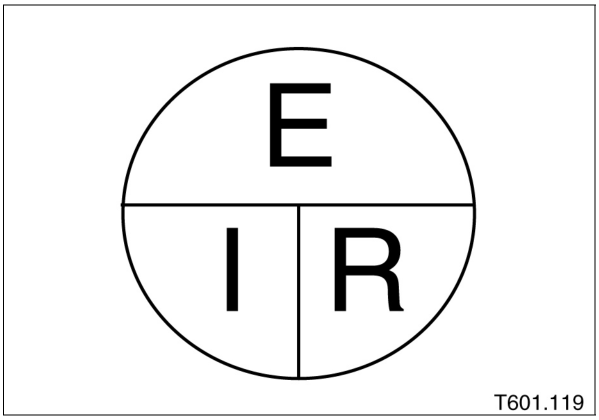


Fig. 21

The diagram above simplifies remembering the three formulas of Ohm's Law.

OHM'S LAW FORMULAS

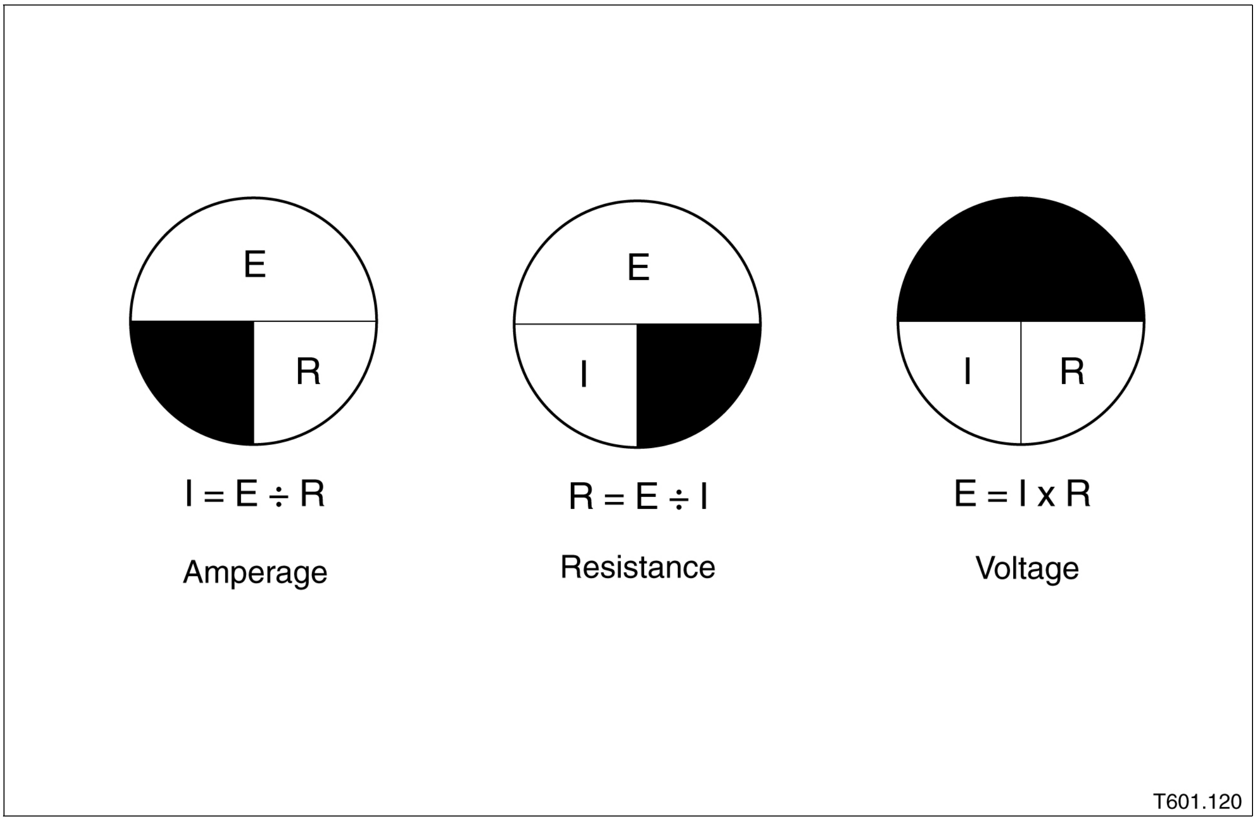


Fig. 22

By covering the value needed, the relationship of the two remaining values will produce the answer.

Amperage

- Cover the I.
- E and R remain.
- Horizontal line indicates divide by.
- Divide the voltage (E) by the resistance (R) to provide the amperage (I).

Resistance (Ohms)

- Cover the R.
- E and I remain.
- Horizontal line indicates divide by.
- Divide the voltage (E) by the amperage (I) to provide the resistance (R).

Voltage

- Cover the E.
- I and R remain.
- Vertical line indicates multiply by.
- Multiply the amperage (I) by the resistance (R) to provide the voltage (E).

OHM'S LAW IN CIRCUIT DIAGNOSIS

With a base voltage of 12 volts and starting resistance of the circuit at 4 ohms, use the following examples to identify the practical application of Ohm's Law while diagnosing a simple circuit.

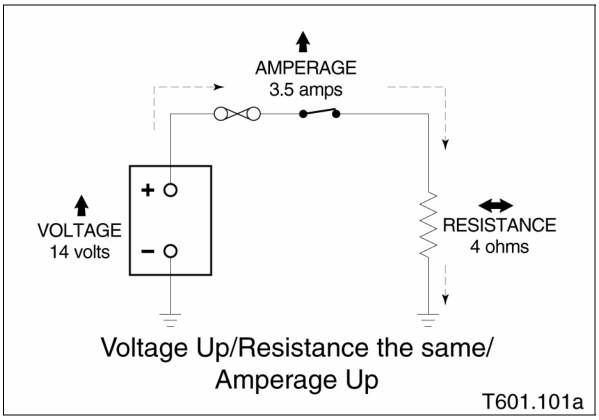


Fig. 23

If an AC generator is over charging, the voltage rises while the resistance remains the same. The result will be that amperage will rise, possibly causing damage to electrical loads in the circuit.

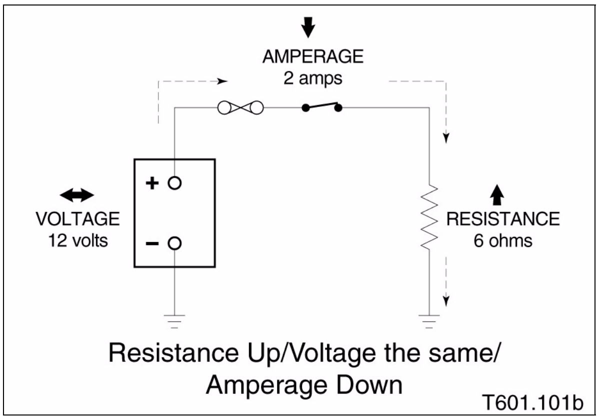


Fig. 24

If corrosion on electrical terminals or contacts occurs, resistance will increase in that area. The result will be that amperage will lower causing the performance of electrical loads to lower.

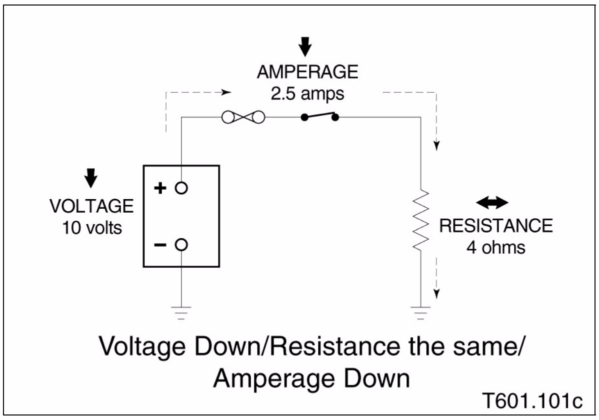


Fig. 25

If the battery voltage is low, the performance of a load such as the starter motor will decrease. The resistance remains the same; therefore, the amperage lowers.

OHM'S LAW (WATTS)

P = I x E
(WATTS = AMPERES x VOLTS)
I = P ÷ E
(AMPERES = WATTS ÷ VOLTS)
E = P ÷ I
(VOLTS = WATTS ÷ AMPERES)

T601.118

Fig. 26

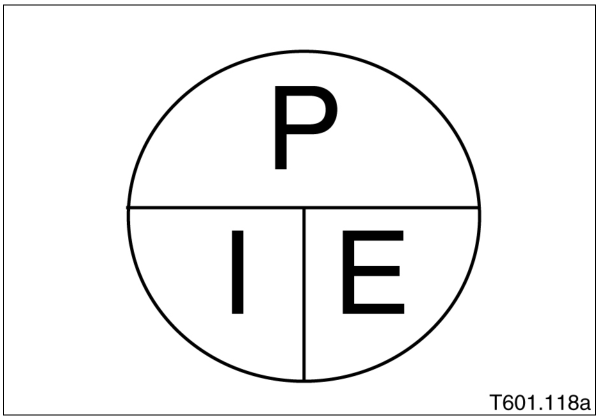


Fig. 27

Many electrical devices are rated by how much power they consume, rather than by how much they produce. Power consumption is expressed in watts.

746 watts = 1 horsepower or 33,000 LBS. FT. per minute

The relationships among power, voltage, and current are expressed by the Power Formula: P = E x I

In other words, watts equals volts multiplied by amps.

For example, if the total current in a circuit is 10 amps and the voltage is 120 volts, then: P = 120 x 10 or P = 1200 watts

In a circuit, if voltage or current increases, then power increases. If voltage or current decreases, then power decreases. The most common application of a rating in watts is probably the light bulb. Light bulbs are classified by the number of watts they consume.

WORKSHEET –

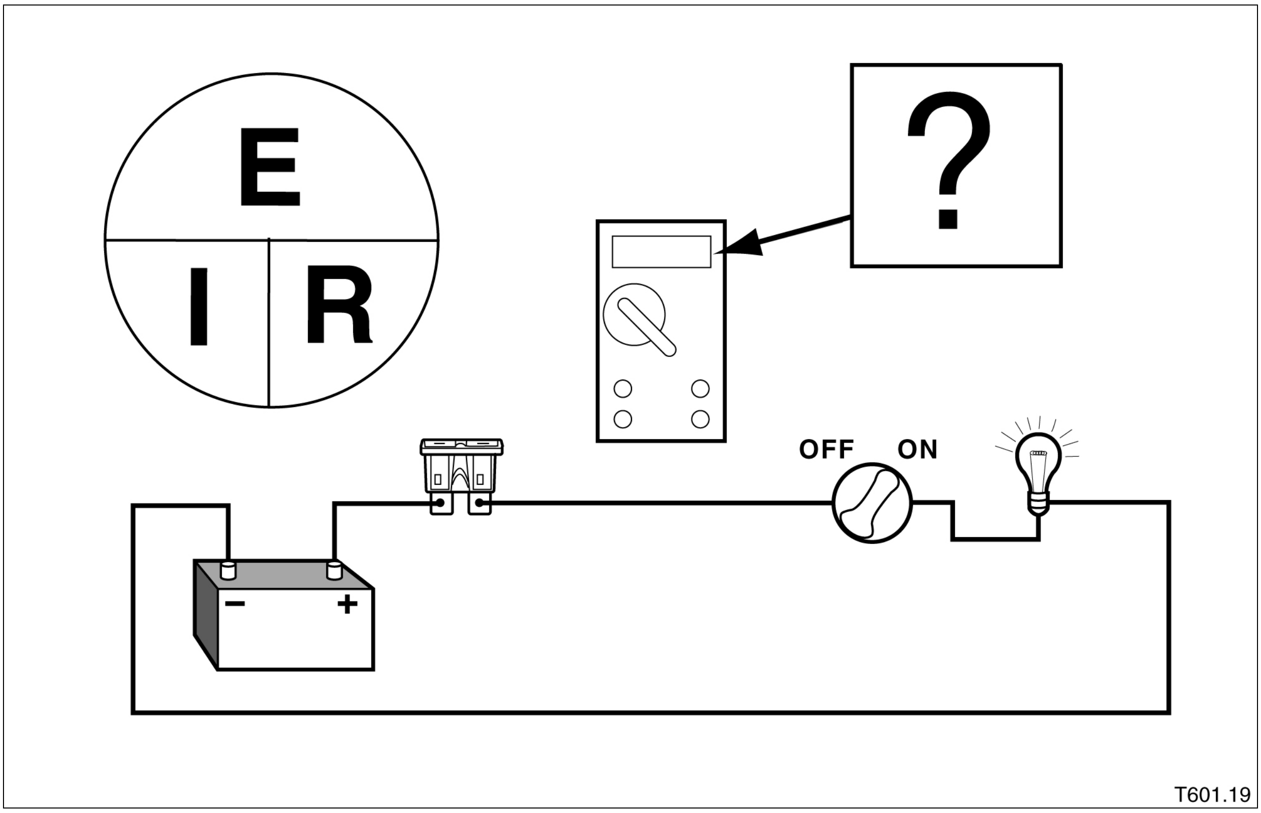


Fig. 28

Using the following information and Ohm's Law, determine:

1. The current flowing in a circuit that has a 12 volt power supply and a total resistance of 10 Ohms.

2. The total resistance in a circuit that has a 12 volt power supply and 3 amps of current.

3. The voltage in a circuit that has a total resistance of 12 Ohms and 3 amps of current.

4. The current flowing in a circuit that has a 14.2 volt power supply and a total resistance of 2k Ohms.

5. The total resistance in a circuit that has a 14.3 volt power supply and 4 amps of current.

SIMPLE CIRCUIT

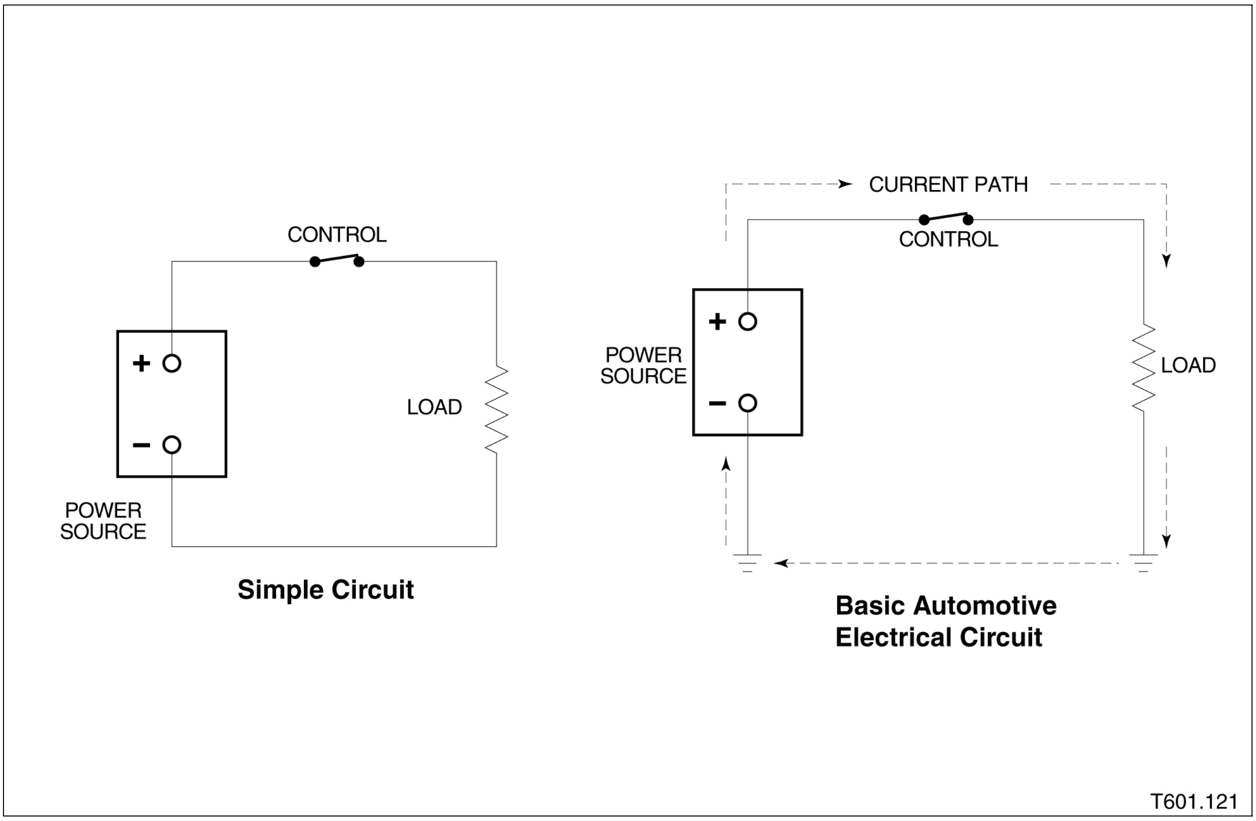


Fig. 29

Electrical circuits contain four basic components:

• Power source

• Method of control

• Consumer of electricity (load)

• Conductor that connects the power source, control and the load.

The three types of automotive circuits used are:

• Series circuit

• Parallel circuit

• Series / parallel circuit

For a circuit to perform its function, the path for current flow from the power source back to the power source must be complete. In automotive electrical systems, the connecting conductor is usually made up of wire or printed circuit, with the vehicle acting as the return path to the power source.

SERIES CIRCUIT

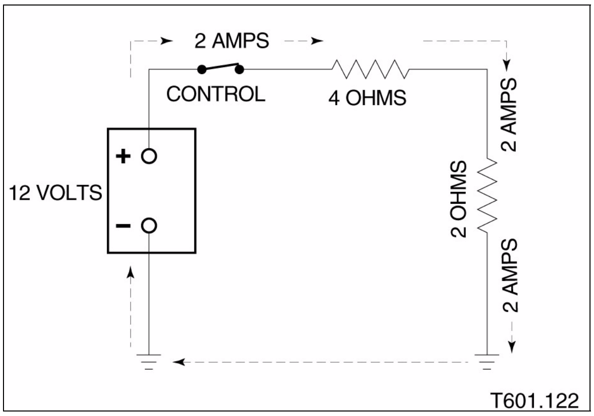


Fig. 30

A series circuit is laid out with only one current path through two or more loads. Current flows through all the components so that a break in the current path at any point in the circuit will disable the entire circuit. A series circuit has the following characteristics:

• More than one load.

• Only one path for current.

• The current flowing in a series circuit is the same at any point in the circuit.

• The sum of the individual voltage drops is equal to the source voltage.

- First resistance is 4 ohms x 2 amps = 8 volts

- Second resistance is 2 ohms x 2 amps = 4 volts

- 8 volts + 4 volts = source voltage or 12 volts

• The total circuit resistance is equal to the sum of the individual resistances.

- 4 ohms + 2 ohms = 6 ohms

PARALLEL CIRCUIT

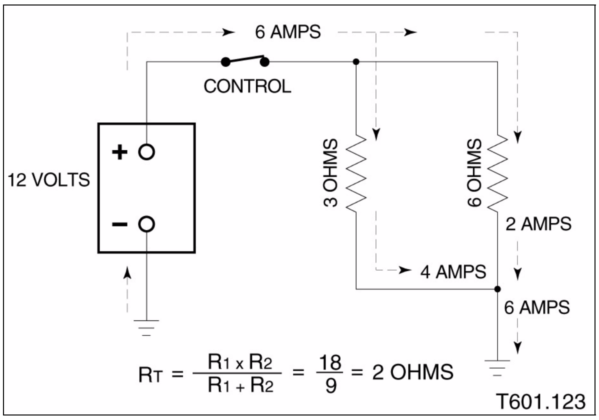


Fig. 31

A parallel circuit is laid out with more than one current path, each through a load. After control, current flows through separate paths for each component. A break in one current path (after control) will disable only that path in the circuit. A parallel circuit has the following characteristics:

• More than one load.

• More than one path for current.

• The sum of the branch circuit currents is equal to the total circuit current.

- 4 AMPS + 2 AMPS = 6 AMPS or total circuit current.

• The voltage drop across each branch circuit is the same.

• The current in each branch circuit is different if the resistance values are different.

- First branch (3 OHMS x 4 AMPS = 12 VOLTS)

- Second branch (6 OHMS x 2 AMPS = 12 VOLTS)

• The total circuit resistance is less than the value of the lowest resistance.

- Resistance 1 x resistance 2, divided by resistance 1 + resistance 2 or 3 x 6 = 18 divided by 3 + 6 or 9 = 2 OHMS.

Three or More Parallel Circuits

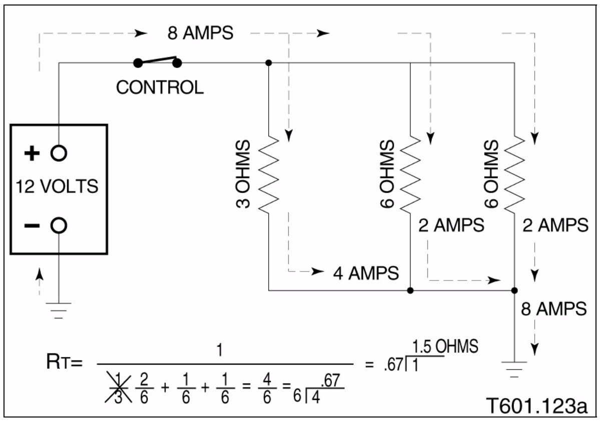


Fig. 32

To find the total resistance of a circuit, independent of voltage and amperage, place a 1 over the resistance value from each circuit and add the fractions. Remember when adding fractions you must come up with a common denominator first. Now, divide the fraction. Finally, divide 1 by the sum of that equation. In this example total resistance is 1.5 ohms.

SERIES/PARALLEL CIRCUIT

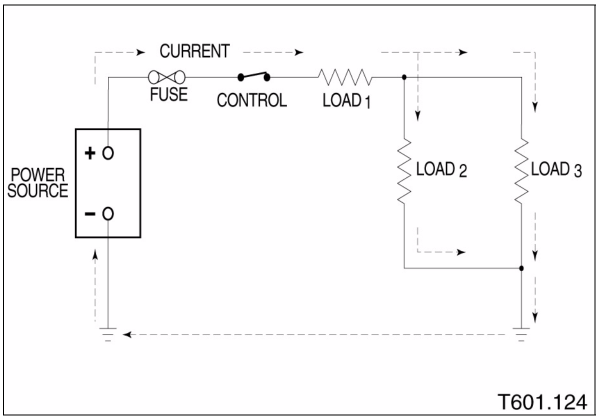


Fig. 33

A series/parallel circuit combines the series and parallel portions of the circuit and can be arranged in many ways as illustrated.
A series/parallel circuit has the following characteristics:

- More than one load.
- Loads connected in series and in parallel.
- More than one path for current.
- The current flowing in a series/parallel circuit divides among the separate branches of the parallel portion of the circuit.
- The current flowing in the series portion of the circuit is the same at any point.
- The total circuit current in the parallel portion of the circuit is equal to the sum of the individual branch circuits.

Most automotive circuits are series/parallel circuits.

CIRCUIT PROTECTION

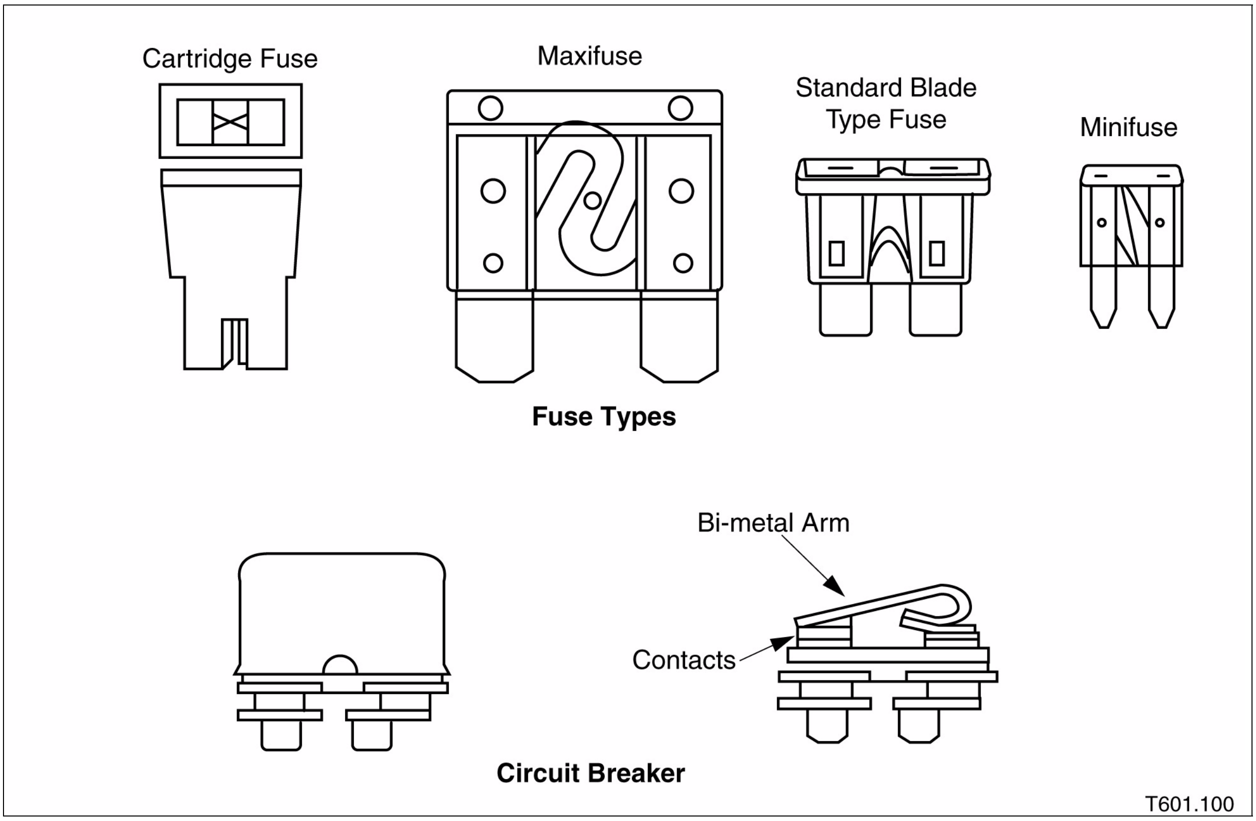


Fig. 34

Electrical circuits are protected from overload by fuses. Some switch modules (such as the window switch module) contain internal circuit breakers. Both devices interrupt current flow when excess heat is generated in the circuit. The fuse link melts to break the circuit and the contacts of the circuit breaker open to break the circuit.

Always use the recommended fuse for the circuit.

CIRCUIT FAULTS

Open Circuit

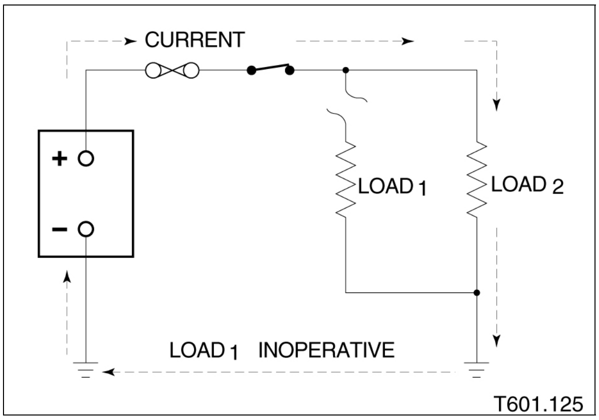


Fig. 35

Open circuit describes a complete break at some point in the circuit. Depending on where an open circuit occurs, one or more of the loads will not function.

