Power Sources On The Car

Two power sources are used on Toyota vehicles. When the engine is not running or is being started, the **battery** provides power. When the engine is running, the **alternator** provides power for the vehicle's loads and for recharging the battery.

THE BATTERY

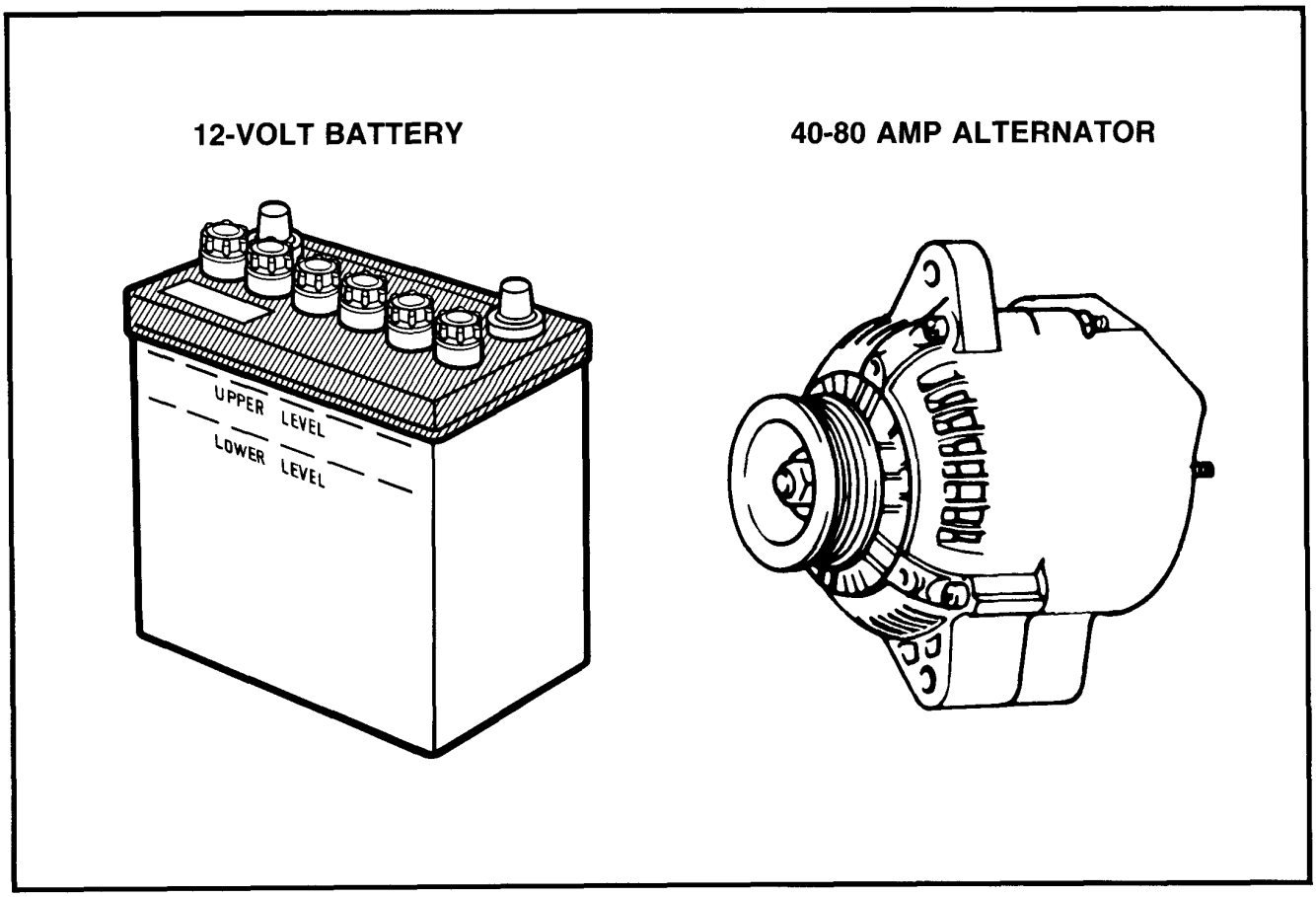
The battery is the primary "source" of electrical energy on Toyota vehicles when the engine is not running or is being started. It uses an electrochemical reaction to change chemical energy into electrical energy for starting, ignition, charging, lighting, and accessories.

All Toyota vehicles use a 12-volt battery. Batteries have polarity markings ... the larger (thicker) terminal is marked "plus" or "POS" (+), the other terminal is marked “minus" or "NEG" (-). Correct polarity is important; components can be damaged if the battery is connected backwards.

THE ALTERNATOR

The alternator is the heart of the vehicle's electrical system when the engine is running. It uses electromagnetism to change some of the engine's mechanical energy into electrical energy for powering the vehicle's loads and for charging the battery.

All Toyota alternators are rated by amps of current output ... from 40 to 80 amps.



Loads

Working devices - or loads - consume electricity. They change electrical energy into another form of energy to do work. This energy may be thermal (heat), radiant (light), mechanical (motive), audio (sound), chemical, or magnetic. The electrical energy is changed by the resistance of the working device. Resistance is put to work in many ways on Toyota vehicles.