Short to Power (Crossed Circuit)

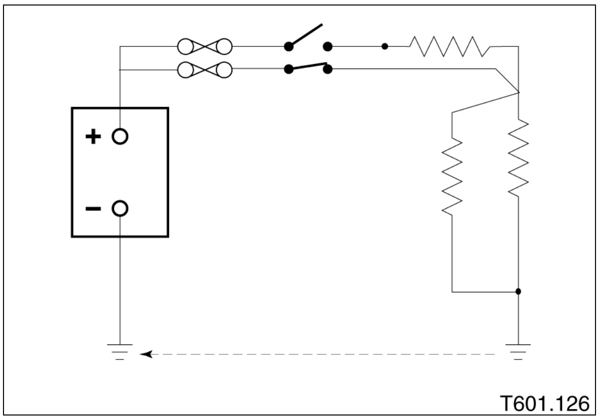


Fig. 36

Short circuit describes an accidental bypass of a load or loads in the circuit. Since electricity will always take the path of least resistance, the result of a short circuit will be higher current flow and excess heat. Depending on where the short circuit occurs, the loads may or may not function.

Short to Ground (Grounded Circuit)

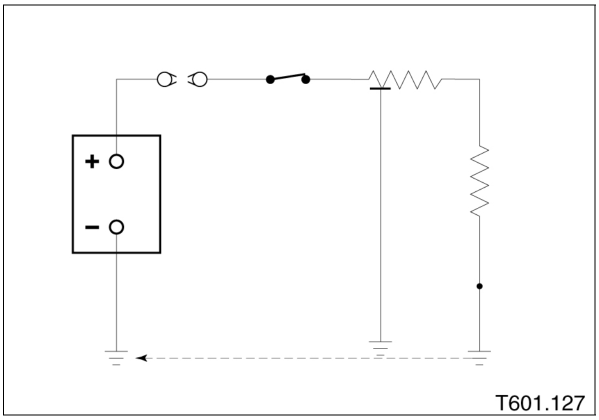


Fig. 37

A grounded circuit describes an accidental bypass of a load or loads to the ground path returning to the power source. Since electricity always takes the path of least resistance, a grounded circuit will cause very high current flow and excess heat. Without circuit protection, a grounded circuit will burn or melt circuit components.

VOLTAGE DROP TEST

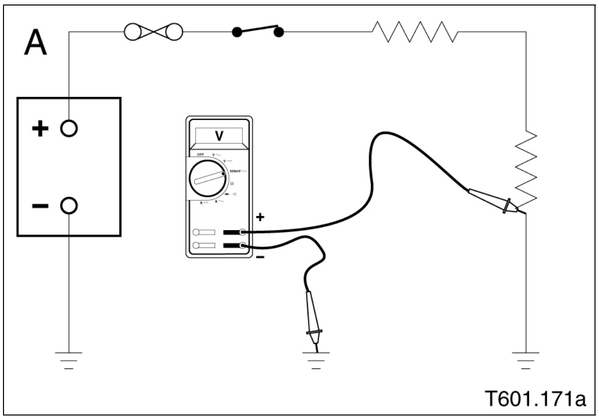


Fig. 38

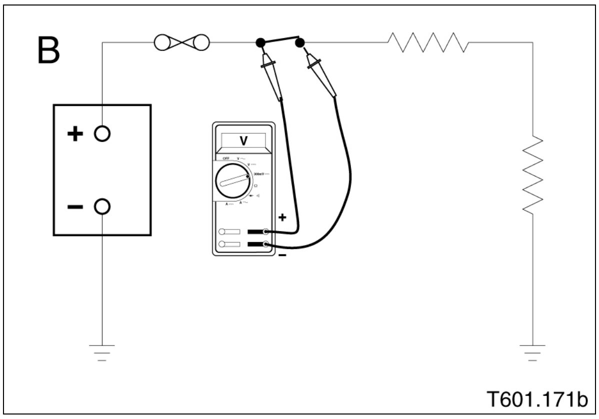


Fig. 39

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
- Switch 300 mv
- Ground connection 100 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.

Voltage drop test: ground side (A)

Tests for ground circuit high resistance, open circuit.

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

Voltage drop test: switch or connector (B)

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).

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 Ohm 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 200 Watts (83%) of starting power. The starter will develop only 2.68 HP.

Voltage drop measurements indicate circuit resistance without disturbing the circuit.

NOTES

WORKSHEET –

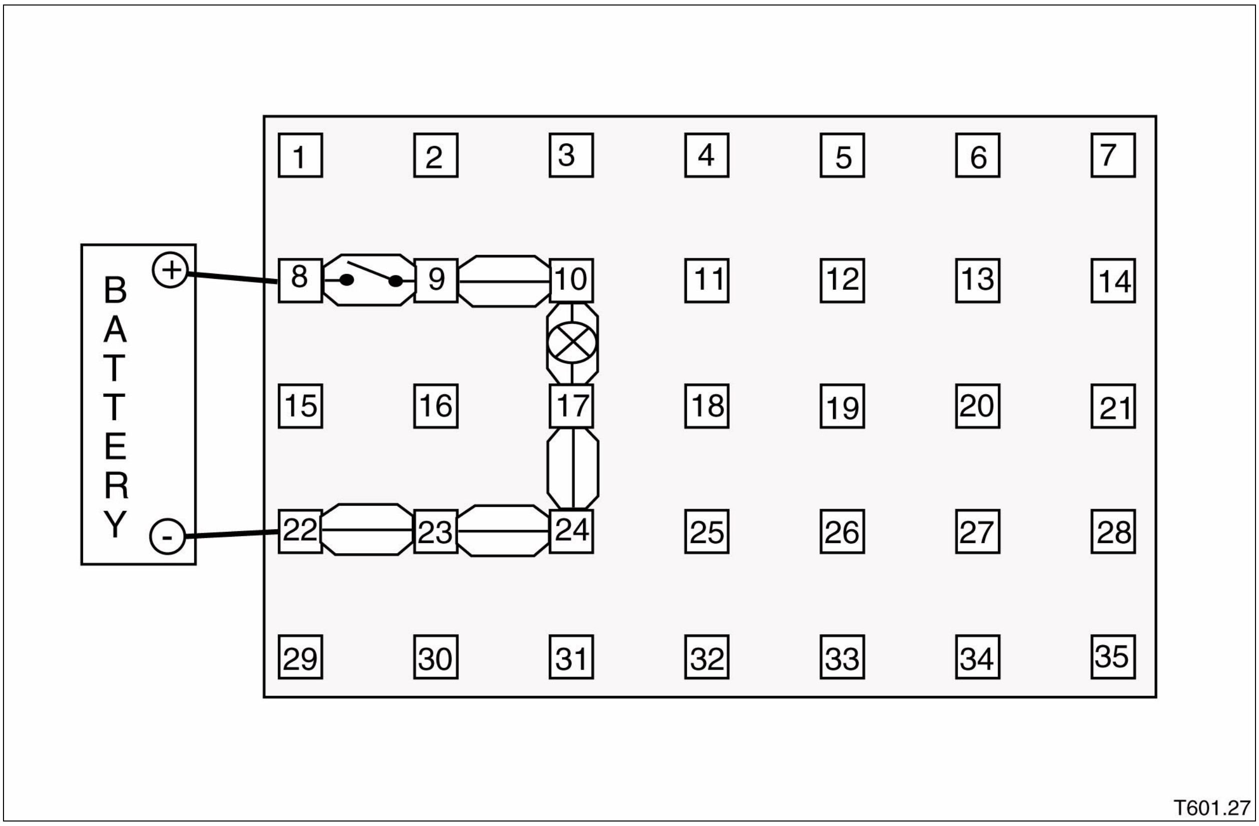


Fig. 40

Build this circuit using the bread board and perform the following measurements:

1. 1. Measure the voltage drop from 8 to 10 and indicate it here.

Now replace the conductor between 9 and 10 with a 10 ohm resistor, to simulate a corroded connector.

2. Re-measure the voltage drop from 8 to 10 and indicate it here.

3. Measure the voltage drop from 22 to 17 and indicate it here.

Now replace the conductor between 23 and 24 with a 10 ohm resistor, to simulate a corroded connector.

4. Re-measure the voltage drop from 22 to 17 and indicate it here.

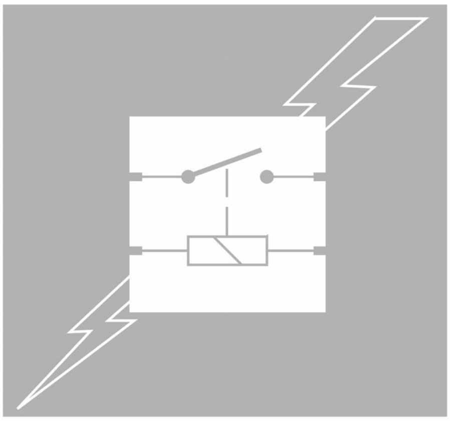
Now replace the conductor between 23 and 24 with a 1K ohm resistor, to simulate a corroded connector.

5. Re-measure the voltage drop from 22 to 17 and indicate it here.

JAGUAR

TRAINING PROGRAM

JAGUAR ELECTRICAL SYSTEMS



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CONVENTIONAL AUTOMOTIVE ELECTRICAL CIRCUIT

Basic Circuit

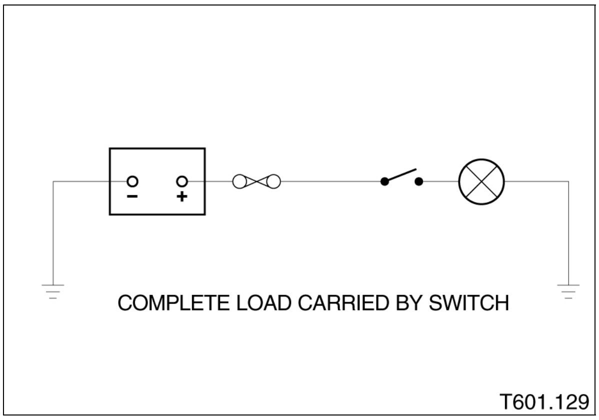


Fig. 41

In a basic automotive electrical circuit, switching control for the circuit normally occurs on the supply B(+) side of the circuit. The switch is the potential weak link in this circuit.

Conventional Automotive Electrical Circuit

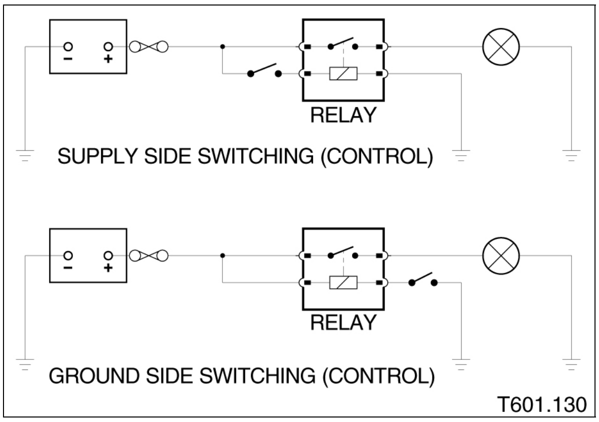


Fig. 42

To overcome this weakness, relays are used to carry heavy current loads to allow the use of a lighter duty switch to control the relay coil circuit. In certain circumstances the switch is located on the ground side of the coil circuit.

JAGUAR ELECTRICAL GUIDES

Electrical Guides

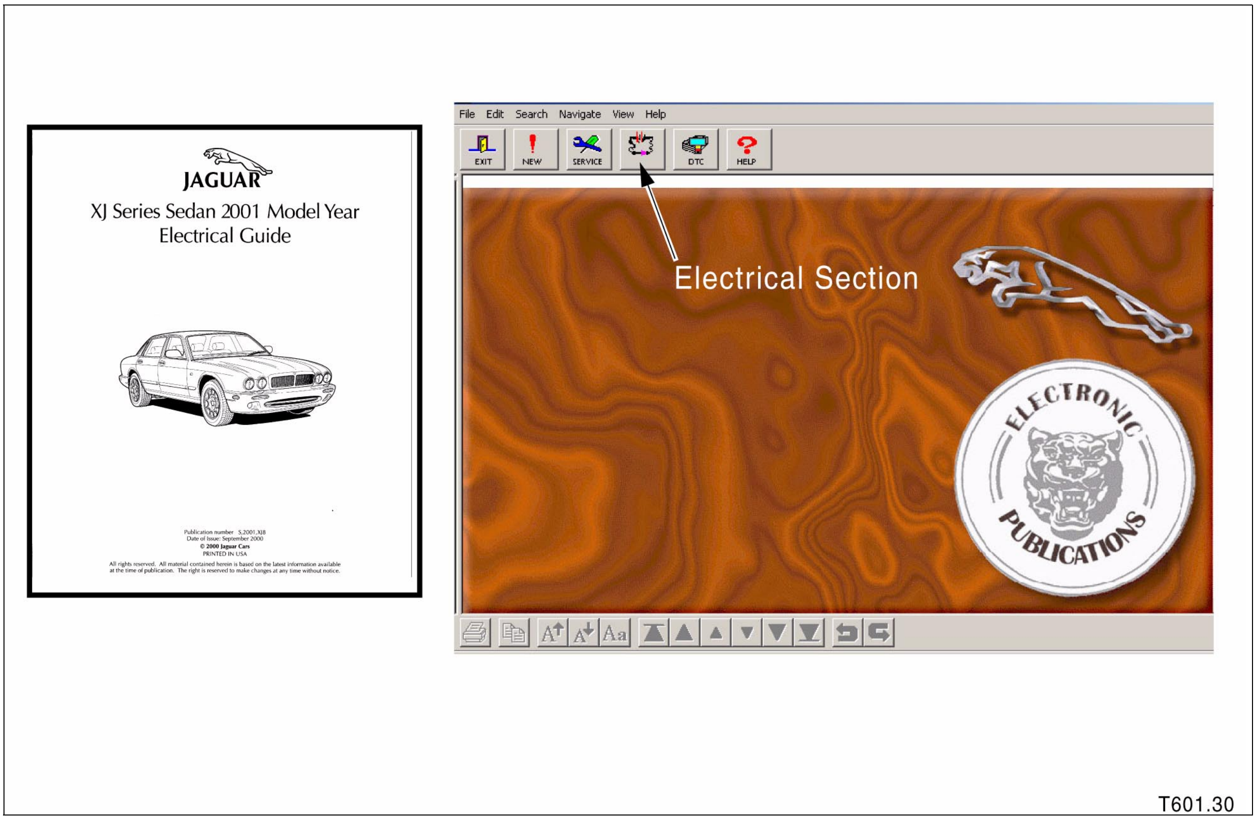


Fig. 43

After performing a visual inspection of an electrical concern, the next logical step is to break open the appropriate electrical guide, or launch the Jaguar Technical Information System (JTIS) and navigate to the appropriate Jaguar Electrical Guide. Once a technician knows where to locate and interpret the information, electrical concerns become easier to diagnose and repair.

Introduction

The introduction section contains an explanation of:

- Guides format
- An explanation of the standard abbreviations used throughout the guide.
- An explanation on how to interpret the to/from Vehicle Identification Number (VIN) range usage.
- An explanation of the specific electrical system the vehicle has (positive/negative switching etc.).

Table of Contents/Component Index

The table of contents and component index pages are similar to all other guides. They identify the page or figure the required information is located on.

Figure and Data Page Layout

These pages identify the information available on the figure and data pages.

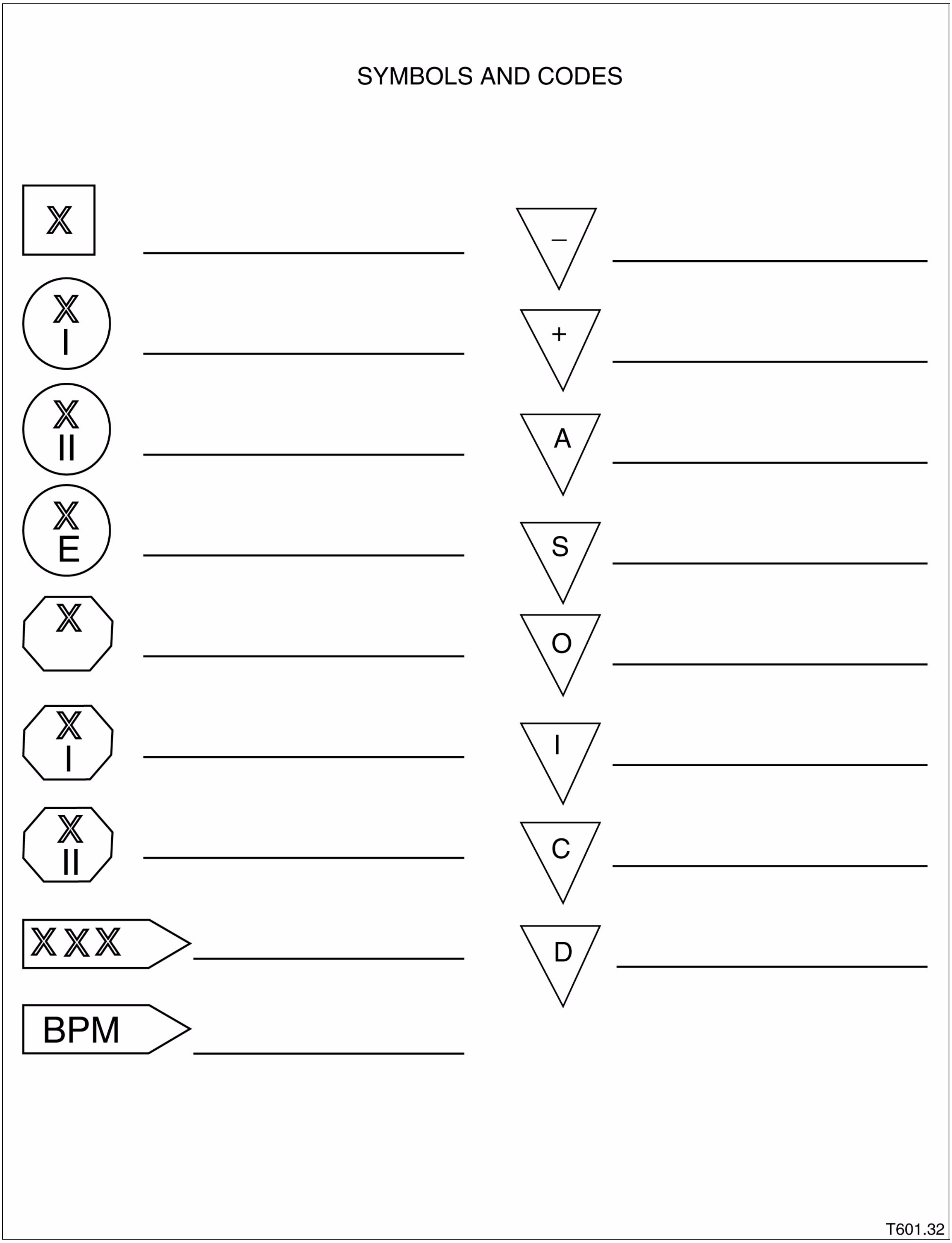


Fig. 44

SYMBOLS AND CODES (CONTINUED)

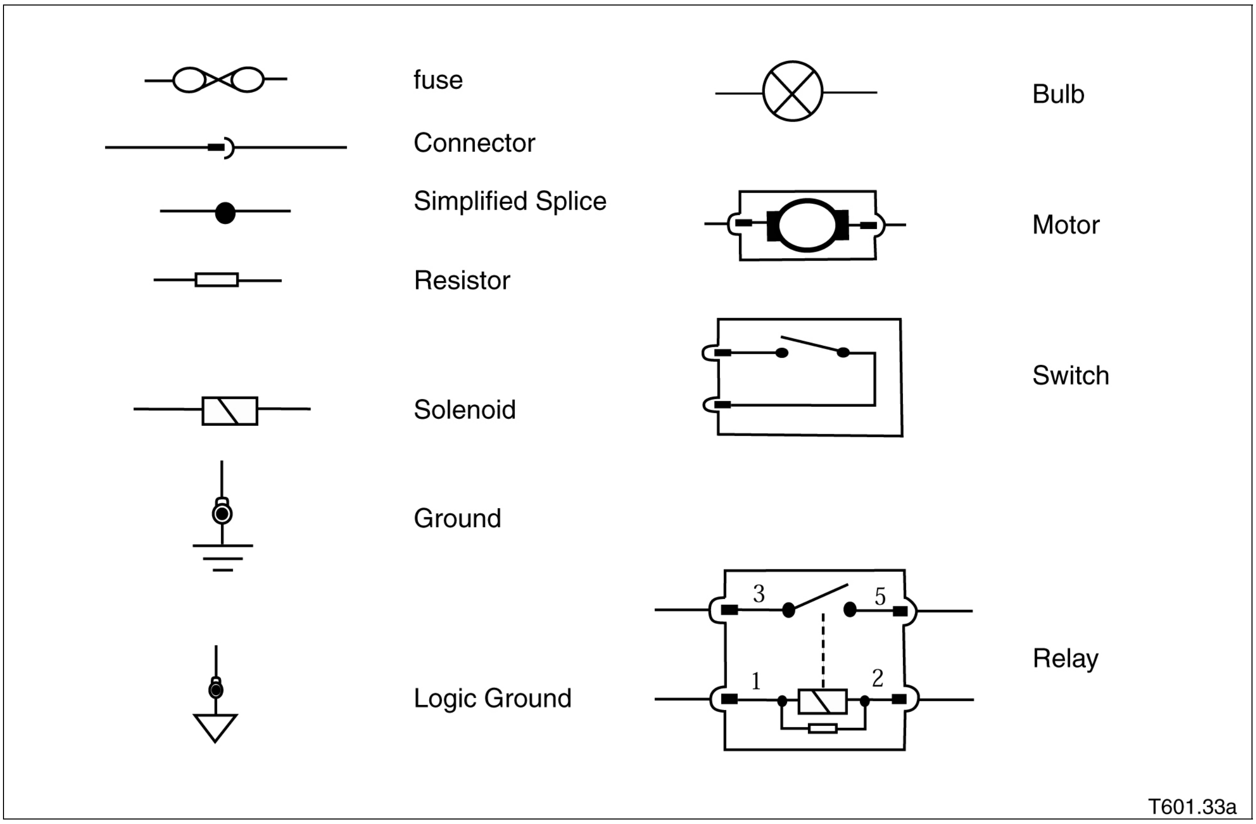


Fig. 45

Symbols and Codes

The symbol and code section of the guide contains written and graphical explanations of the symbols and codes used throughout the electrical guide. These codes and symbols should be memorized so that it is not necessary to flip back and forth to the reference section.

Wiring symbols indicate the types of components and conductors the circuit is made up of.

RESISTORS

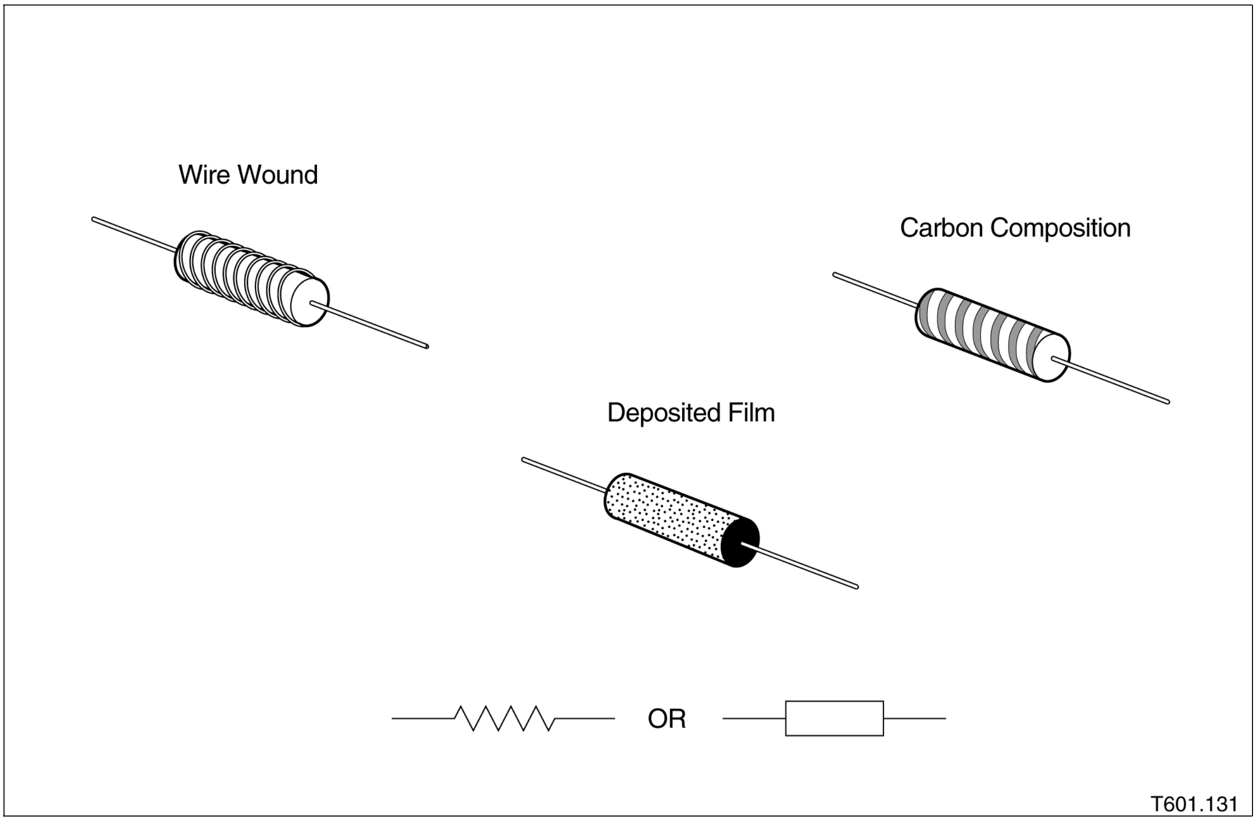


Fig. 46

A resistor is an electronic component that has a specified resistance value. The resistor is used in a circuit to introduce a desired amount of resistance into the circuit. Three methods of construction are employed to manufacture resistors: wire wound, carbon composition and deposited film.

Wire wound resistor

The wire wound resistor consists of a specified length of small gauge wire wound around an insulator such as a ceramic tube.

Carbon composition resistor

The element carbon is a semiconductor and makes an ideal material for resistors. By combining carbon granules and a powdered insulating material in various proportions, a wide range of resistor values can be achieved.

Deposited film resistor

The deposited film resistor operates in a similar way to the wire wound resistor. A carbon film is deposited on an insulator rod and then a resistance value is set by cutting a spiral groove through the film. The result is a long flat ribbon around the tube. The groove adjusts the width and length of the ribbon to achieve the desired resistance value.

RELAYS

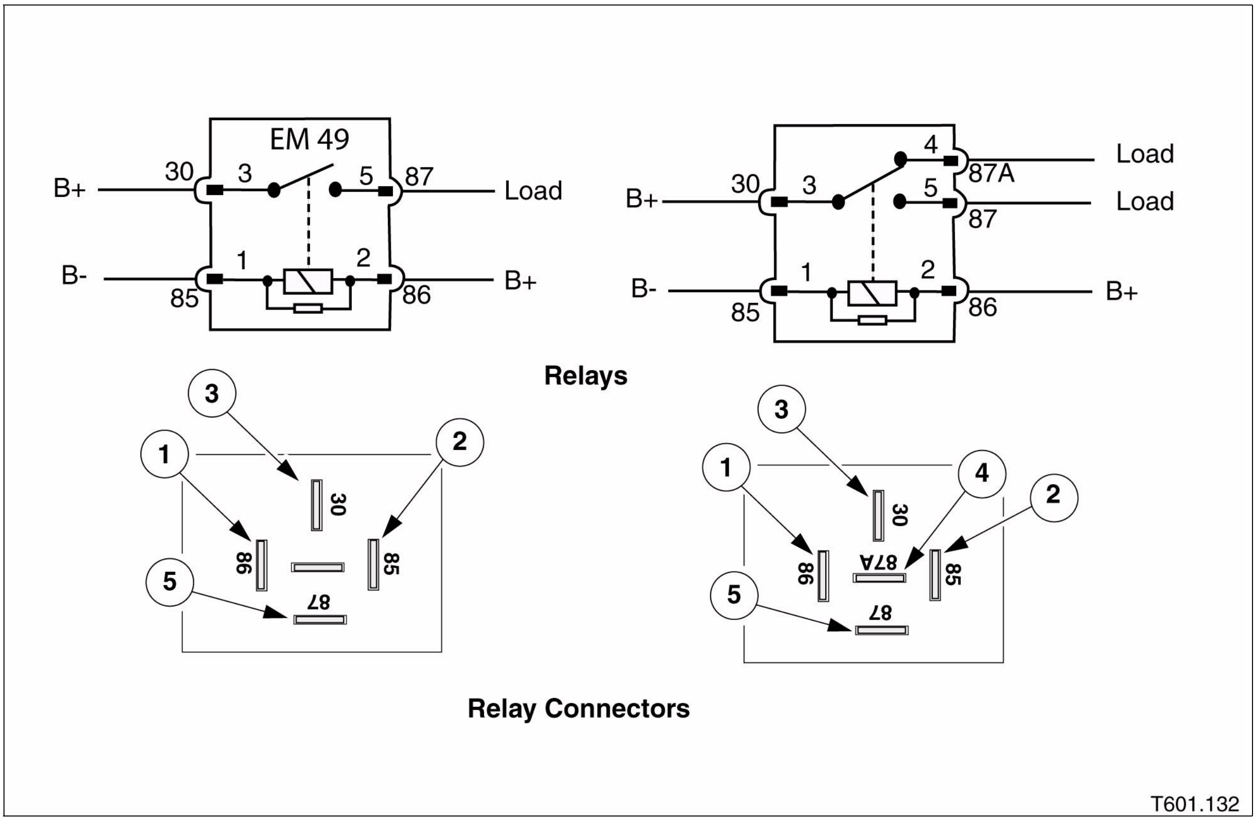


Fig. 47

Four basic types of relays are used in Jaguar circuits.

- 4 pin micro Normally Open.
- 4 pin Normally Open.
- 5 pin micro Change-over.
- 5 pin Change-over.

There are additional special purpose relays but these four make up the majority of those used in the circuits.

The contacts in a relay are opened or closed by the action of an electromagnet. When energized, current flowing through the coil creates an electromagnet, which in turn attracts an armature to make or break the contacts.

RELAY NUMBERING COMPARISON CHART

Table 3

Relay Numbering Comparison		
ISO	**DIN**	**Application**
1	86	Coil Supply
2	85	Coil Ground
3	30	Supply or Circuit
4	87A	Load, Ground, or Not Used
5	87	Load or Ground

The numbering on the relay and the relay connectors have been changed from DIN to ISO standards. However, not all relays and relay connectors have been updated. This means that the numbers on the relay may not match the numbers on the connector it is installed in.

TRANSIENT PROTECTION

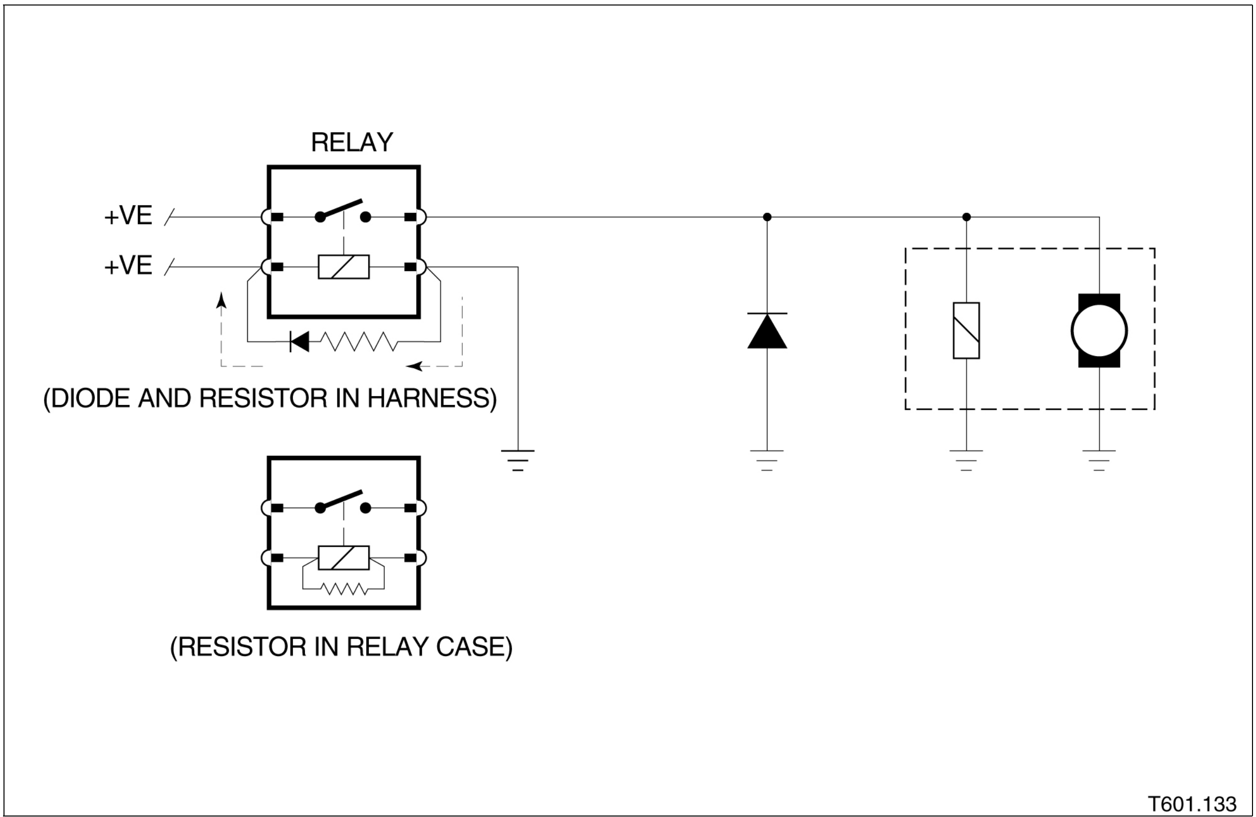


Fig. 48

Relays and inductive power (coil type) consumers also have transient protection. Coils produce high voltage spikes when they are switched off and the magnetic field collapses. Some relays have a resistor placed in parallel with the coil. Other relays have a diode and resistor placed in parallel with the coil.

The voltage drop across the diode plus the drop across the resistor dissipates voltage as it winds down. The majority of current production relays incorporate the protection components within the relay case. Some relays are wired with the protection components in the connecting harness.

Relay modules and integral relays have the circuit incorporated into the circuit board. Inductive power consumers such as the A/C clutch, horns, and radiator fan have a diode placed in the circuit which dissipates voltage when the component is switched off.

MOTORS

Brush Motor

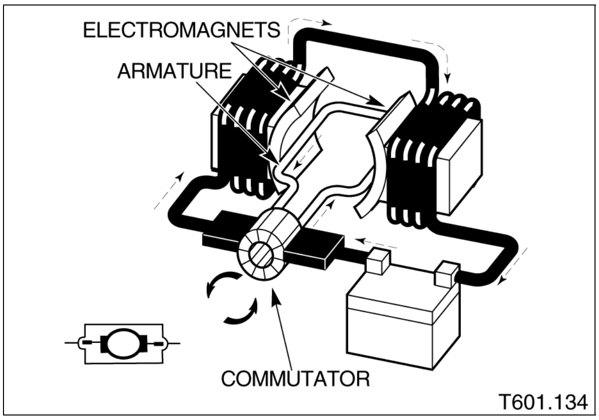


Fig. 49

A motor is similar to a generator. In the case of the brush motor, an external circuit supplies current to the armature through the brushes and commutator. The armature becomes a powerful electromagnet that rotates in the magnetic field produced by the electromagnets in the motor's frame.

Brushless Motor

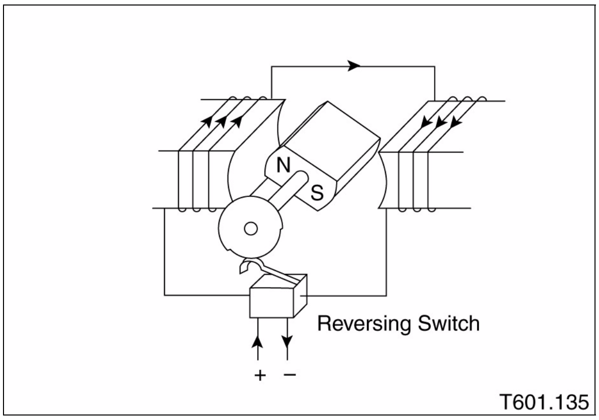


Fig. 50

In the case of the brushless motor, the permanent magnet becomes the rotating part and the windings are put on the stator. An electronic control module is used to turn the magnetic field ON and OFF, while reversing polarity. This causes the magnet on the shaft to rotate. The brushless motor is used on some climate control blower motor applications.

Solenoid

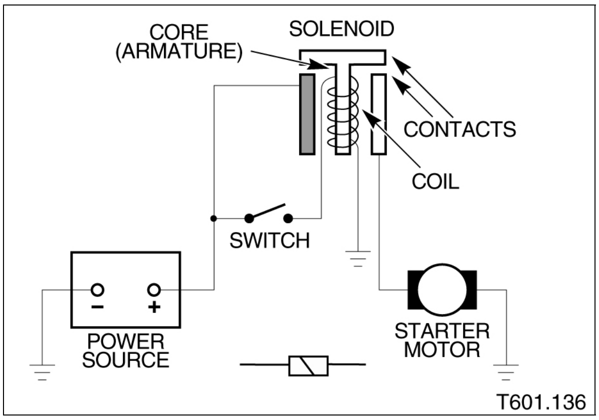


Fig. 51

Solenoids are tubular coils used to produce a magnetic field. An iron core is free to move within the air core so that when current flows in the coil, the core moves to perform work. This work includes switching of electrical, hydraulic and vacuum circuits.

HARNESS, COLOR, AND CONNECTOR CODES

Harness Codes

AC Climate Control	LF LH Front Wheel Speed Sensor
AL LH Side Airbag	LR LH Rear Wheel Speed Sensor
AR RH Side Airbag	LS LH Front Seat
BL LH Rear Door	NA Navigation System
BR RH Rear Door	PA Pedals
CA Cabin	PH Telephone
EN Engine	RB Rear Bumper
FB Front Bumper	RC Roof Console
FL LH Front Door	RF RH Front Wheel Speed Sensor
FR RH Front Door	RR RH Rear Wheel Speed Sensor
FT Fuel Tank	RS RH Front Seat
GC Cooling Pack	TL Trunk Lid
IL Injector Rail	TM Trunk Main
IP Instrument Panel	VM Vacuum Module
JB Junction Box	VP Vacuum Pump

Wiring Color Codes

N Brown	O Orange
B Black	S Slate
W White	L Light
K Pink	U Blue
G Green	P Purple
R Red	BRD Braid
Y Yellow	BOF Fiber optic (D2B Network)

Code Numbering

When numbering connectors, grounds, and splices, Jaguar Engineering uses three-position format: AC001, AC002, etc. Because space is limited in the Electrical Guide, the codes have, in most cases, been shortened. Thus AC001-001 becomes AC1-1, AC002-001 becomes AC2-1, etc.

T601.34

Fig. 52

Harness codes and wiring codes are used to save space on the figure. From time to time this chart may need to be referenced.

GROUNDS

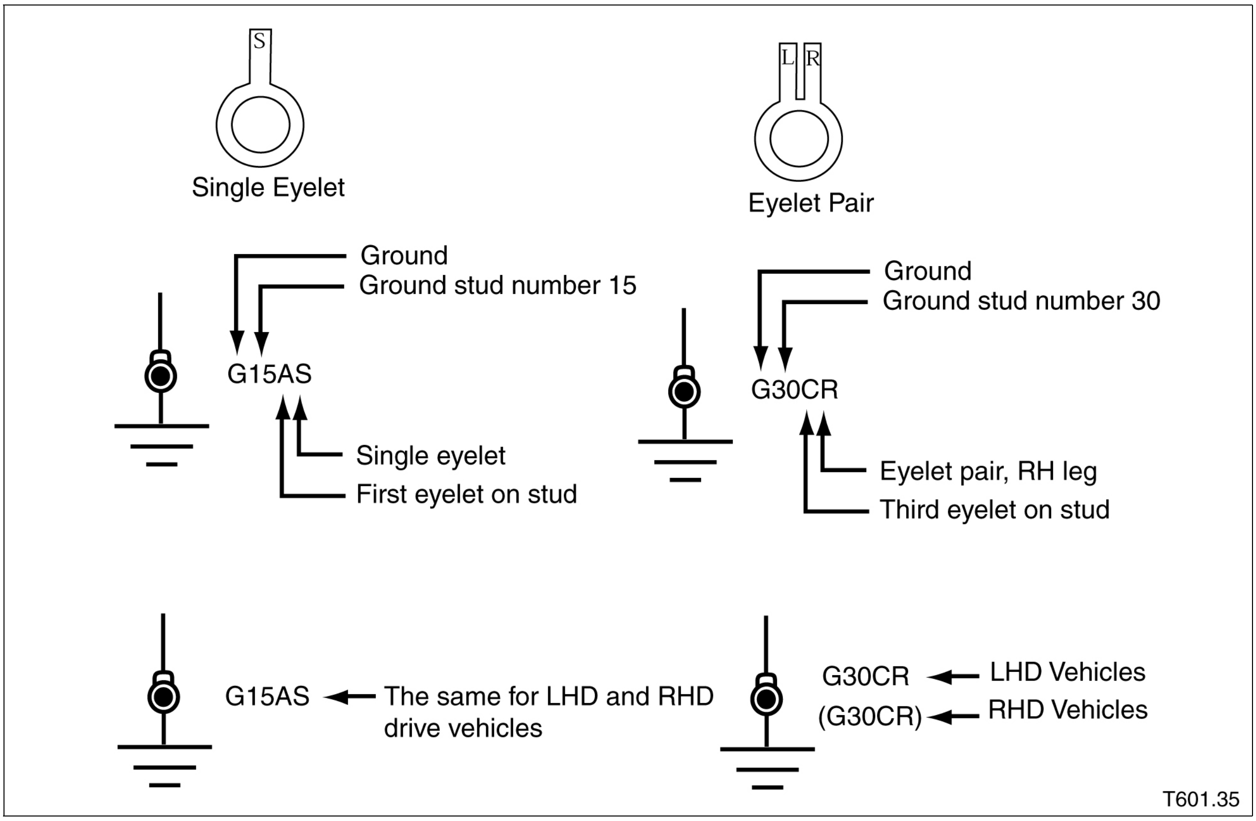


Fig. 53

There may be up to three eyelets on one ground stud. A, B, and C are used to indicate the position of the eyelet on the stud: A is first (bottom), B is second (middle), and C is third (top). Two eyelet variations are used: a single eyelet, and an eyelet pair. The single eyelet has a single leg and is identified with an S. The eyelet pair has two legs and they are identified with a L (left) and R (right).

On figures where the RHD and LHD are combined and the ground designations differ from LHD to RHD, the RHD is shown in parentheses. If the ground designation is the same for LHD and RHD, then only one ground designation is used.

NETWORKS

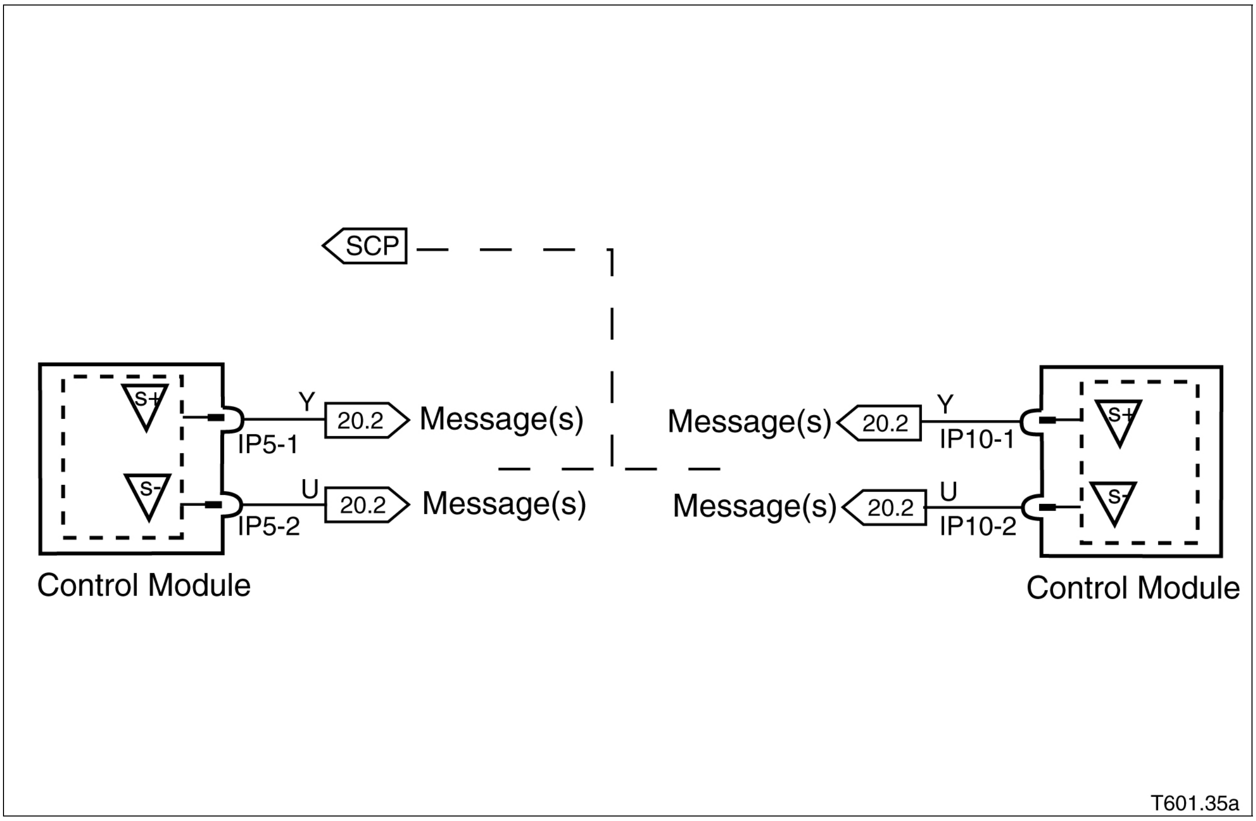


Fig. 54

In most instances, networks are shown as a broken gray line to indicate that there is network communication between the depicted control modules.

OTHER VIEWS

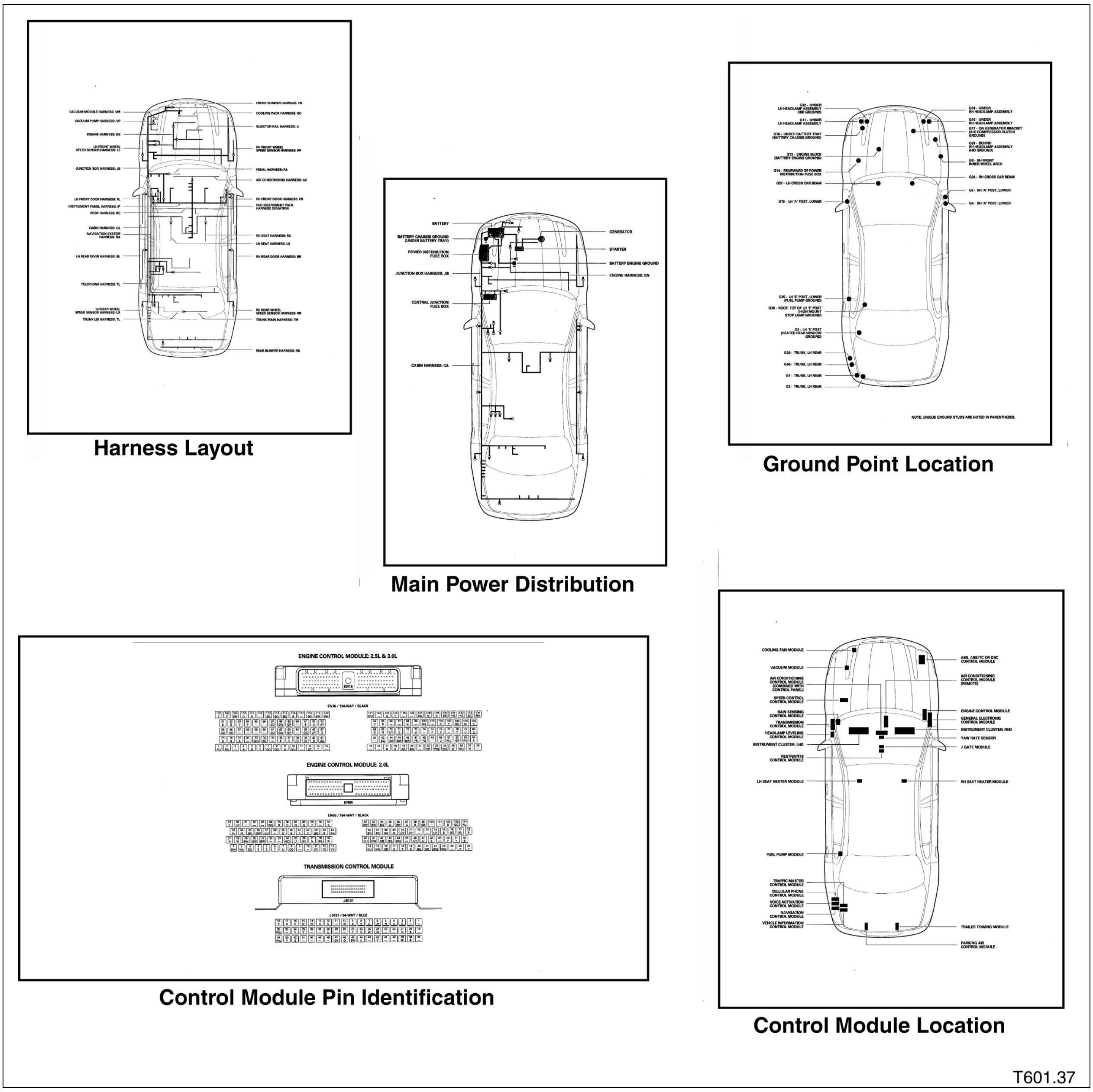


Fig. 55

Views of connectors, main power distribution, ground point location, harness layout (LHD and RHD), control module location (LHD and RHD), control module pin identifications, and relay and fuse box locations are vehicle or application specific.

CONTROL MODULE PIN OUT INFORMATION

Using the Jaguar Electrical Guide, fill in the description and active and inactive states, for the following module pins.

Table 4

PIN	Description	Active	Inactive
EM82–06			
EM81–22			
EM85–05			
EM82–13			
EM83–20			
EM80–09			
EM81–14			
EM81–15			
CC28–17			
EM81–08			

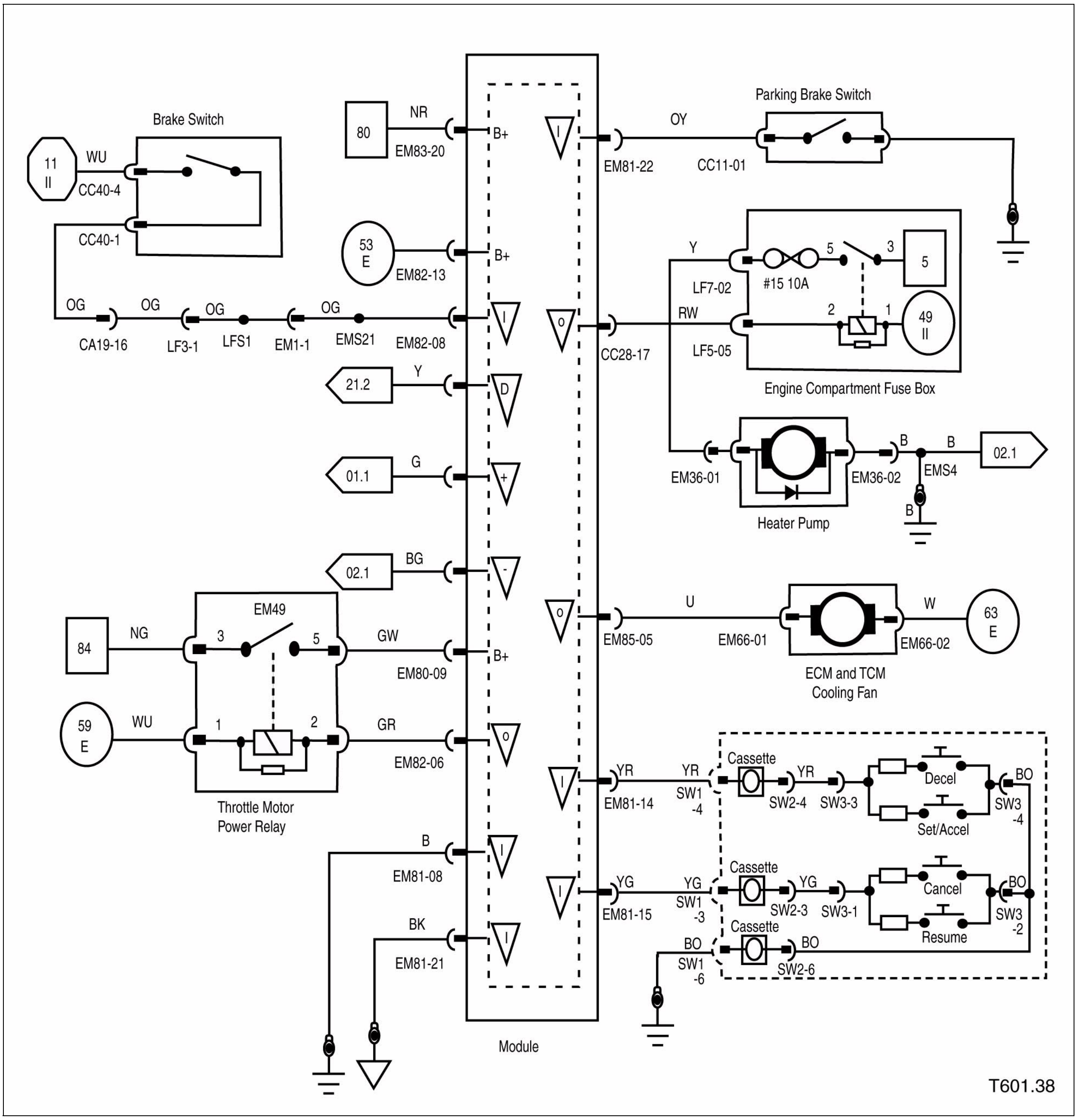

Brake Switch
11
II
WU
CC40-4
CC40-1
OG
CA19-16
LF3-1
LFS1
EM1-1
EMS21
EM82-08
80
NR
EM83-20
B+
53
E
EM82-13
21.2
Y
01.1
G
02.1
BG
EM49
84
NG
3
5
GW
EM80-09
59
E
WU
1
2
GR
EM82-06
Throttle Motor
Power Relay
B
EM81-08
BK
EM81-21
Module
Parking Brake Switch
OY
EM81-22
CC11-01
LF7-02
#15 10A
5
RW
LF5-05
49
II
CC28-17
Engine Compartment Fuse Box
EM36-01
EM36-02
EMS4
Heater Pump
U
EM85-05
EM66-01
W
EM66-02
63
E
ECM and TCM
Cooling Fan
YR
EM81-14
SW1
-4
Cassette
SW2-4
SW3-3
Decel
Set/Accel
BO
SW3
-4
YG
EM81-15
SW1
-3
SW2-3
SW3-1
Cancel
Resume
SW3
-2
SW1
-6
SW2-6
T601.38

Fig. 56

1. Where is the fuse located that protects Motor A?

____

____

____

2. Write down the pin number and the color of the wire, going to the following pins, of the Power Relay: Pin#1, Pin#2, Pin#3, and Pin#4

____

____

____

____

WORKSHEET –

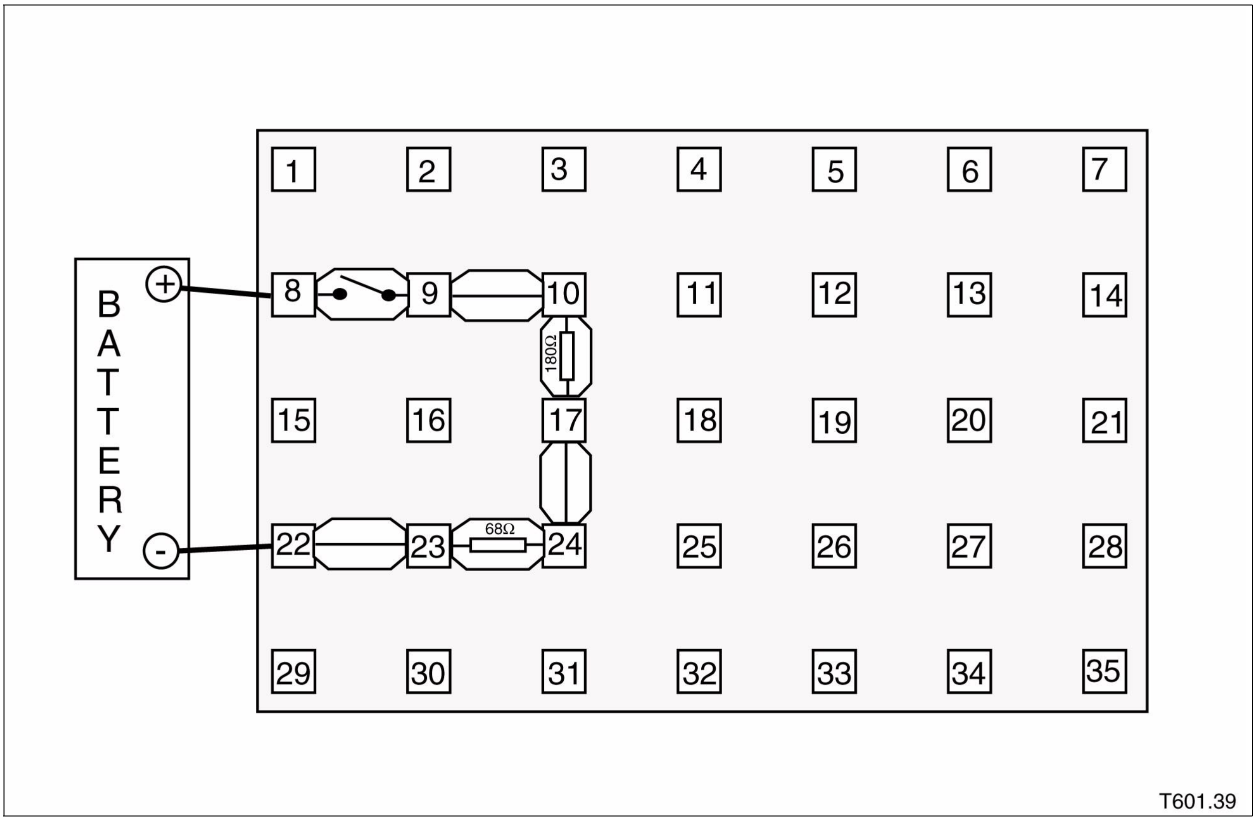


Fig. 57

Build this series circuit using the bread board and then perform the necessary measurements to answer the following questions:

1. What is the battery voltage?

2. What is the voltage drop at pin 10?

____

____

3. What is the voltage drop at pin 24?

____

____

4. What is the voltage drop at pin 23?

____

____

5. What is the total resistance of the circuit?

____

____

6. Using Ohm's Law, what should the amperage be?

____

____

7. Using a DVOM in series, what is the amperage?

WORKSHEET –

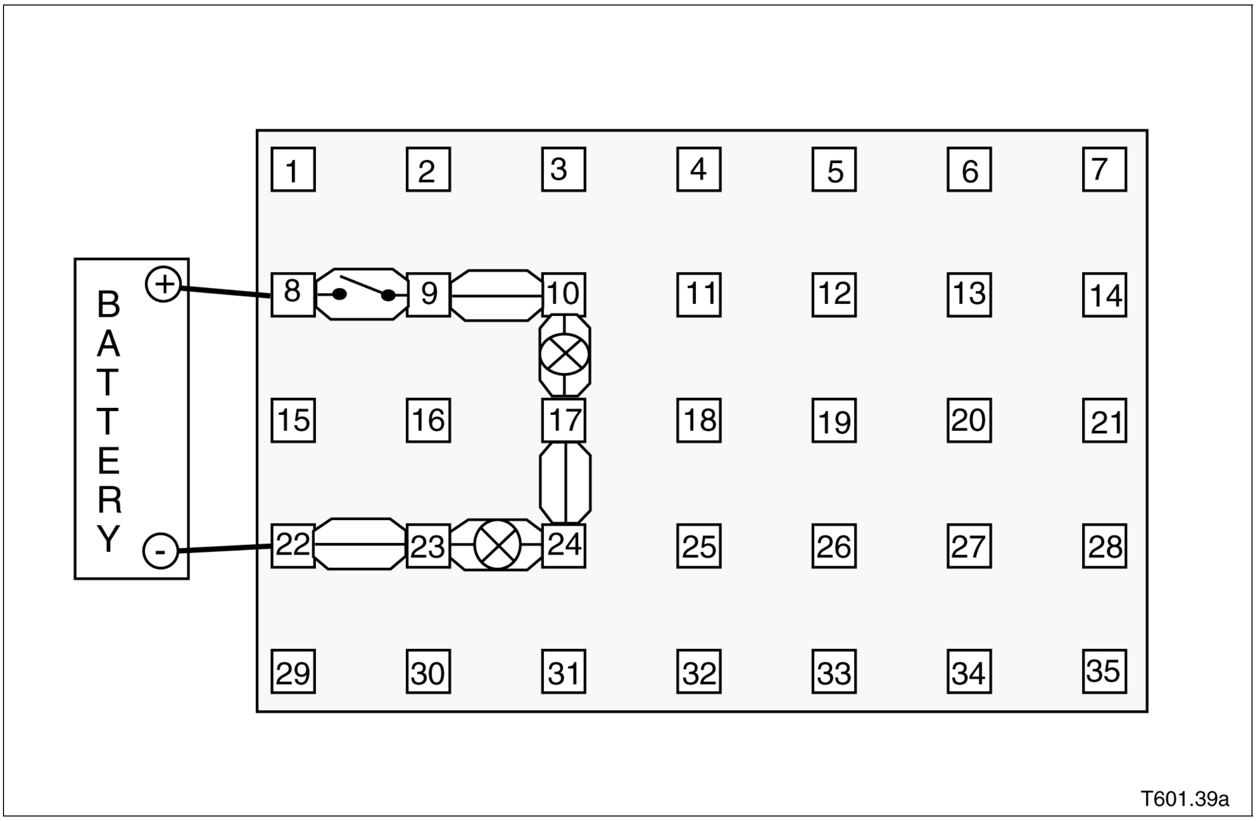


Fig. 58

Build this series circuit using the bread board and then perform the necessary measurements to answer the following questions:

1. What is the battery voltage?

2. What is the voltage drop at pin 10?

3. What is the voltage drop at pin 24?

4. What is the voltage drop at pin 23?

5. What is the total resistance of the circuit?

6. Using Ohm's Law, what should the amperage be?

7. Using a DVOM in series, what is the amperage?

WORKSHEET –

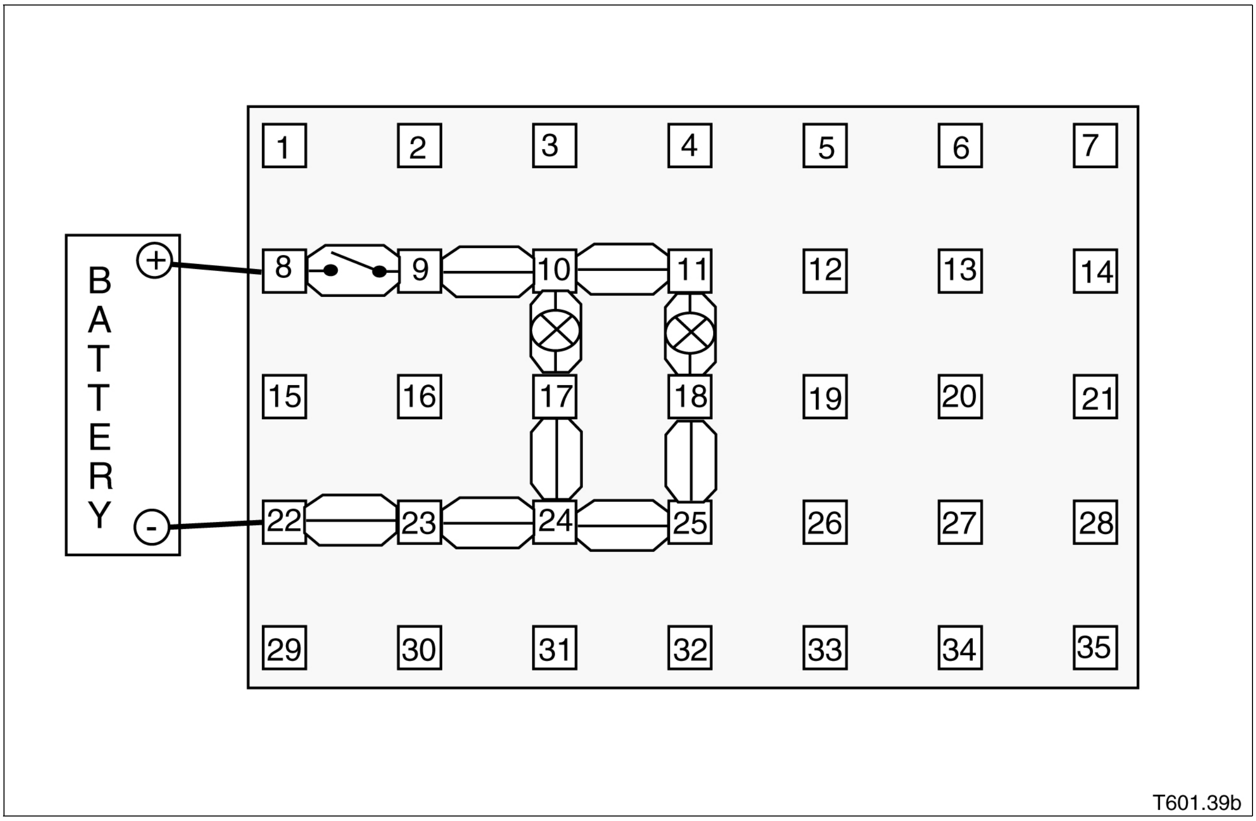


Fig. 59

Build this parallel circuit using the bread board and then perform the necessary measurements to answer the following questions:

1. What is the battery voltage?

2. What is the voltage drop at pin 10?

3. What is the voltage drop at pin 11?

4. What is the voltage drop at pin 25?

5. What is the voltage drop at pin 24?

6. What is the total resistance of the circuit?

7. Using Ohm's Law, what should the amperage be?

8. Using a DVOM in series, what is the amperage?

WORKSHEET –

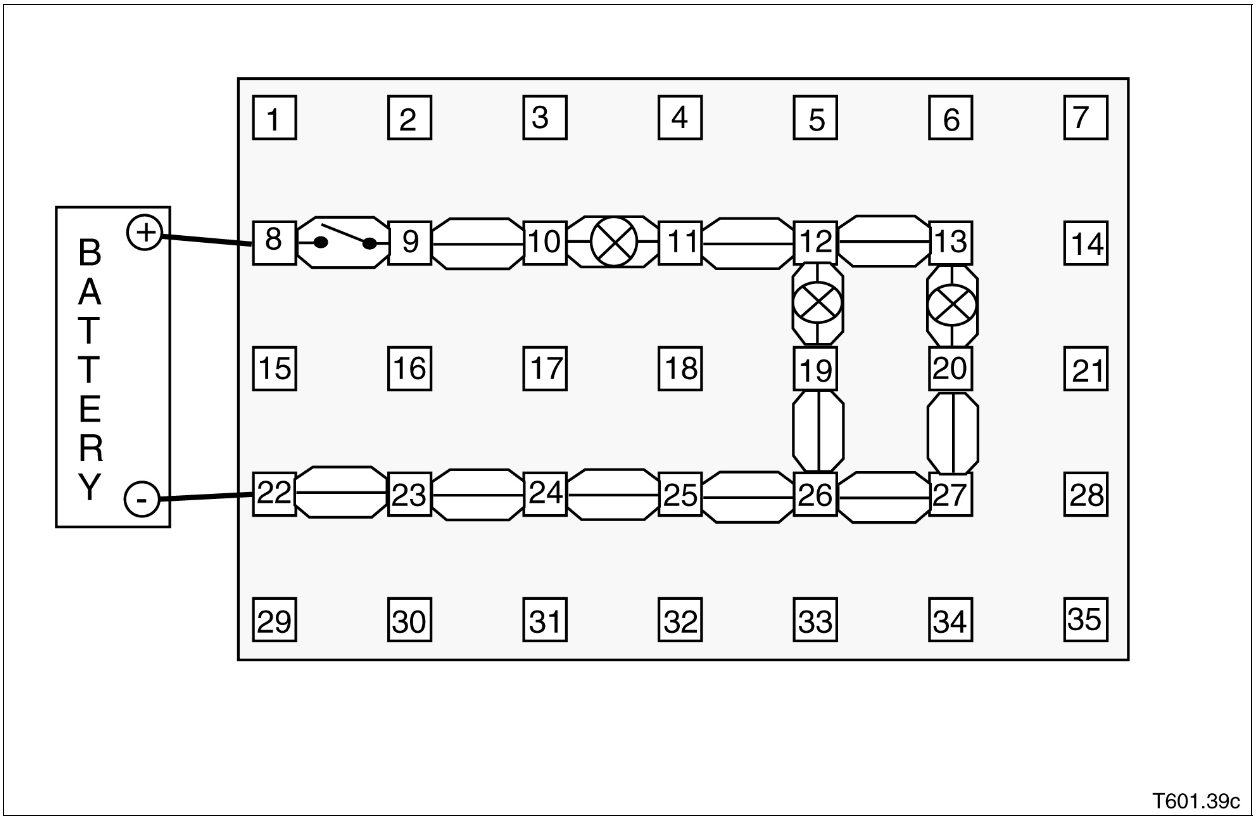


Fig. 60

Build this series/parallel circuit using the bread board and then perform the necessary measurements to answer the following questions:

1. What is the battery voltage?

2. What is the voltage drop at pin 10?

3. What is the voltage drop at pin 12?

4. What is the voltage drop at pin 27?

5. What is the total resistance of the circuit?

6. Using Ohm's Law, what should the amperage be?

7. Using a DVOM in series, what is the amperage between pins 26 and 19?

8. Using a DVOM in series, what is the amperage between pins 20 and 27?

WORKSHEET –

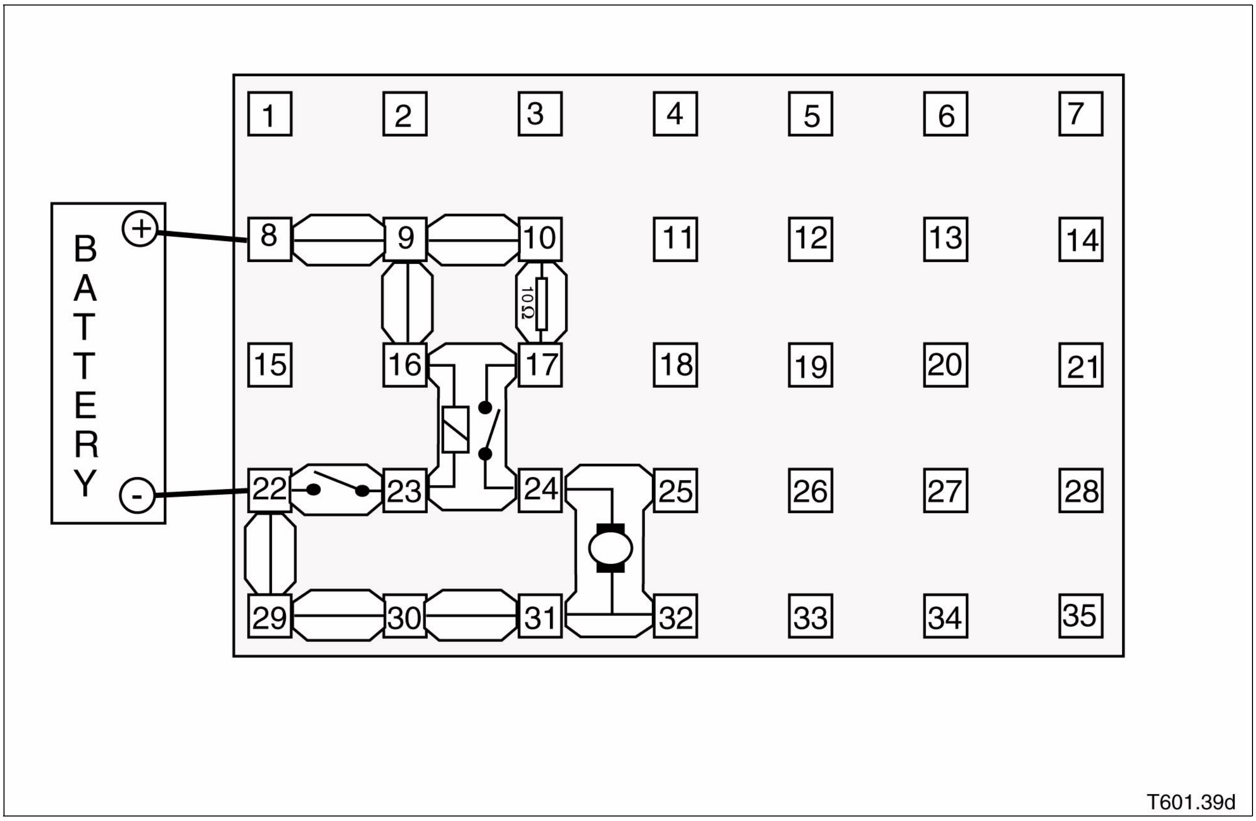


Fig. 61

Build this circuit using the bread board and then perform the necessary measurements to answer the following questions:

1. What is the battery voltage?

2. What is the voltage drop at pin 24?

3. What is the voltage drop at pin 17?

4. Using a DVOM, what is the amperage?

5. Using Ohm's law, what is the total resistance of the circuit?

Remove the conductor between pins 9 and 10 and install a diode with the arrow facing towards the motor.

6. What happened when you pressed the switch?

Turn the diode around and have the arrow face the switch.

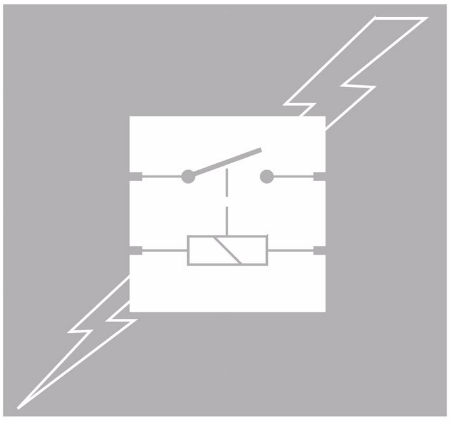
7. What happened when you pressed the switch?

Do the same between pins 30 and 31.

8. What are the results?

TRAINING PROGRAM

JAGUAR ELECTRICAL SYSTEMS



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SYMBOLS AND COMPONENTS

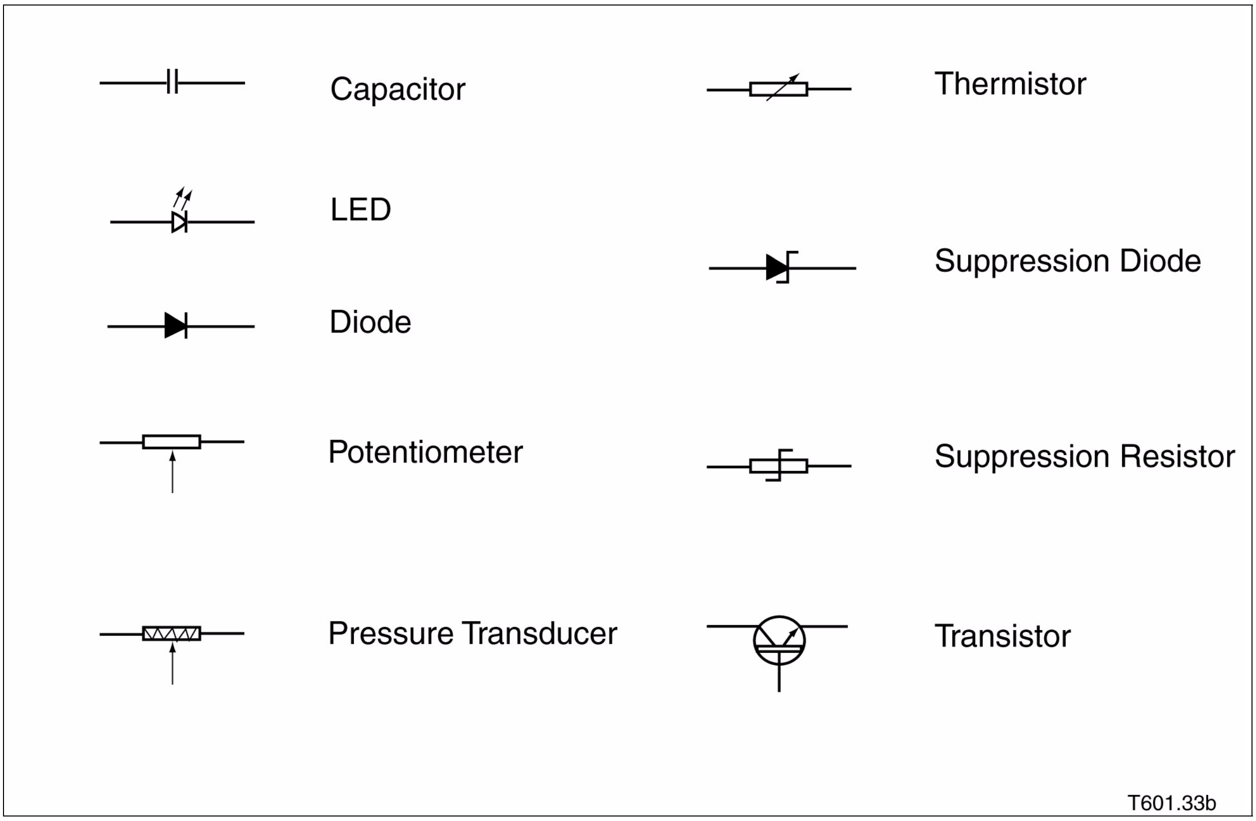

Fig. 62

In addition to the wires, connectors, fuses, bulbs, and other components discussed in lesson two, there are several other electrical/electronic devices necessary to control or regulate current.

CAPACITOR

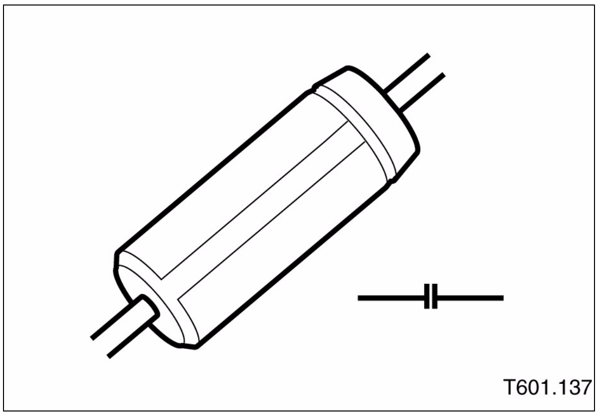

Fig. 63

Capacitors absorb or store electrical charges. The capacitor is made up of two or more conducting plates with non-conducting material between them. Direct Current (DC) cannot flow through a capacitor, but Alternating Current (AC) can. The slight flow of direct current that does occur is useful in soaking up voltage spikes, preventing arcing across opening contacts. Capacitors also serve as noise filters when used in audio applications. Capacitors are rated in units called Farads (F).

AC Generator

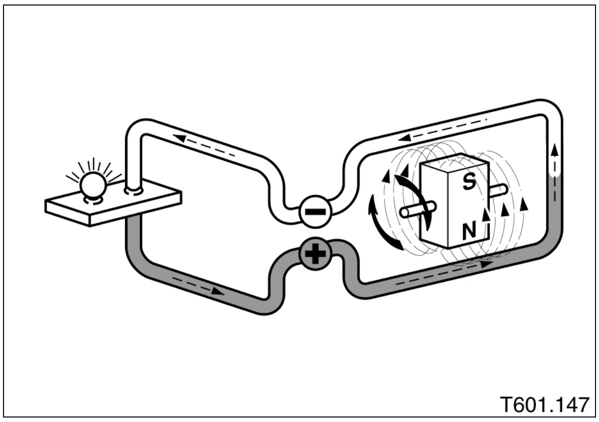

Fig. 64

In an AC generator, the magnetic field moves (rotates) through the stationary conductor producing voltage in the circuit. The voltage induced by an AC generator produces AC voltage that must be changed to DC voltage for automotive use.

Ignition coil

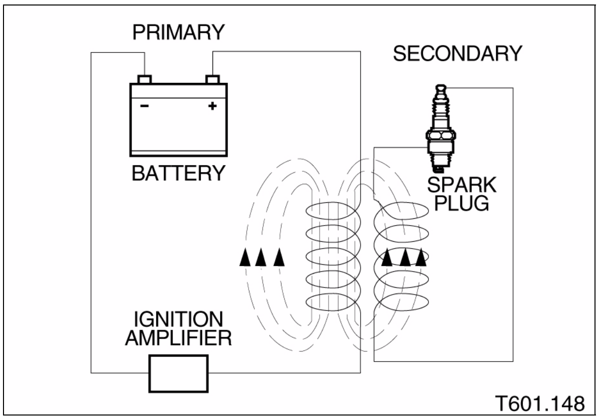

Fig. 65

Voltage can also be induced by the building or collapsing of a magnetic field across a stationary conductor. An example of this is an ignition coil.

THERMISTOR

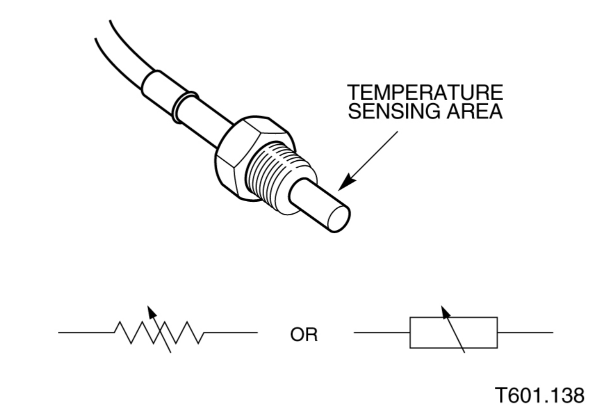

Fig. 66

The resistance of materials can change with a change in temperature; therefore, resistors can have changing resistance value depending on the temperature. A thermistor is a resistor that can achieve a large change in resistance for a small change in temperature. Thermistors normally have a negative temperature coefficient, (as temperature increases, resistance decreases), but some thermistors are positive temperature coefficient (as temperature increases, resistance increases).

Pressure Transducer

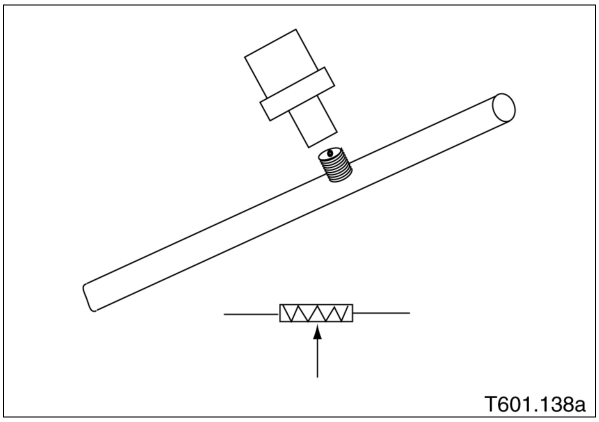

Fig. 67

A pressure transducer is a resistor that can achieve a change in resistance by a change in pressure. A good example of a pressure transducer is an A/C pressure transducer. The A/C pressure transducer is located in the compressor discharge line and communicates with the PCM. If high or low refrigerant pressures are experienced, the PCM will interrupt A/C compressor operation.

VARIABLE RESISTORS

Variable resistors are used to vary the control of circuits and to provide a means of converting mechanical position into a voltage. Two types of variable resistors are used in automotive circuits, potentiometer and rheostat.

Potentiometer

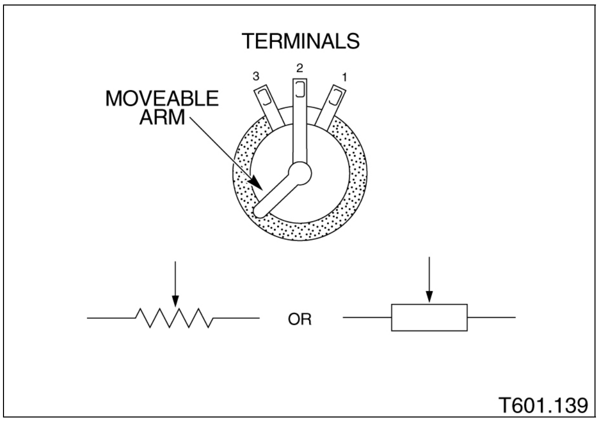

Fig. 68

The potentiometer is made up of a circular flat carbon ribbon connected to two terminals (1 and 3) with a third terminal (2) connected to a moveable contact. The contact moves along the resistance as the shaft turns, increasing or decreasing the relative resistance between terminals 1 and 2 and terminals 3 and 2.

Rheostat

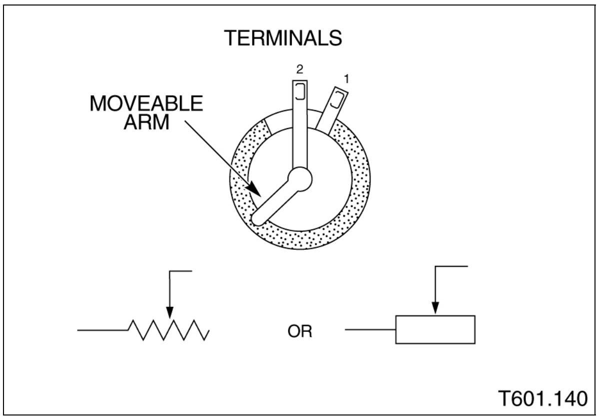

Fig. 69

A rheostat is identical to a potentiometer except that terminal 3 is omitted. This arrangement allows the resistance to be varied between terminals 1 and 2.

SEMICONDUCTOR COMPONENTS

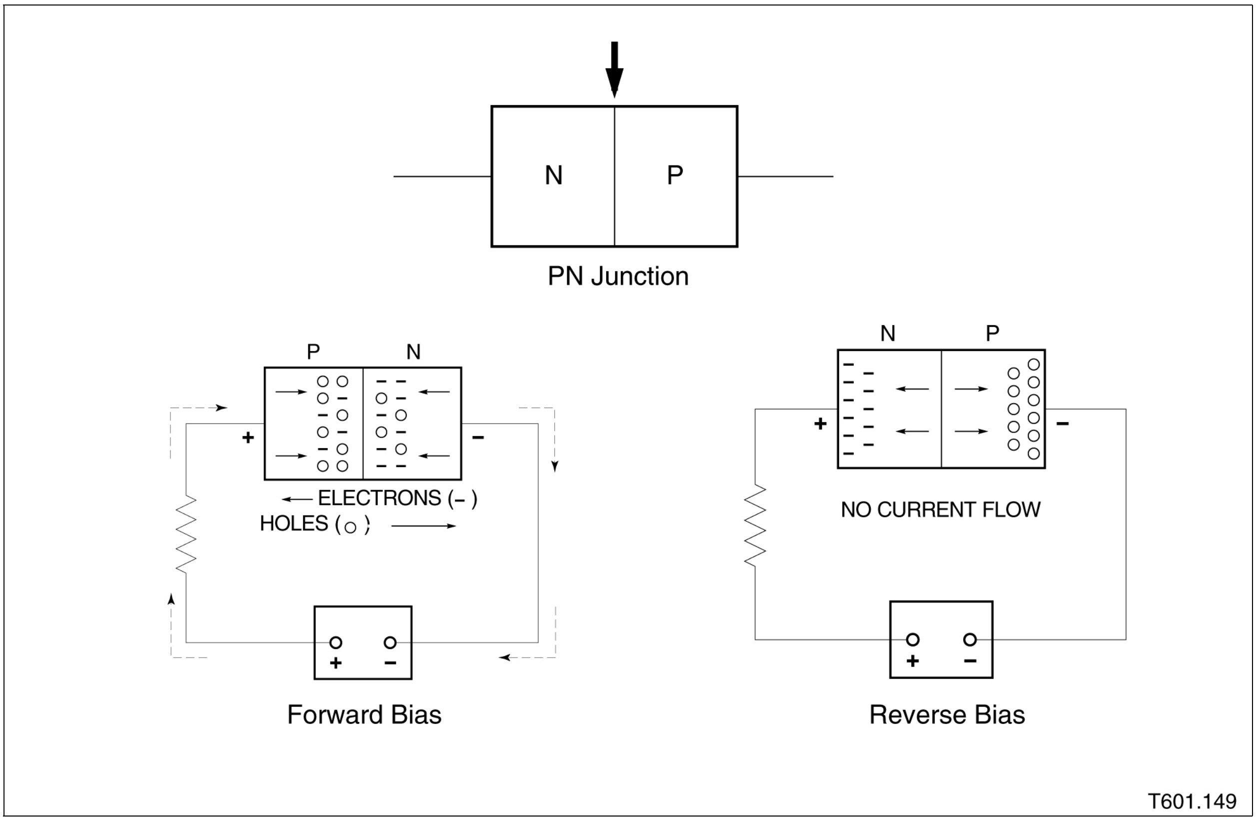

Fig. 70

Semiconductor material is neither a good conductor nor insulator. However, by altering the atomic structure of the semiconductor material the conductivity of the material can be increased. The atomic structure of the semiconductors material can be restructured two ways:

• With additional electrons that are free to move (N type semiconductor).

• With a deficiency of electrons that provide a place (holes) for free electrons to move toward (P type semiconductor).

SEMICONDUCTOR COMPONENTS (CONTINUED)

Diodes

When N and P type semiconductor materials are grown together to form a single crystal, a solid state diode is created that allows electron flow in one direction only.

The area where the N and P type materials join is called the PN junction. When a battery is connected to the PN junction so that negative voltage is applied to the N type material and positive voltage is applied to the P type material, electrons will cross the junction and combine with holes (after .5 to .6 volts are exceeded) creating a conductor. Current flows through the diode creating a condition called forward bias. When the battery connections are reversed, electrons and holes are attracted by the unlike charges of the battery and move away from the junction. No current can flow through the diode creating a condition called reverse bias.

Solid State Diode

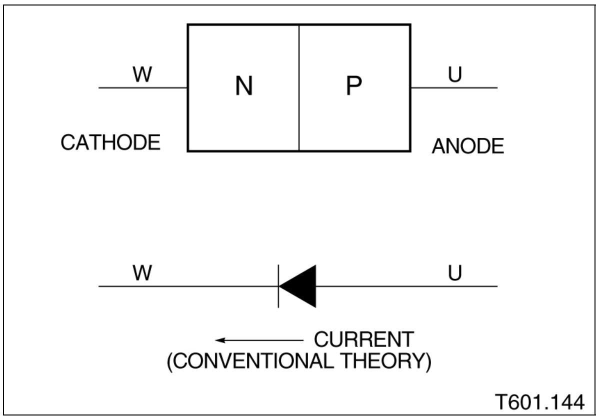

Fig. 71

The PN junction acts as a switch because it conducts only when it is forward biased. The N type material is referred to as the cathode and the P type material as the anode. In most Jaguar circuits, the cathode end is identified by a white wire and the anode end by a blue wire. The arrowhead in the symbol points in the opposite direction to electron flow.

Zener/Light Emitting Diode

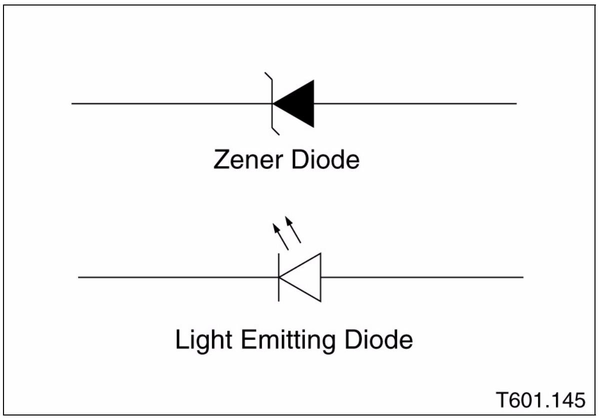

Fig. 72

Zener

A Zener diode is designed to have a specified reverse breakdown that allows conduction. By conducting in the reverse direction at a specific voltage, Zener diodes can act as voltage sensitive switches. Zener diodes are typically used in voltage regulators and over-voltage protection devices.

Light emitting diode

All diodes emit some electromagnetic radiation when they are forward biased. Certain materials will emit considerably more radiation that becomes visible when forward biased. Light emitting diodes (LED) are typically used for locate and state lighting of controls.

TRANSISTORS

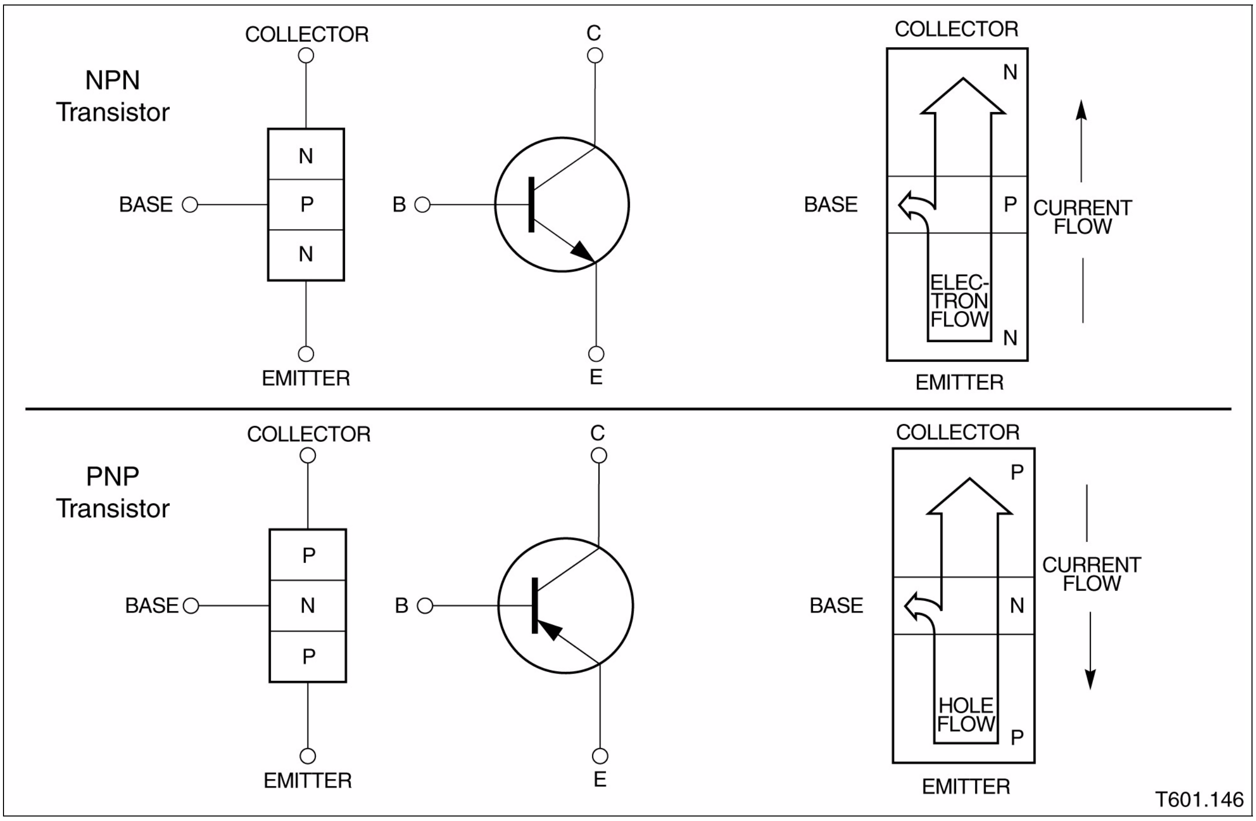

Fig. 73

The transistor is an extension of the diode. A transistor is a single semiconductor crystal that contains two PN junctions (a diode has one). The transistor can be constructed in two ways. The P section can be sandwiched between two N sections. The N section can be sandwiched between two P sections.

These are referred to as NPN and PNP transistors. The three sections of the transistor are called the emitter, the base and the collector.

In the symbols, the emitter is identified by an arrowhead. The arrowhead points in the direction opposite of electron flow. The arrowhead also points to the N type material. When current is applied to the base, current will flow through the transistor. Current flows through the NPN transistor in one direction and through the PNP transistor in the opposite direction.

The three modes of transistor operation are off, switch and amplifier. When no voltage is applied to the base, no current flows through the transistor. When a constant minimal voltage is applied to the base, the transistor will act as a switch and allow current to flow. If the base voltage is varied, the current flow will follow the variation allowing the transistor to act as an amplifier.

MICROPROCESSORS

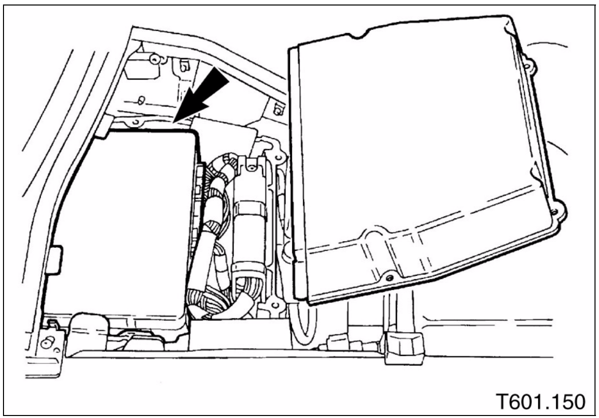

Fig. 74

Microprocessors are electronic devices that are used to perform complex, high-speed switching functions. Today automobiles use a 32-bit processor, which means the processor can perform calculations with numbers containing 32 digits. In automotive use, microprocessors are contained in vehicle control modules. They provide sophisticated circuit control necessary for systems such as engine management, anti-lock braking and transmission control. Microprocessors operate on different kinds of memory:

• **Read Only Memory (ROM)** is in permanent storage and cannot be altered. The programmed instructions are used by the microprocessor as directed by sensor input. The engine control module uses ROM to control all engine management functions.

• **Programmable Read Only Memory (PROM)** is in permanent storage, however, the user can select which functions to enable or disable. The security system control module uses PROM to allow the vehicle operator a choice of security system functions.

• **Electronic Erasable Programmable Read Only Memory (EEPROM)** is memory which can be erased and reprogrammed while still in the vehicle. The EEPROM can be programmed in the vehicle using a diagnostic tool.

• **Random Access Memory (RAM)** is used by a microprocessor to perform the processing functions. As used in a computer, RAM is used to both read and write information, meaning that documents can be created and modified based on programs contained in the ROM.

• **Keep-Alive Memory (KAM)** is used to store information such as diagnostic trouble codes and learned values until the battery is disconnected or the information is erased using a diagnostic tool.

BLOWER MOTOR CIRCUIT

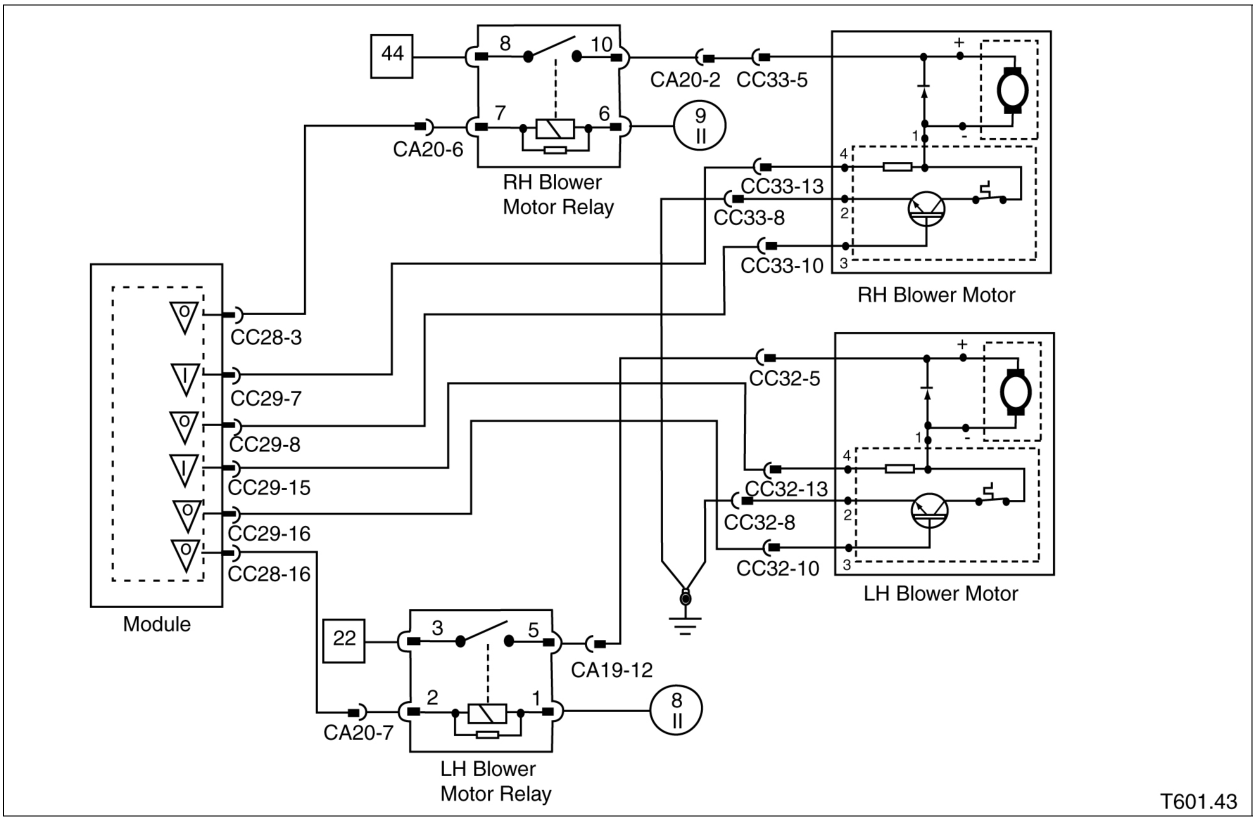

Fig. 75

The blower motor circuit used in the 2001 XJ Series Jaguar uses a relay to control B(+) voltage to the blower motors. Varying voltage is supplied to the base of the transistor, which controls B(-) voltage and the blower motor speed.

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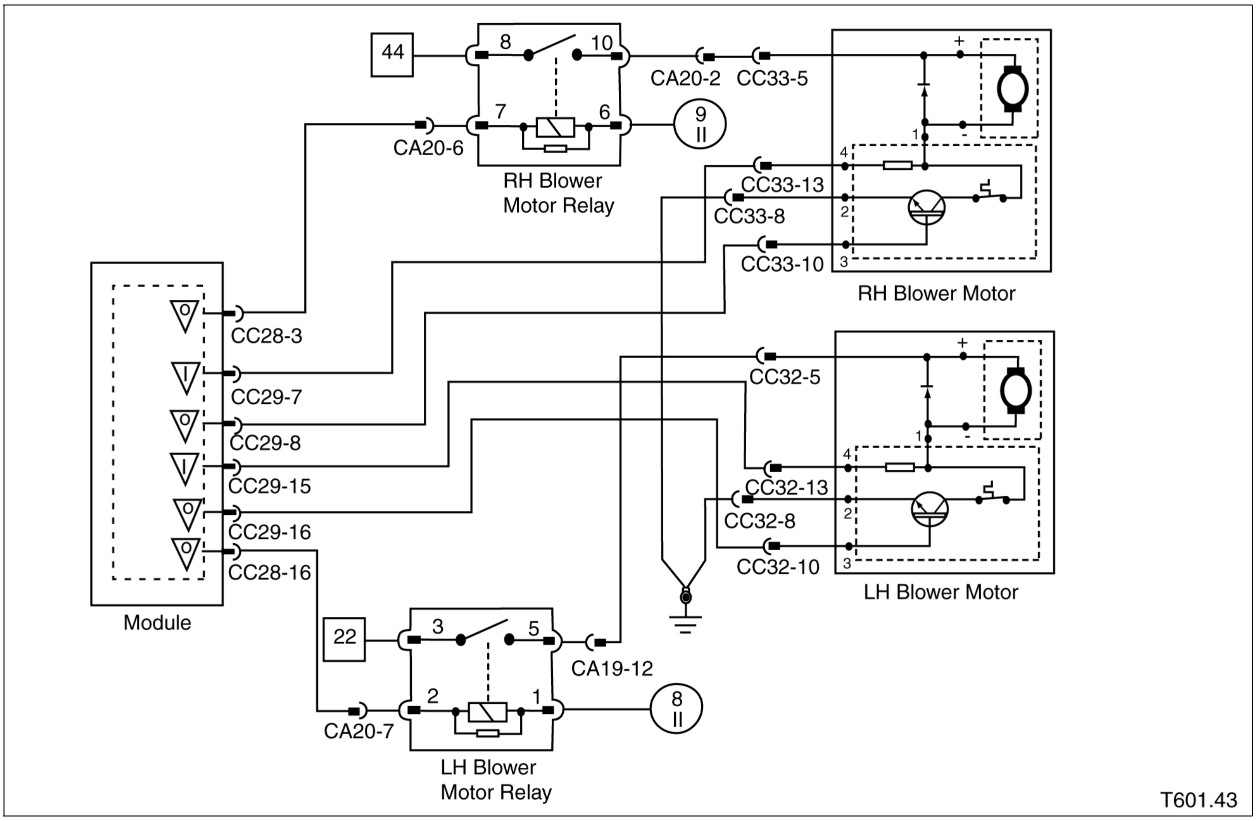

Fig. 76

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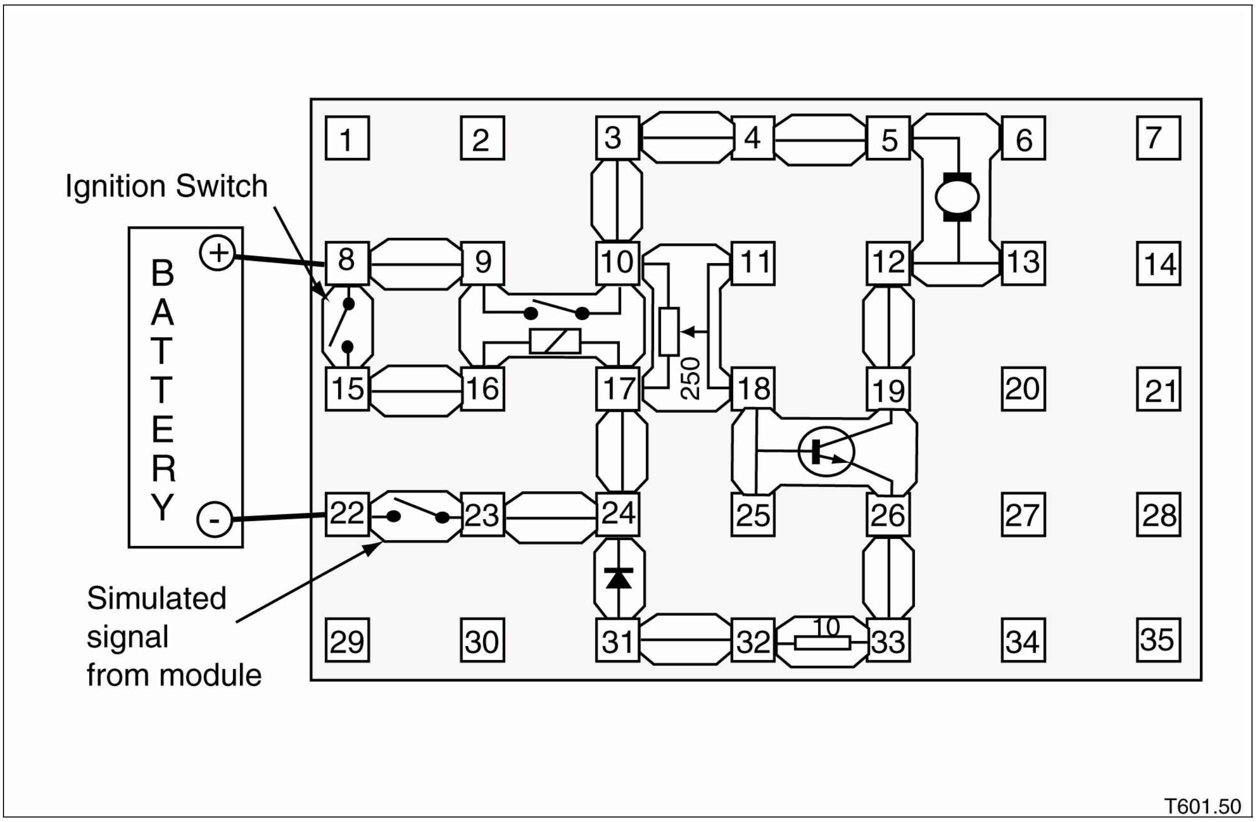

Fig. 77

Build the above circuit using the bread board and answer the following questions:

1. How is the blower motor speed controlled?

2. With the ignition switch in the ON position, what has to happen before B(+) is supplied to the motor?

3. What happens if you turn the diode around in the circuit?

4. Why is the resistor in the circuit?

RADIATOR FAN CIRCUIT

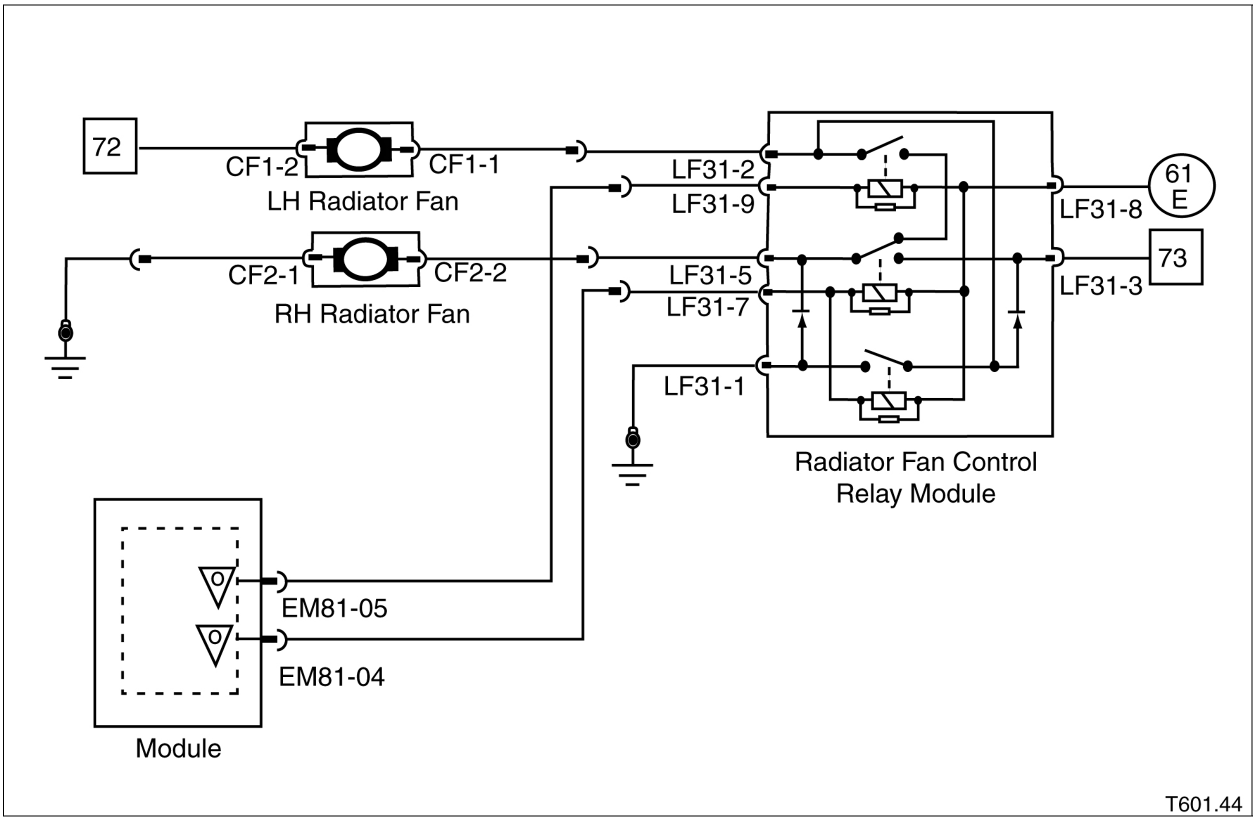

Fig. 78

The radiator fan circuit on the 2001 XJ Series Jaguar uses a parallel circuit to obtain high speed operation of both motors, and a series circuit to obtain low speed on both motors. This is accomplished by controlling current flow through three relays in the radiator fan control module.

WORKSHEET –

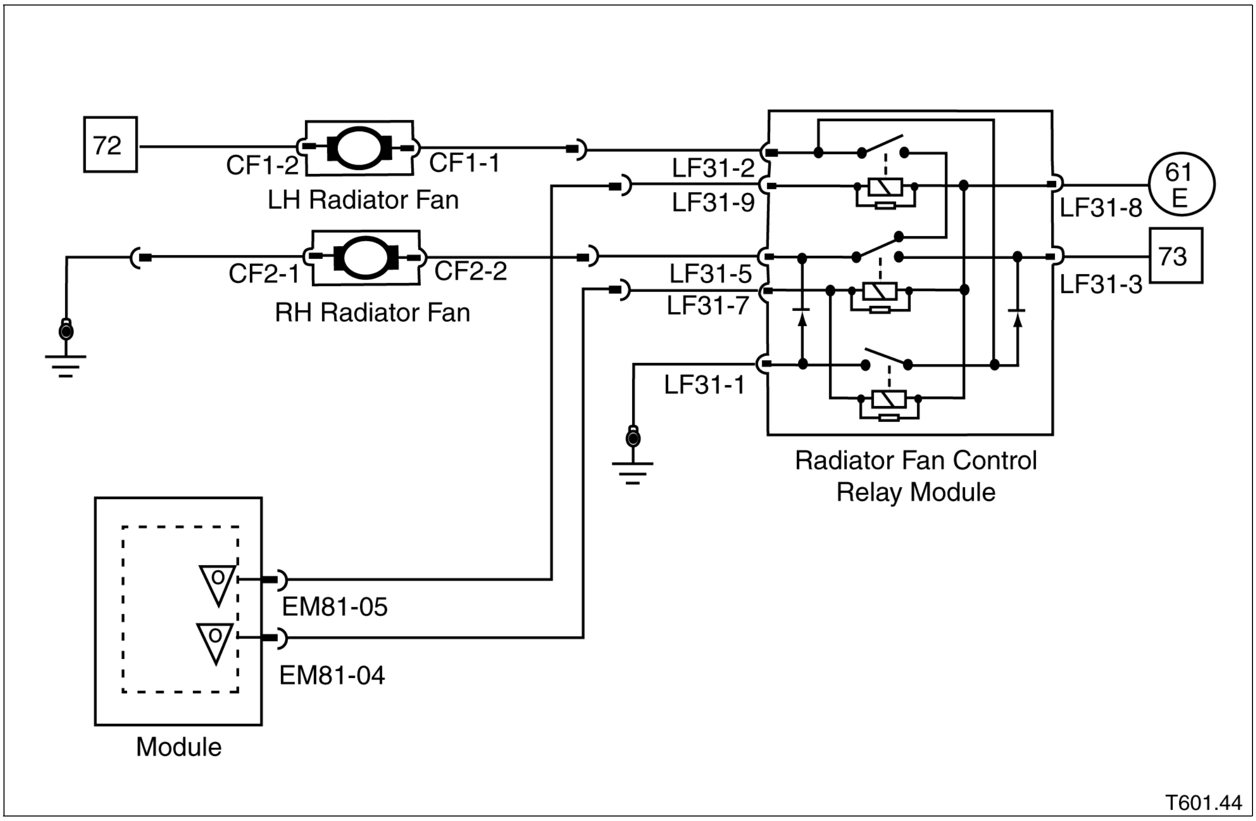

Fig. 79

Build this circuit using the bread board and the electric guide.

1. What would happen if polarity was reversed?

SENSORS AND LED

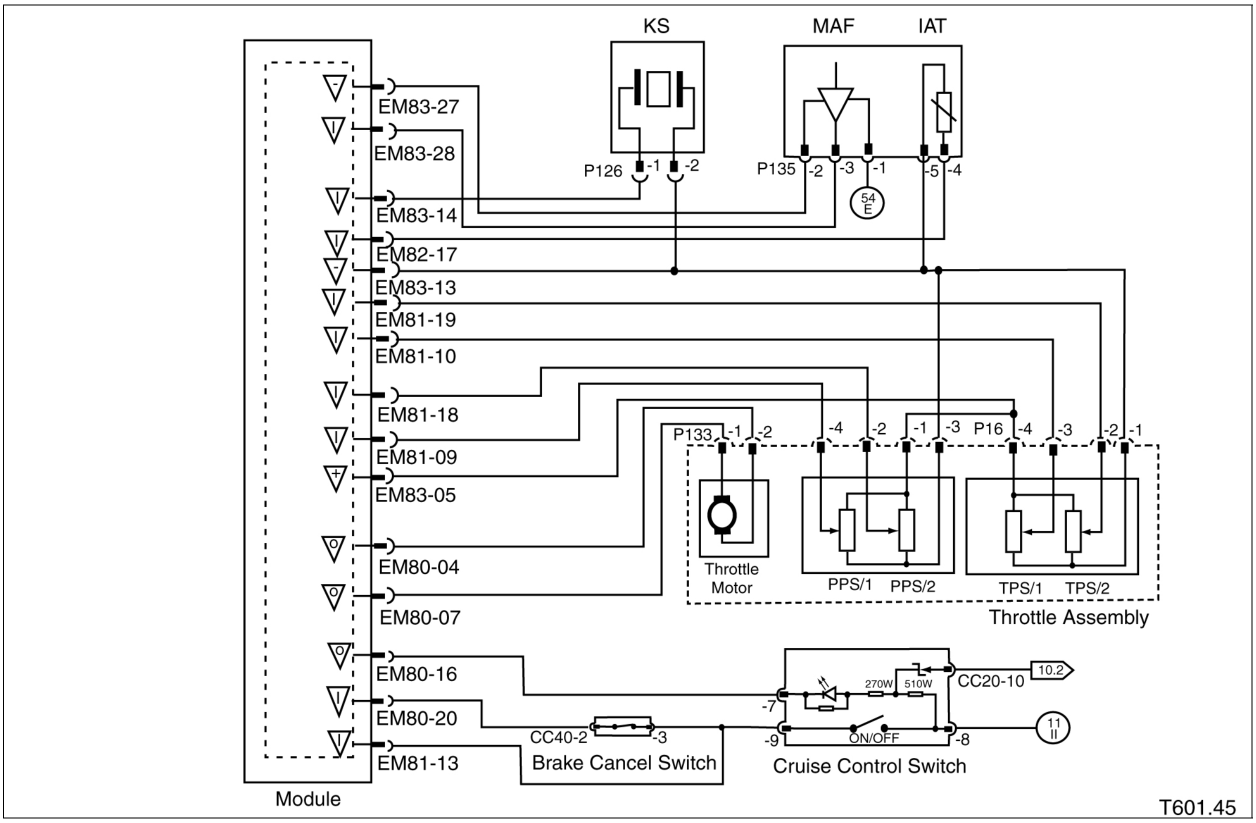

Fig. 80

Jaguars are very sophisticated automobiles. One example of the degree of sophistication is the accelerator system used on the 2001 XJ.

No mechanical device is directly used to control incoming air. A throttle motor is used along with the two Throttle Position Sensors (TPSs) and two Pedal Position Sensors (PPSs). Given input from all four sensors the ECM drives the motor forward or in reverse to control engine speed.

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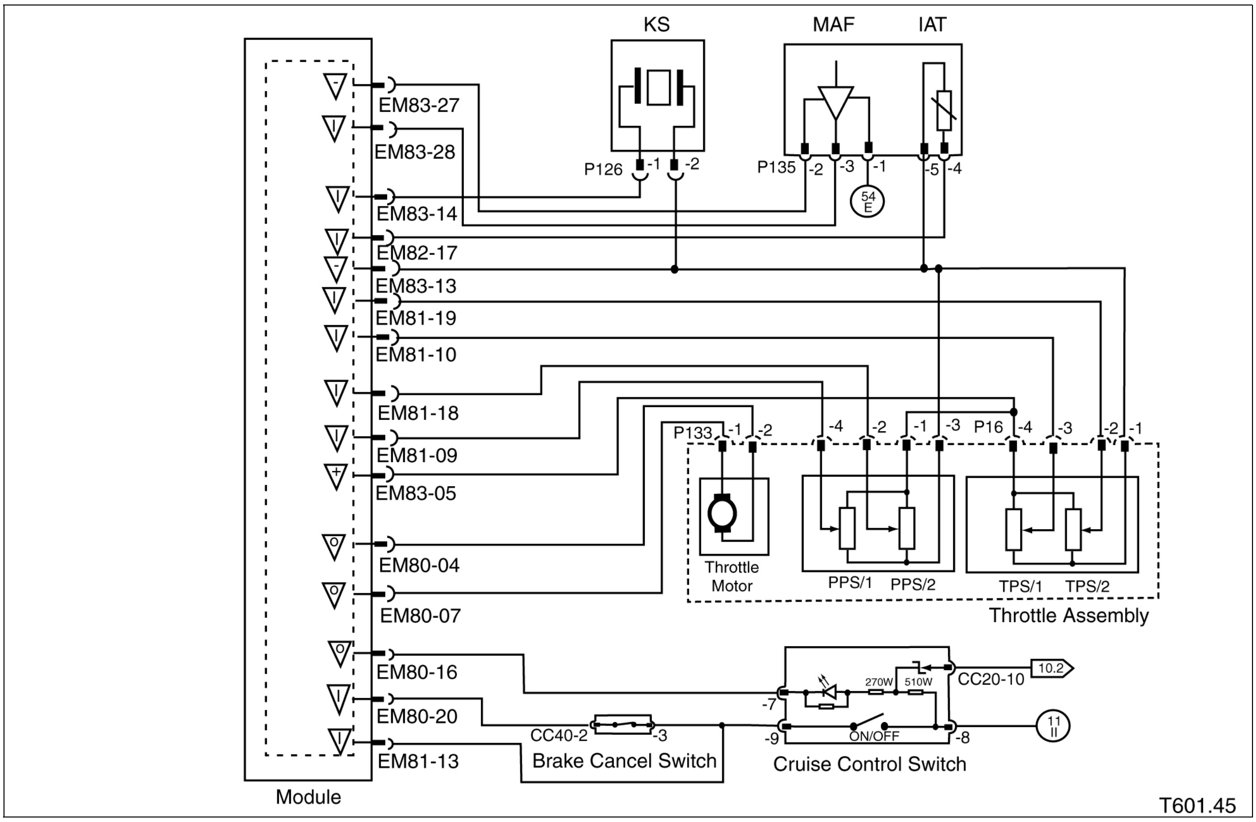


Fig. 81

WORKSHEET –

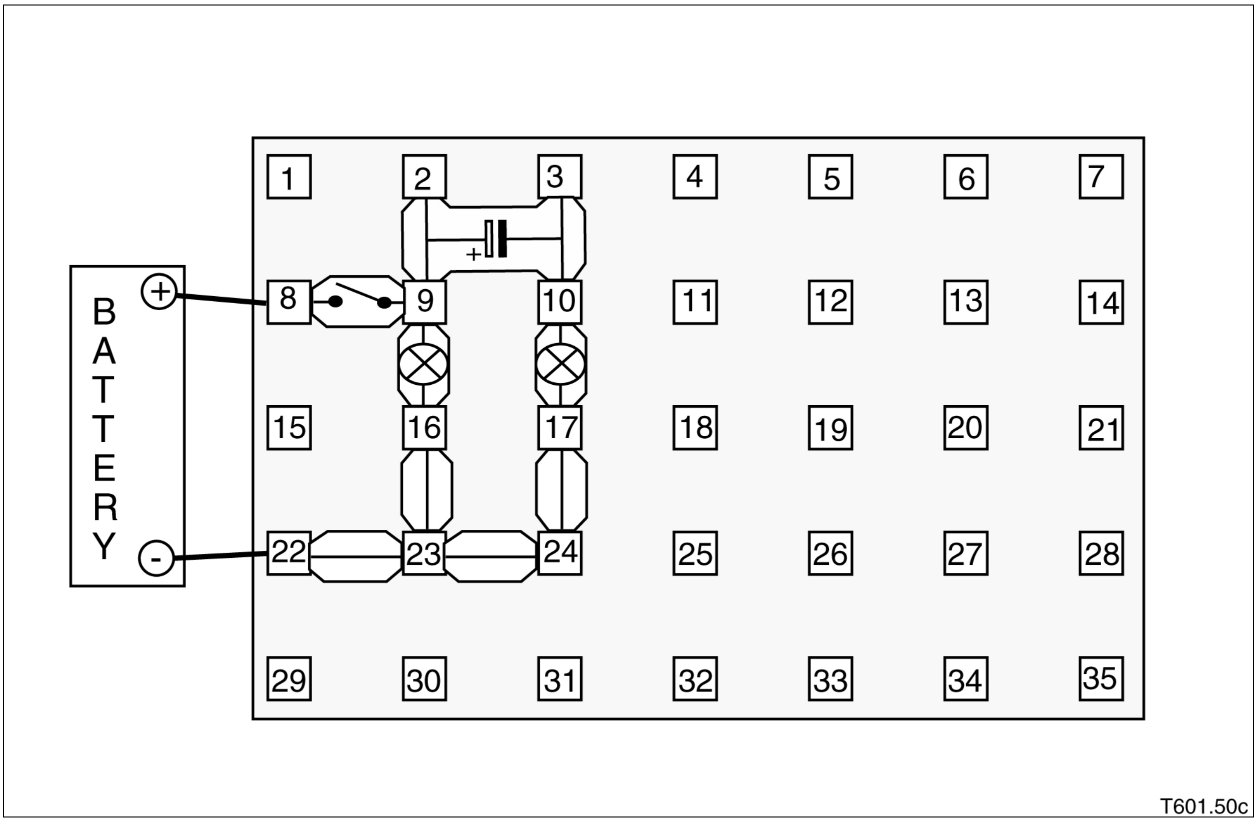


Fig. 82

Build this circuit using the bread board, then perform the following measurements to answer the following questions:

1. What happens to the capacitor when the switch is closed?

2. With the load between 16 and 9 removed, close the switch momentarily and note the voltage between pins 24 and 9. What voltage did you get?_______What happened to it? _________

____

____

3. Using the scenario from question 2, after you momentarily close the switch and note the voltage, reinstall the load while watching the DVOM. What happens to the voltage stored in the capacitor?

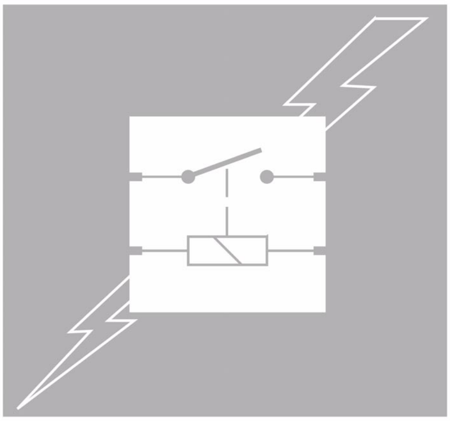
____

____

JAGUAR

TRAINING PROGRAM

JAGUAR ELECTRICAL SYSTEMS



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DIAGNOSIS AND REPAIR

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 is not, 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 message.

• 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.

• Test the circuits and components using WDS 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.

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.

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.

NEVER:

• Back probe a sealed connector. This will damage the seal allowing moisture and other contaminants to enter the connector and cause corrosion.

• Pierce the insulation of a conductor. This will allow moisture and other contaminants to enter the conductor and cause corrosion.

• Use circuit powered or self-powered test lights to test circuits or components. This could damage sensitive electronic components or circuits.

ALWAYS:

• Calibrate test equipment and check resistance of test leads and adapters to ensure accurate measurements.

• Use the correct testing adapters.

Circuit Failure Testing (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 the 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?

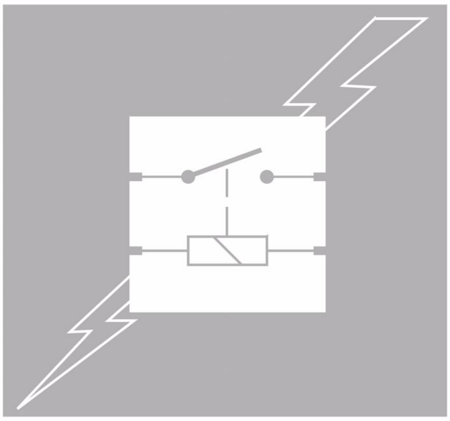
• Does the failure occur at any specific temperature, time of day, engine or transmission operating condition? Try to recreate the failure by operating the vehicle under the conditions reported. If the failure can be recreated, follow the general diagnostic procedures.

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. Apply the “wiggle” test while following the general diagnostic procedures.

JAGUAR

TRAINING PROGRAM

JAGUAR ELECTRICAL SYSTEMS



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WIRE/TERMINAL REPAIR

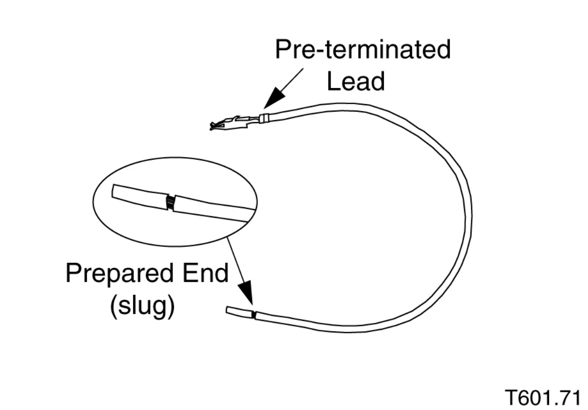


Fig. 83

The only acceptable method to repair a damaged wire or faulty terminal is as follows.

If the terminal is damaged:

• Withdraw the affected terminal from its connector.

• Cut the lead close to the connector.

• Replace the damaged terminal using a pre-terminated lead of the same type and size.

• Join the prepared end of the lead to the cut harness using AMP Preinsulated Diamond Grip (PIDG) butt splices.

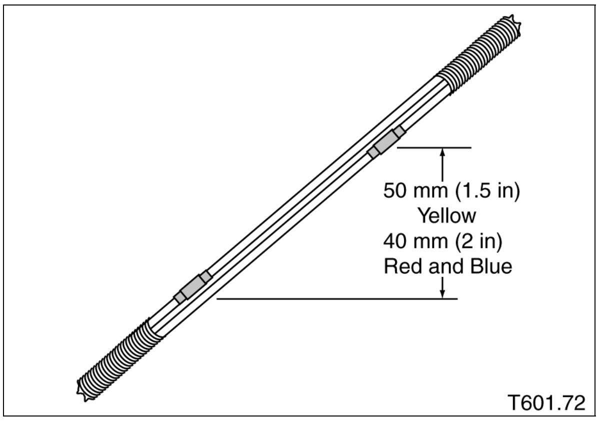


Fig. 84

If the wire alone is damaged:

• Cut the affected lead at each end of the damaged section.

• Remove the damaged section and replace with a new length of lead, using the exact size and color as the piece removed.

• Join the ends using AMP PIDG splices of corresponding size

If two or more wires are damaged in the same harness, make the splices at least 40 mm (1.5 in) between centers for red or blue splices, and 50 mm (2 in) for yellow splices.

EXTRACTION HANDLE AND TIPS

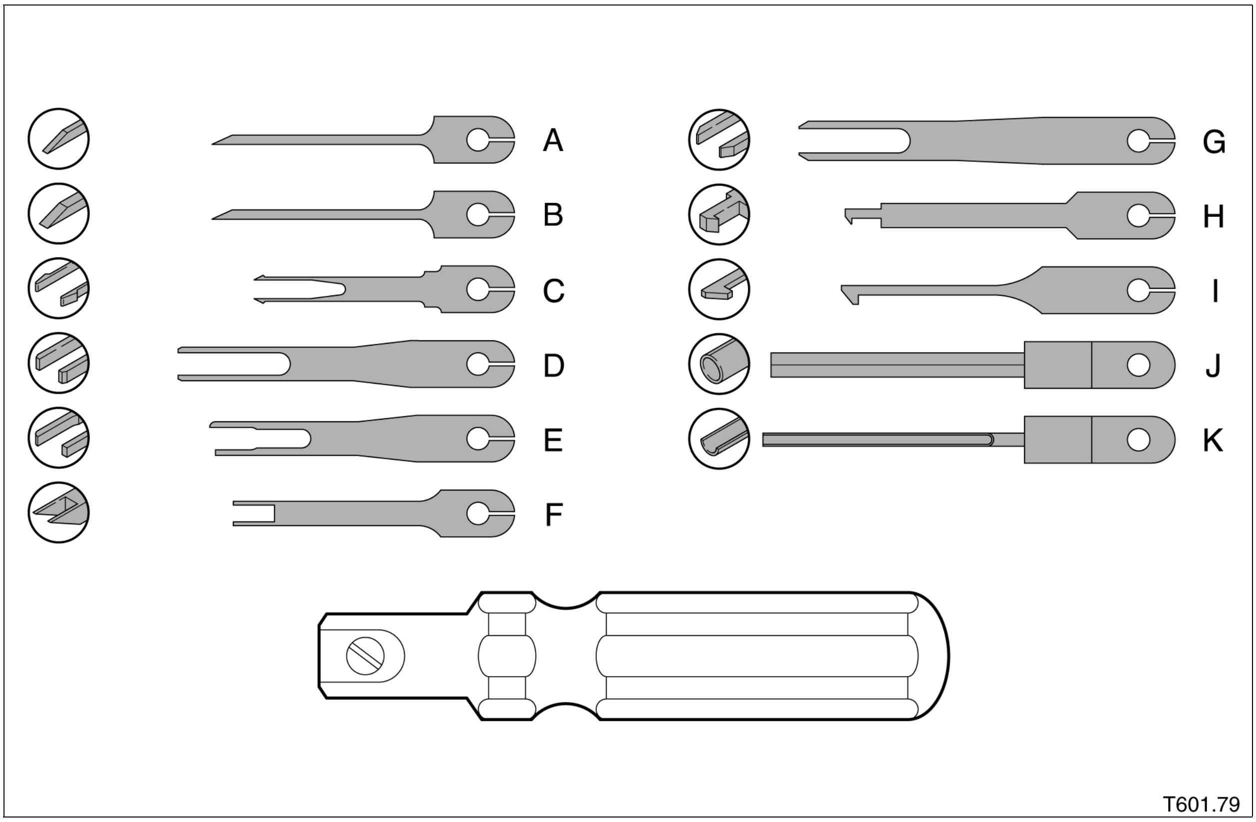


Fig. 85

Use the extraction handle, in conjunction with the correct tip, to remove a terminal from a connector. Each tip contained in the kit is marked with an identification letter, A to K inclusive. Each tip has been specially designed to extract a particular type of terminal

The tip is fastened to the handle by a screw which holds the tip firmly yet enables it to be easily replaced.

Use of any other tool is not recommended and is liable to cause damage to the connector.

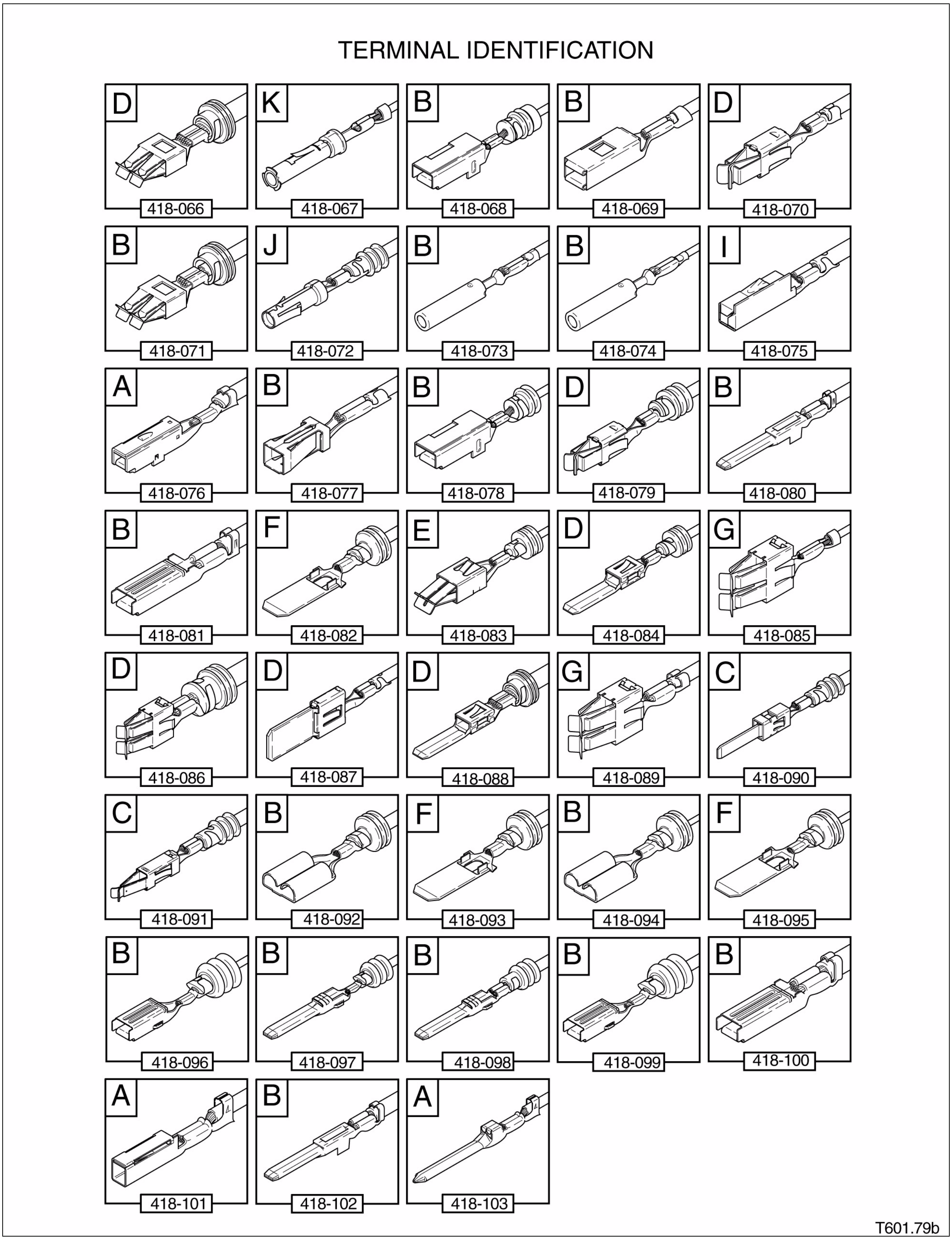

TERMINAL IDENTIFICATION
D
418-066
K
418-067
B
418-068
B
418-069
D
418-070
B
418-071
J
418-072
B
418-073
B
418-074
I
418-075
A
418-076
B
418-077
B
418-078
D
418-079
B
418-080
B
418-081
F
418-082
E
418-083
D
418-084
G
418-085
D
418-086
D
418-087
D
418-088
G
418-089
C
418-090
C
418-091
B
418-092
F
418-093
B
418-094
F
418-095
B
418-096
B
418-097
B
418-098
B
418-099
B
418-100
A
418-101
B
418-102
A
418-103
T601.79b

Fig. 86

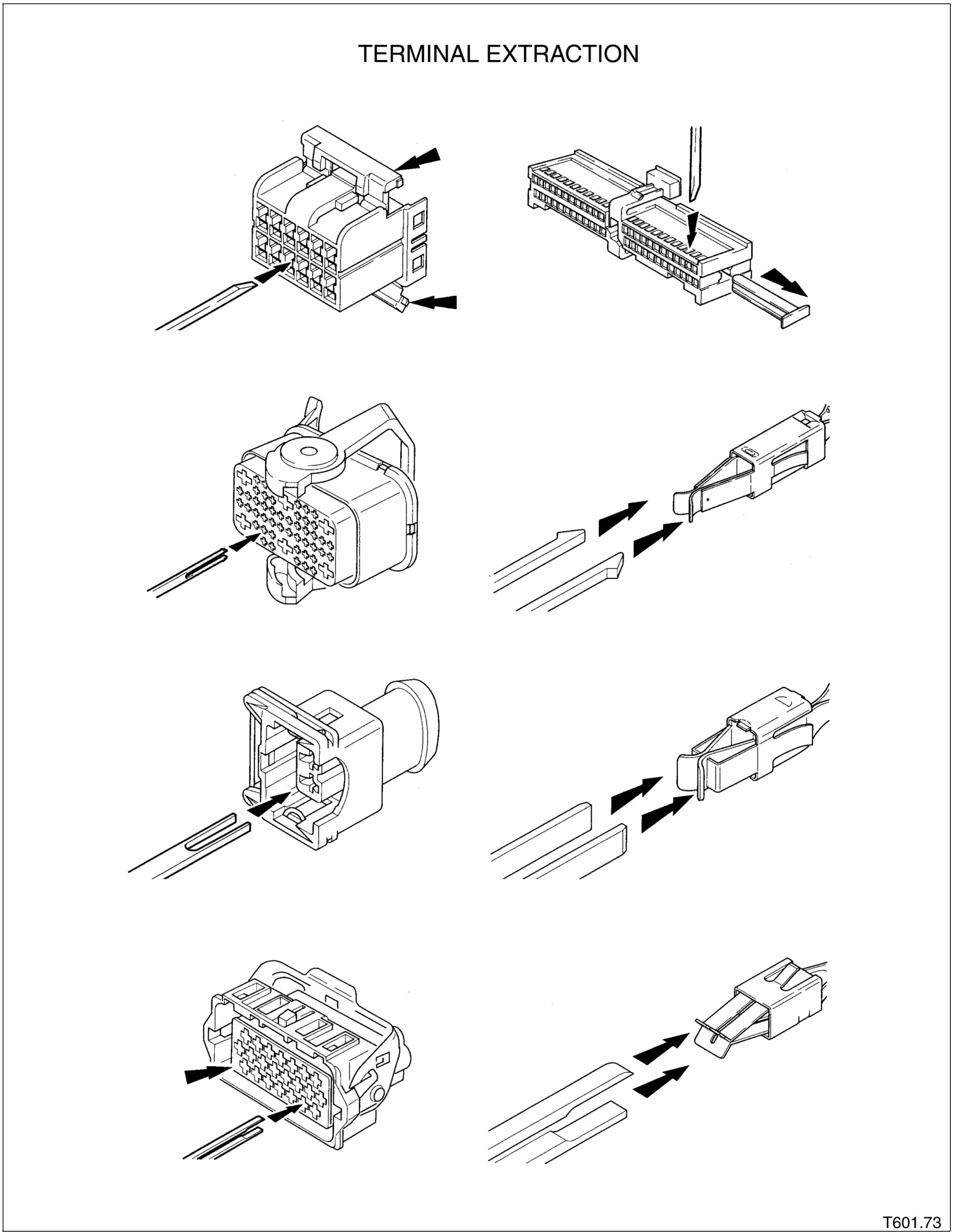
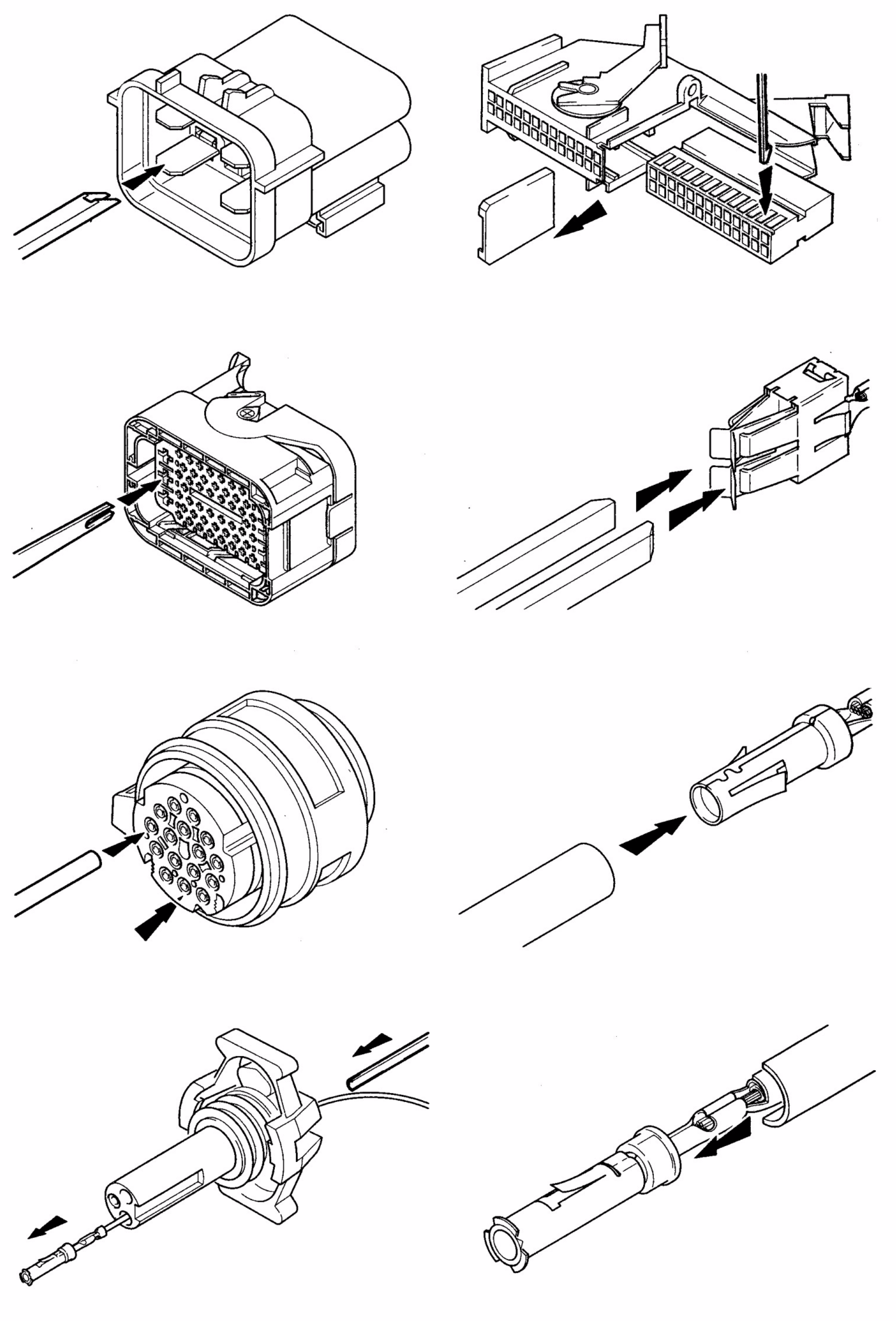


Fig. 87

TERMINAL EXTRACTION



T601.74

Fig. 88

RELATIONSHIP TABLE

Table 5

Cable Conductor Size	Pre-Terminated Lead	Insulation Strip Length
Up to 1.00 mm^2	Red	6.00 to 7.00mm
1.00mm^2–2.00mm^2	Blue	6.00 to 7.00mm
3.00mm^2–6.00mm^2	Yellow	9.00 to 9.50mm

By following this relationship table, the correct amount of insulation will be stripped from the cable.

Cable Stripping

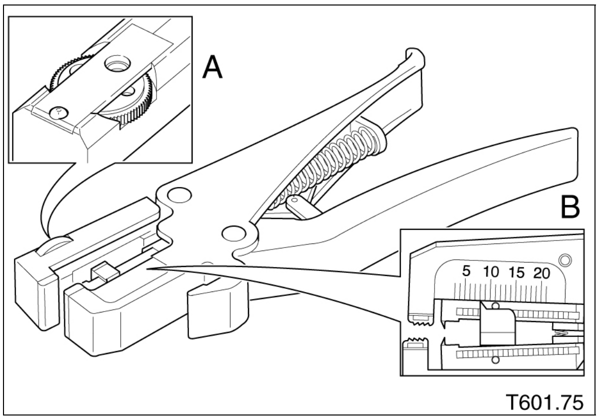


Fig. 89

The insulation stripper has an adjuster wheel with a series of holes **(A)** . Turn the wheel and place the cable in the matching hole to automatically adjust the jaw to the correct pressure.

Press the outer edges of the cable length stop together so the adjuster can be slid up or down the scale **(B)** .

BUTT SPLICE CONNECTOR CRIMPING

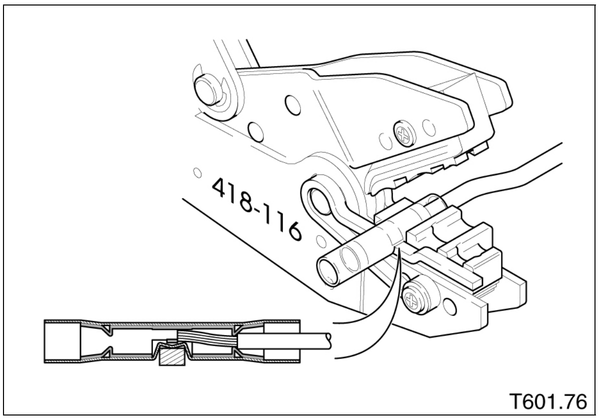


Fig. 90

To crimp the connector:

• Place the appropriate butt splice connector in the crimping tool, matching the color of the butt connector to the color on the tool.

• Make sure that the window indentation in the butt connector is resting over the guide bar on the lower jaw.

• Partially close the jaw onto the butt connector, just enough to secure it in the tool while inserting the cable.

• Insert the stripped end of the cable into the connector until it hits the stop inside.

• Completely close the grip to complete the process.

If the grips have been completely closed, then the connector will be released. If the grips have not been completely closed, the tool will not open to allow the connector to be released. If this happens, simply finish closing the grips and the tool will open.

WORKSHEET –

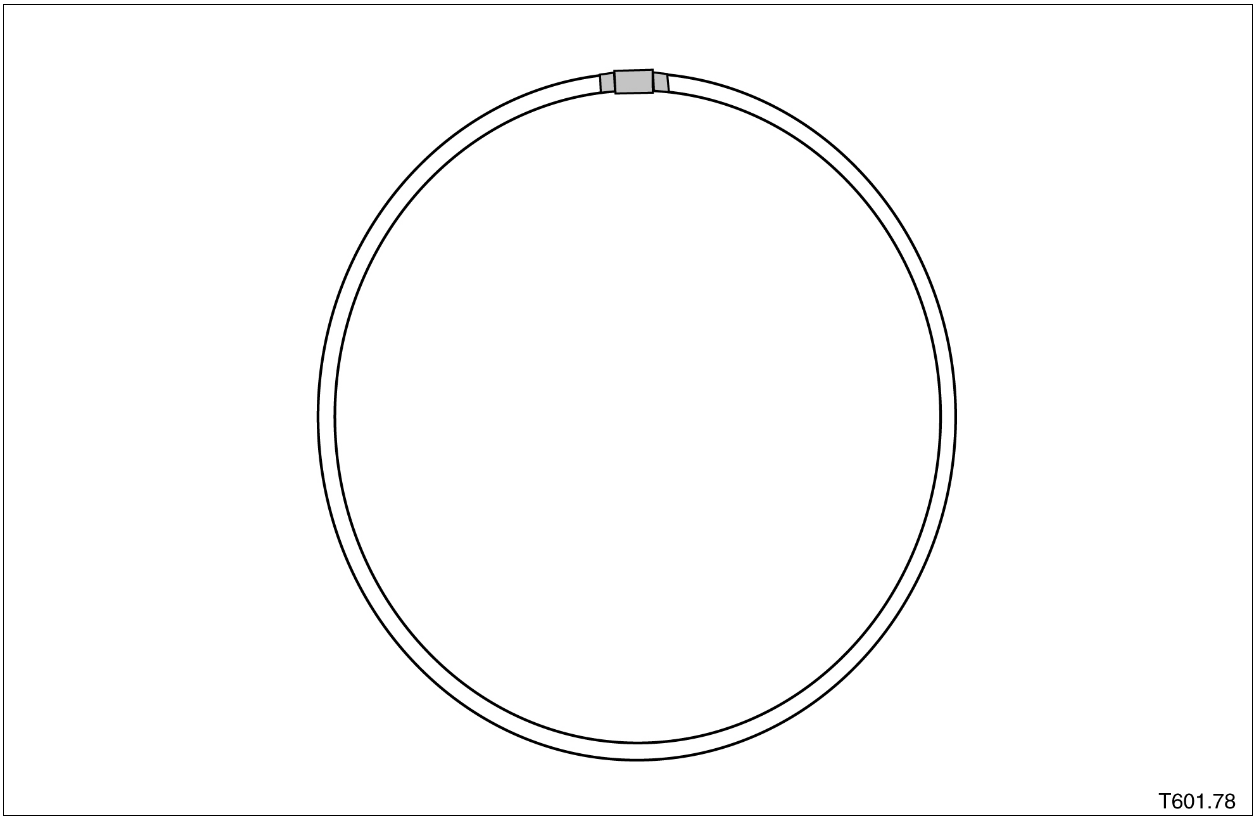


Fig. 91

Connect both ends of the wire together using the piece of cable, butt connector, stripper, and crimper.

BATTERY

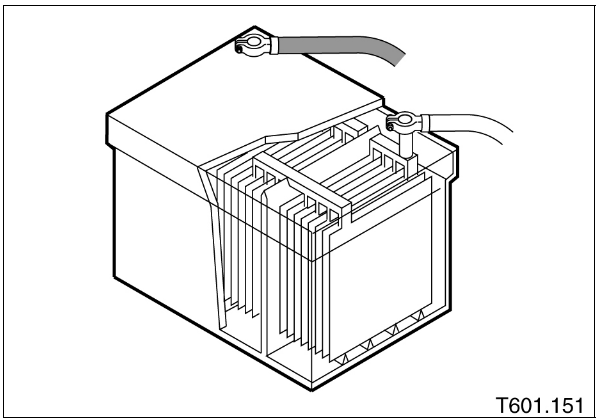


Fig. 92

During starting, the battery supplies electricity to the starter motor, ignition, and fuel system components. The battery provides all vehicle power when the engine is off. Once the vehicle is running, the battery serves as an additional electrical source when vehicle demands temporarily exceed the output of the charging system.

A battery produces electricity through a chemical reaction between positive and negative plates submerged in a solution of sulfuric acid and water. When the battery is fully charged, the chemical difference between the positive and negative plates is high because there is a surplus of electrons at one of the terminals. As the battery discharges, the plates become more alike and the potential difference (voltage) drops. Charging a battery produces a chemical reaction that increases the potential difference of the plates. A fully charged battery outputs between 12.6 and 12.7 volts.

The capacity of the battery is usually given in cold cranking amps (CCA). Cold cranking amps indicate the amount of current the battery can deliver at -17.8°C (0ºF) for 30 seconds while maintaining 7.2 volts, and after 90 seconds maintaining 6V.

In some regions of the world, batteries are rated in ampere-hours. Ampere-hours refers to how much current the battery can deliver during 20 hours at 25°C (77ºF) while maintaining 10.5V. A 100 ampere-hour battery can deliver 5A during 20 hours. The average automobile battery has a capacity of approximately 60 ampere-hours.

The two common types of batteries used in automobiles are low maintenance and maintenance-free. Maintenance-free batteries are completely sealed and do not require addition of water. Low maintenance or standard lead batteries are not sealed and require periodic electrolyte level inspection.

NOTE: If the electrolyte level is low, only use distilled water to top up level.

Reserve capacity

Reserve capacity is determined by the length of time in minutes that a fully charged battery can be discharged at 25 amperes before battery cell voltage drops below 1.75 volts per cell. The reserve capacity rating gives an indication of how long the vehicle can be driven, with the headlights on, if the charging system should fail.

BATTERY TESTING

CAUTION: Always wear safety glasses and safety gloves while working with batteries.

Step 1: Visually inspect the battery

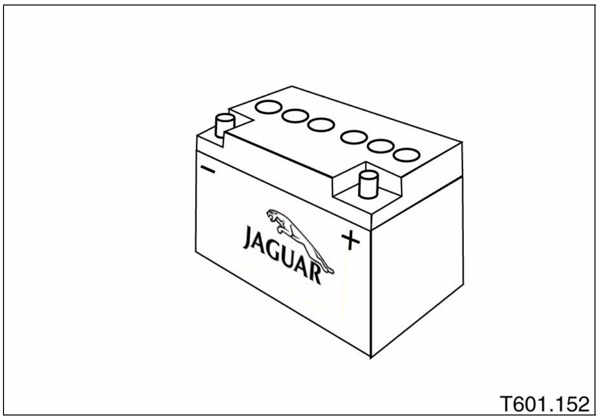


Fig. 93

Check for any obvious cracks, bulges, and corrosion.

Step 2: Test the open circuit voltage

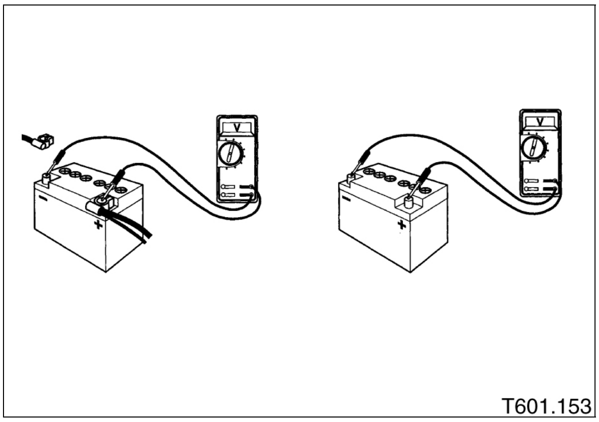


Fig. 94

Measure the battery Open-Circuit Voltage (OCV). If the OCV is 12.6 volts or higher, the battery may be put into service. If the OCV is 12.59 or lower, recharge the battery.

Step 3: Prepare the battery for charging

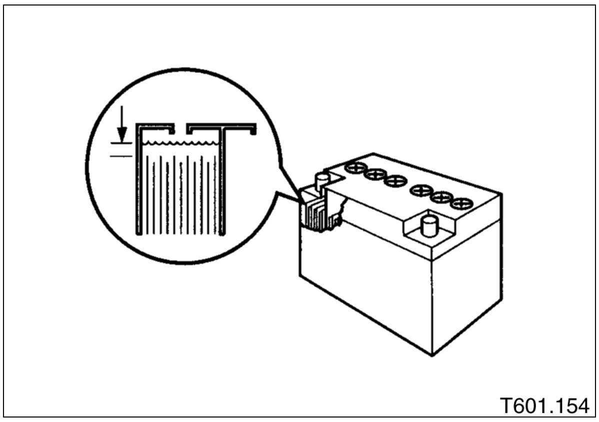


Fig. 95

Check the electrolyte level and top-off with distilled water if necessary. Clean the battery terminals to ensure a proper connection.

Step 4: Recharge if necessary

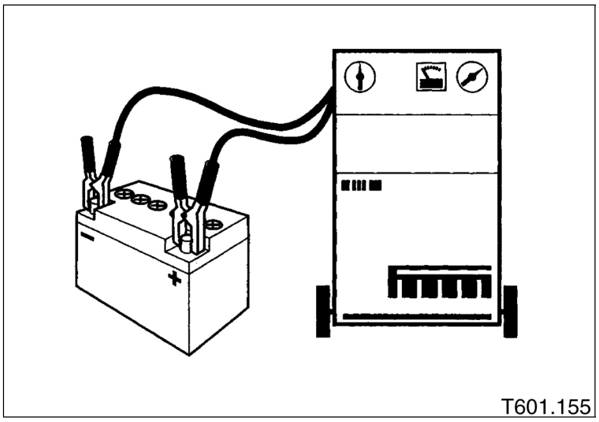


Fig. 96

Determine the rate of charge by comparing the OCV measurement to the values in tables A and B. Remove the covers and charge the battery for the specified rate and time.

NOTE: Do not allow the electrolyte to exceed 50° C (125° F) during charging.

BATTERY TESTING (CONTINUED)

Step 5: Check and record specific gravity

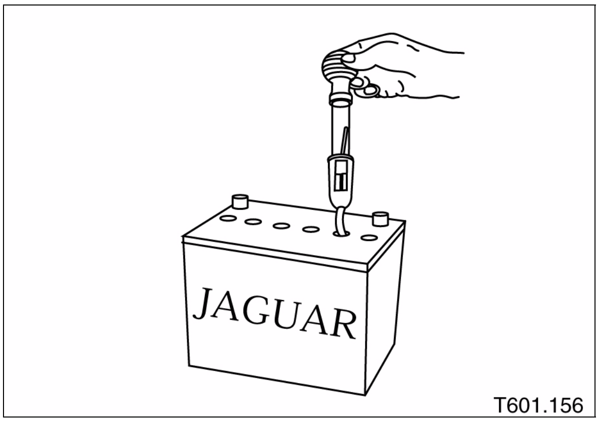


Fig. 97

Measure the specific gravity of each battery cell. Ensure the readings are temperature-compensated. If the lowest cell reading is 1.224 or lower, recharge the battery. If the lowest cell reading is 1.225 or higher, load test the battery.

Step 6: Remove surface charge (if necessary)

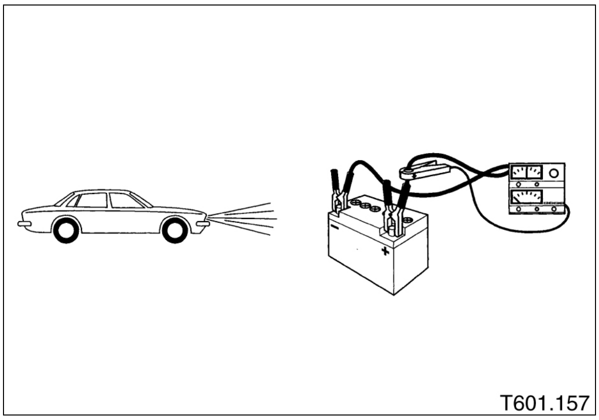


Fig. 98

Battery in vehicle - If the battery has been charged or the engine has ran in the previous 4 hours, remove the surface charge by switching the headlights ON for one minute.

Battery on bench - If the battery has been charged or the engine has ran in the previous 4 hours, remove the surface charge with a discharge tester. Connect the discharge tester to the battery and apply 300 amps for 3 seconds.

BATTERY TESTING (CONTINUED)

Step 7: Measure OCV

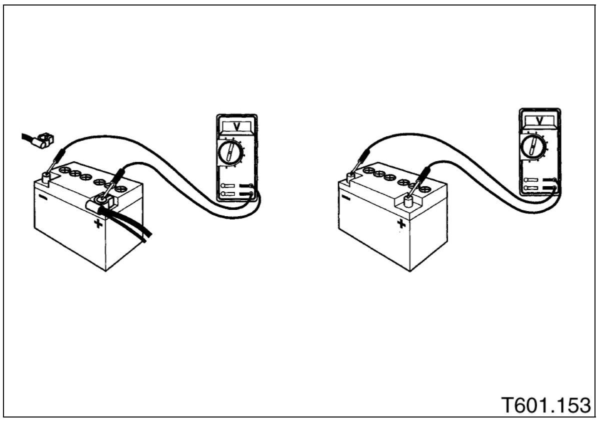


Fig. 99

Measure the battery OCV. If the OCV is 12.6 volts or higher, the battery may be put into service. If the OCV is 12.59 or lower, replace the battery.

Step 8: Load test the battery

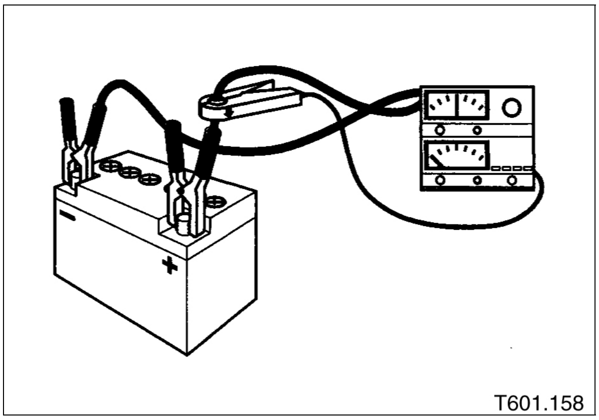


Fig. 100

Connect the load tester to the battery and apply one half of the battery's CCA rating for 15 seconds. Observe and record voltage throughout the test. Immediately reduce current to 0. If the observed voltage is at or above the minimum voltage from table C, the battery is good. If the observed voltage is below minimum voltage from table C, then the battery is defective.

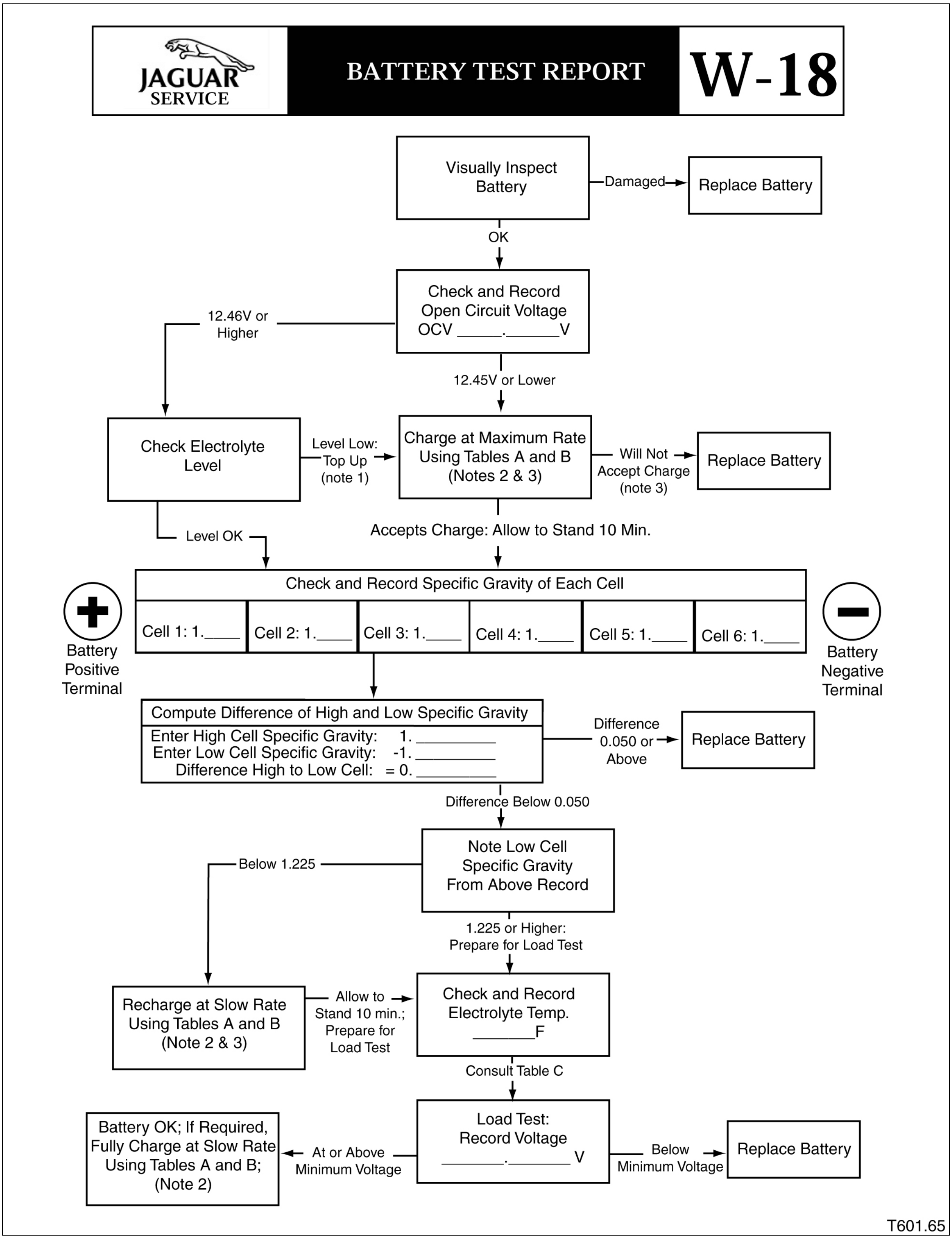

JAGUAR SERVICE
BATTERY TEST REPORT
W-18
Visually Inspect Battery
Damaged
Replace Battery
OK
Check and Record Open Circuit Voltage OCV _____._____V
12.46V or Higher
12.45V or Lower
Check Electrolyte Level
Level Low: Top Up (note 1)
Charge at Maximum Rate Using Tables A and B (Notes 2 & 3)
Will Not Accept Charge (note 3)
Replace Battery
Level OK
Accepts Charge: Allow to Stand 10 Min.
Check and Record Specific Gravity of Each Cell
Cell 1: 1.____
Cell 2: 1.____
Cell 3: 1.____
Cell 4: 1.____
Cell 5: 1.____
Cell 6: 1.____
Battery Positive Terminal
Battery Negative Terminal
Compute Difference of High and Low Specific Gravity
Enter High Cell Specific Gravity: 1. _________
Enter Low Cell Specific Gravity: -1. _________
Difference High to Low Cell: = 0. _________
Difference 0.050 or Above
Replace Battery
Difference Below 0.050
Note Low Cell Specific Gravity From Above Record
Below 1.225
1.225 or Higher: Prepare for Load Test
Recharge at Slow Rate Using Tables A and B (Note 2 & 3)
Allow to Stand 10 min.; Prepare for Load Test
Check and Record Electrolyte Temp. _______F
Consult Table C
Load Test: Record Voltage _______._______ V
Battery OK; If Required, Fully Charge at Slow Rate Using Tables A and B; (Note 2)
At or Above Minimum Voltage
Below Minimum Voltage
Replace Battery
T601.65

Fig. 101

Table A - Battery State of Charge

Open Circuit Voltage	12.70V	12.45V	12.20V	12.00V	11.80V
Specific Gravity (Temp. Compensated hydrometer)	1.270	1.225	1.190	1.150	1.120
% Charged	100%	75%	50%	25%	0%

Table B - Rate of Charge

Battery Condition		Charge Rates	
Specific Gravity (Temp. Compensated hydrometer)	State of Charge	Maximum Charge Rate / Time	Slow Charge Rate / Time
1.190 - 1.225	50% - 75%	20 amps / 60 min.	5 amps / 120 min
1.150 - 1.190	25% - 50%	30 amps / 60 min.	10 amps / 120 min
1.120 - 1.150	0% - 25%	40 amps / 60 min.	15 amps / 120 min

Table C - Load Test

Test Load	Electrolyte Temperature	Min. Voltage Under 15 Sec. Load
Load to 1/2 Battery Cold Cranking Amps (CCA) Rating See battery specification	70 Degees F	9.6
	60 Degees F	9.5
	50 Degees F	9.4
	40 Degees F	9.3
	30 Degees F	9.2
	20 Degees F	9.1
	10 Degees F	8.9
	0 Degees F	8.7
		8.5

NOTE 1: Only use distilled water for topping off electrolyte.
NOTE 2: The electrolyte must not exceed 125 degrees F during charging.
NOTE 3: A sulphated battery will not accept charge due to internal resistance. The specific gravity readings will be even but low (@ 1.18 or less), even after two charging cycles. Charge the battery for at least ten minutes before concluding that the battery will not accept a charge.

T601.66

Fig. 102

QUIESCENT/PARASITIC DRAW

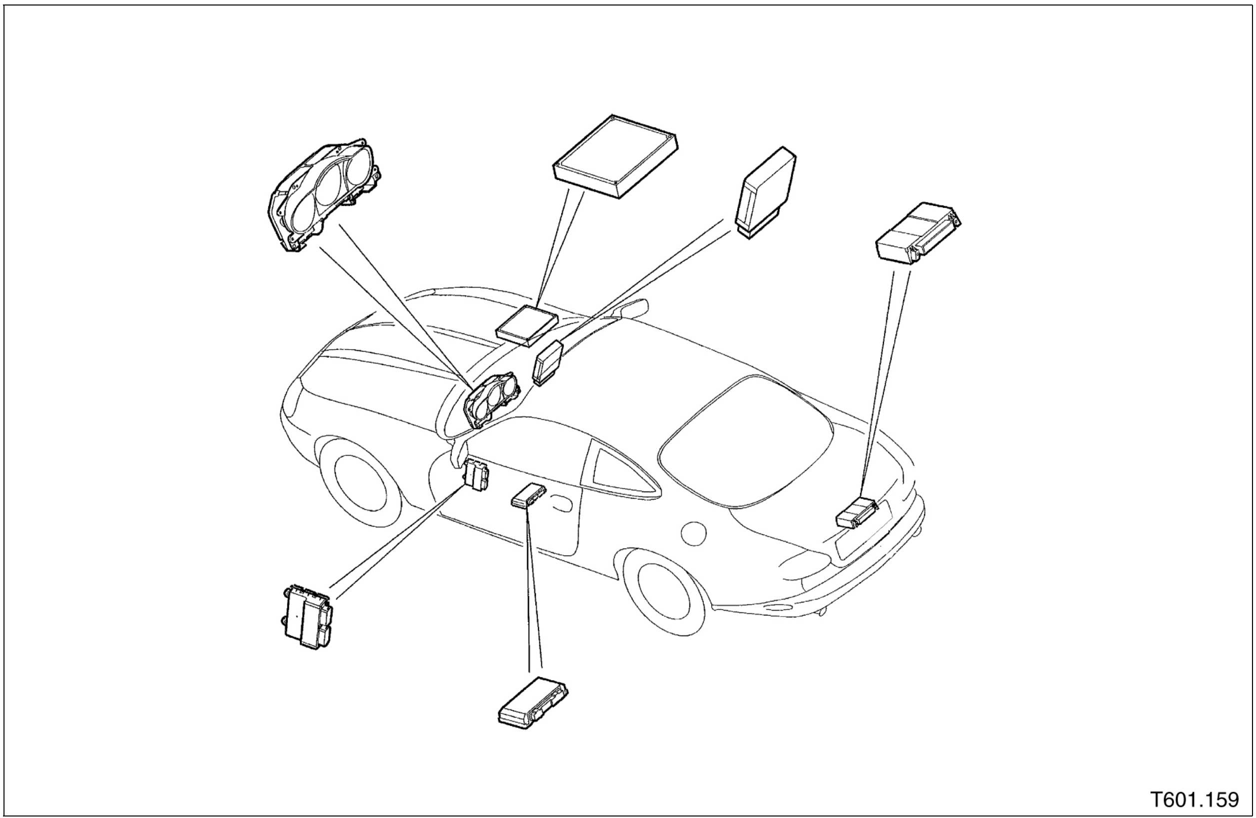


Fig. 103

Quiescent draw is the amount of amperes the normally operating electrical system of a vehicle draws, after all of the factory installed electrical devices are at rest. This amount is vehicle specific and is dependent on the options and accessories the vehicle is equipped with.

Parasitic draw is any draw on the electrical system that exceeds the quiescent specified value.

QUIESCENT/DRAW TEST

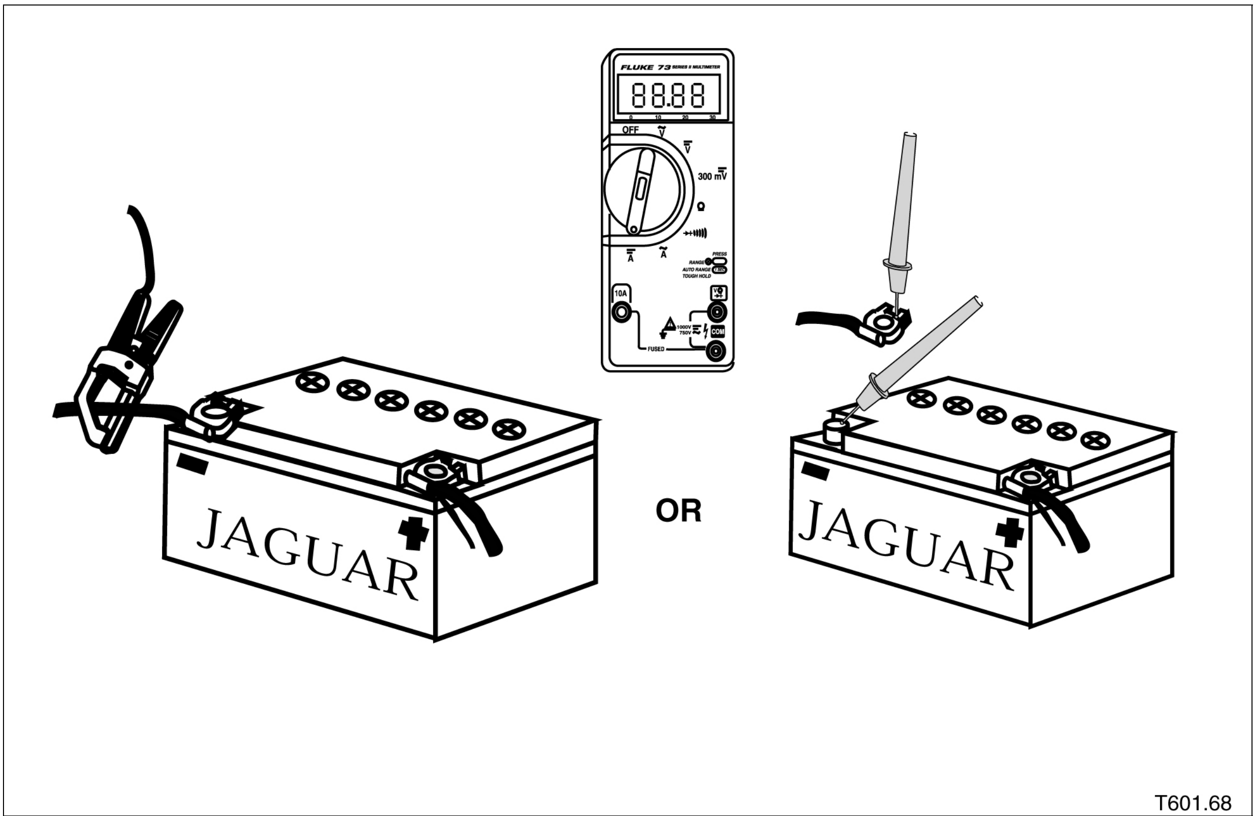


Fig. 104

There are two methods of performing a draw test on the electrical system. The most accurate involves disconnecting the battery and hooking the DVOM in series with the main negative battery terminal.

Under certain circumstances, disconnecting the battery and then reconnecting it will temporarily correct the concern. For this reason it is preferred to use the WDS/DVOM along with the inductive test lead and perform a preliminary test first. Using the inductive test lead does not require the system to be opened, therefore the system is exactly as it is with the fault present. Once a parasitic draw is discovered, the system may have to be opened and a more accurate reading taken.

Specifications

Always refer to the appropriate JTIS publication or current TSBs for the most up to date specifications. The time it takes modules to go to sleep, and the amount of quiescent draw each module has, will vary from model year/series to model year/series.

Activity 6.1

STARTER CIRCUIT VOLTAGE DROP TEST

1. Use the DVOM in DC volts and place the black test lead on the negative battery post and the red test lead on the starter case. Crank engine and note voltage drop. Voltage drop should not exceed 0.5 volts with the engine cranking.

2. Use the DVOM in DC volts and place the red test lead on the positive battery post and the black test lead on the starter motor's permanent voltage supply terminal. With the engine management system disabled, crank engine and note voltage drop. Voltage drop should not exceed 0.5 volts with the engine cranking.

1. If the voltage drop exceeds 0.5 volts during either test, what could be the cause?

Activity 6.2

GENERATOR TASK SHEET

Using the JTIS CD and a PC, document the steps (procedure, pinpoint test number, and results) you would take to isolate a charging system concern where the customer's concern is "The charge indicator is ON with the engine running".

The vehicle is a 2001 X Type with an automatic transmission.

The battery was initially low, but after properly charging and retesting it you find the battery to be good. After running the vehicle for a while, battery voltage was 11.5 volts for all tests and resistance from the generator to battery ground is 2 ohms.

When complete, answer question 2 on the following page by navigating to the proper JTIS section.

-
-
-
-
-
-
-
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2. How do you test the generator and regulator battery circuit (generator output voltage) on a 1997 XK8 Jaguar?

____

____

____

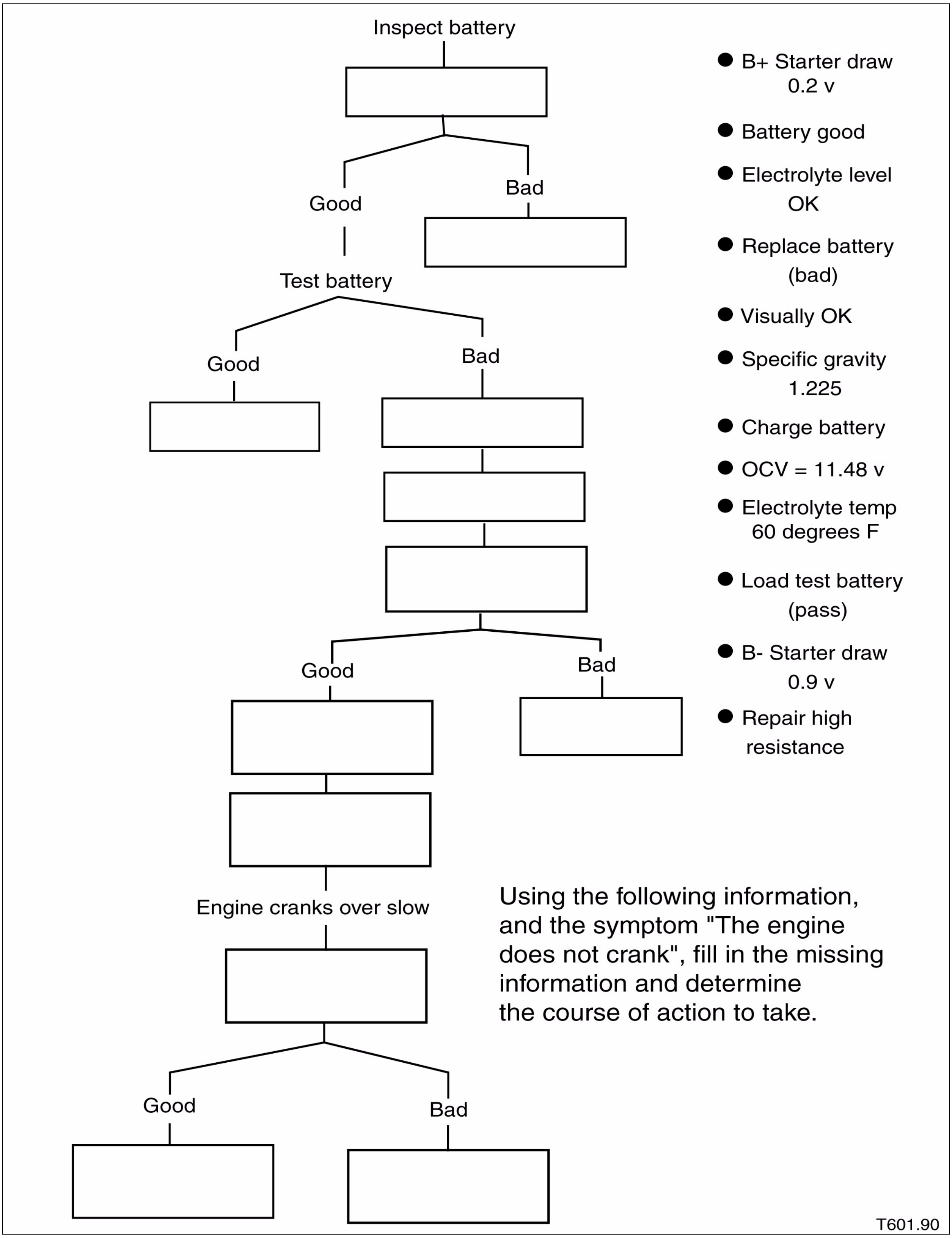
Inspect battery
Good
Bad
Test battery
Good
Bad
Good
Bad
Engine cranks over slow
Good
Bad
● B+ Starter draw 0.2 v
● Battery good
● Electrolyte level OK
● Replace battery (bad)
● Visually OK
● Specific gravity 1.225
● Charge battery
● OCV = 11.48 v
● Electrolyte temp 60 degrees F
● Load test battery (pass)
● B- Starter draw 0.9 v
● Repair high resistance
Using the following information, and the symptom "The engine does not crank", fill in the missing information and determine the course of action to take.
T601.90

Fig. 105

OSCILLOSCOPE

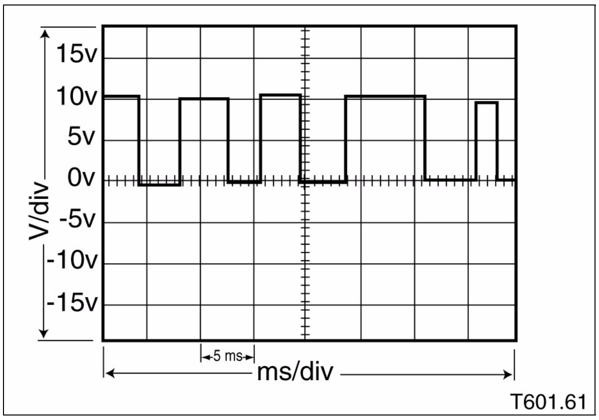

Fig. 106

The WDS oscilloscope measures and displays signals with respect to time. The signals appear as waveforms or traces on a grid comprised of small divisions of time and voltage. An upward movement of the trace represents an increase in voltage, and a downward movement represents a decrease in voltage. As the trace moves from left to right across the screen, the space it occupies represents a specific length of time.

Because the oscilloscope displays actual voltage, it also displays any electrical noise or disturbance accompanying the signal. Some electrical disturbances may be fleeting changes in the voltage due to a momentary shot to voltage or ground. By observing the signal trace, while wiggling harnesses, an intermittent fault may show up.

Basic Waveforms

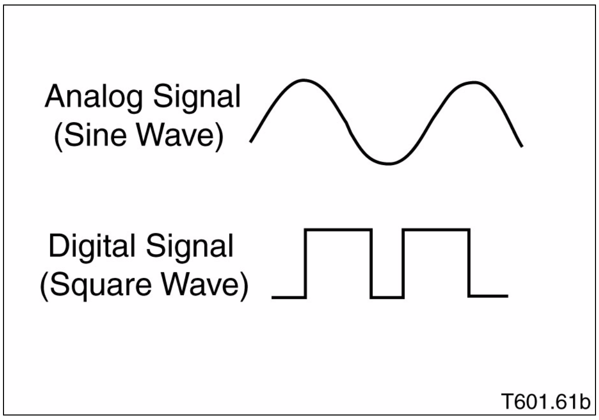

Fig. 107

Most of the signals can be broken into two categories: analog and digital. While analyzing the various waveforms from various circuits, it is clear that each signal has its own unique characteristics, but still fall into one category or the other.

ANALOG CIRCUITS

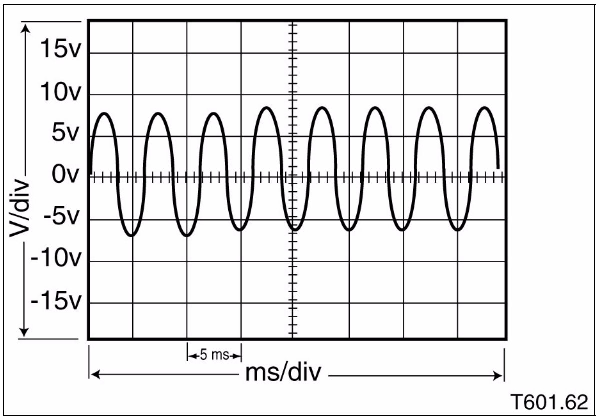

Fig. 108

An analog signal is a varying voltage over a period of time. Analog signals are the result of alternating current produced by such components as crankshaft sensors or speed sensors. The voltage typically alternates from 0 volts to a peak voltage both in a positive and negative voltage direction.

Analog Signal Measurement

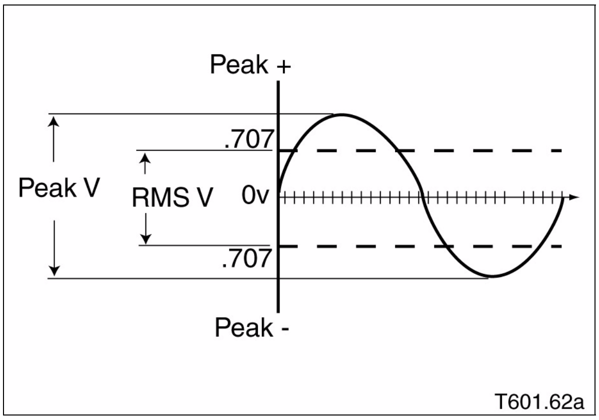

Fig. 109

AC voltage displayed on a oscilloscope is different than the voltage measured with a DVOM. The DVOM takes peak voltage and multiplies it by .707 called Root Mean Square (RMS). To convert RMS voltage to peak voltage, multiply RMS voltage by 1.41.

Digital Circuits

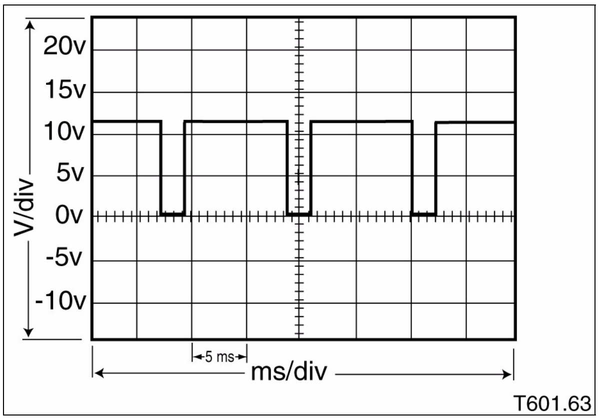

Fig. 110

A digital signal is a square wave. A digital signal is commonly used in computer-based applications because it produces a signal that a computer can understand and process. The ECM converts the ON signal to 1's and the OFF signal to 0's. Using a fuel pump control signal for example, when the component is OFF, voltage is at 13 volts. When commanded ON, voltage drops to 0 volts. Using these signals, the ECM can control ON/OFF time, or the speed at which the fuel pump runs. This enables the ECM to control fuel pressure using the input of the fuel pressure sensor, located in the fuel delivery system.