PERFORM WORK

Some components use resistance to reduce current flow and change electrical energy (voltage) into heat, light, or motion. Resistance produces heat in electric window defrosters and cigarette lighters. Resistance produces light in lamp filaments. And, resistance produces motion in motors and solenoid coils. All circuit loads use resistance to perform work.

CONTROL CURRENT

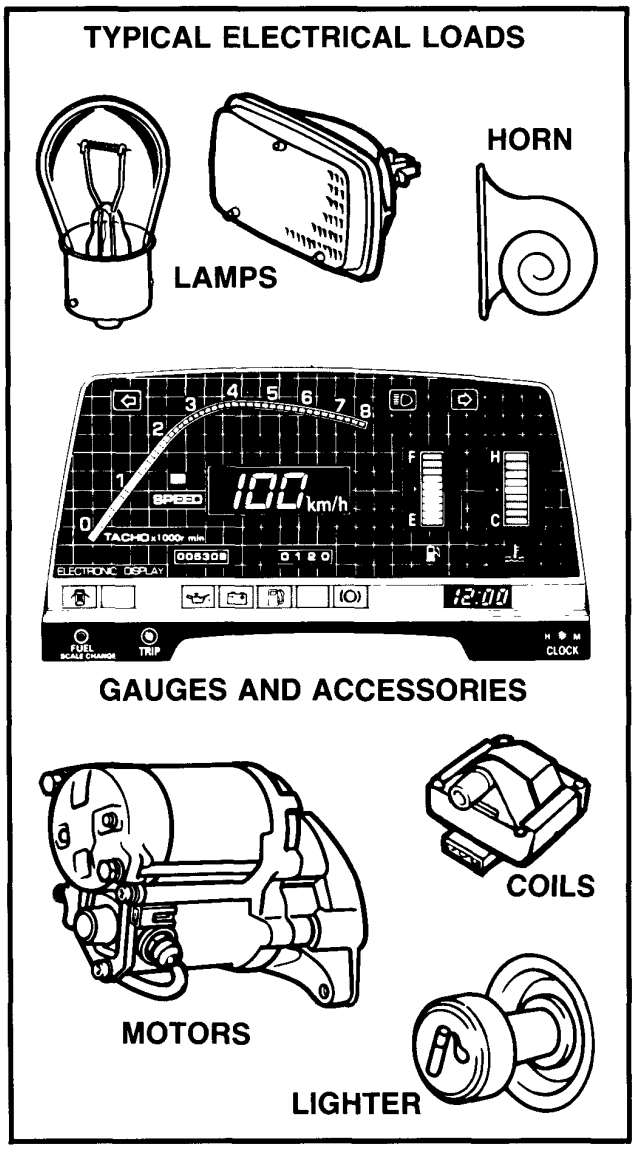
Other components and systems use resistance for current control. Ignition primary resistors, also called **ballast resistors**, maintain and protect the electronic control unit (ECU) from excessive current. The headlamp rheostat adds or subtracts resistance to dim or brighten interior lamps. A carbon pile resistance in the Sun VAT-40 tester "loads" the battery for cranking-voltage and charging system tests. A sliding contact resistance is used on some A/C and heating controls to adjust interior temperature by increasing or decreasing air volume and fan speed. A wire-wound resistor is used on some fuel pumps to reduce pump speed.

REDUCE ARCING AND "RFI"

Some ignition components use resistance to reduce arcing and radio frequency interference (RFI). Condensers use the high resistance of a **dielectric** (insulating) material to separate conductive plates that soak up electrostatic charges and current surges that cause RFI and point arcing. Spark plug cables, also called **carbon resistance wires**, reduce current flow but transmit high voltage to the spark plugs. This causes an extremely hot spark without RFI or rapid burning of the plug electrodes. Spark plugs, themselves, have a carbon core to achieve the same results.

SENSE OPERATING CONDITIONS

Other components use resistance in sensing and monitoring operating conditions. The resistance added to or subtracted from a sensing circuit changes the current flow which is used for input to a control device, gauge, or actuator. The coolant temperature sensor uses a device that changes resistance with temperature. The fuel-level sensor uses a type of potentiometer, or sliding-contact resistance. The automatic headlamp control uses a photoresistor. The manifold vacuum sensor uses a crystal which changes resistance with pressure. And, with the use of electronic control systems growing rapidly, many more sensors and actuators are using the variation of resistance to operate.



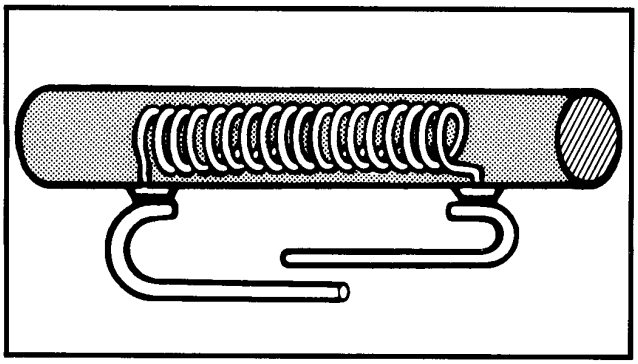
Types Of Resistors

Three basic types of resistors are use a m automotive electrical systems ... fixed value, stepped or tapped, and variable. Different symbols are used for the different types of resistors.

FIXED-VALUE RESISTORS

Two types of fixed-value resistors are used: wire-wound and carbon.

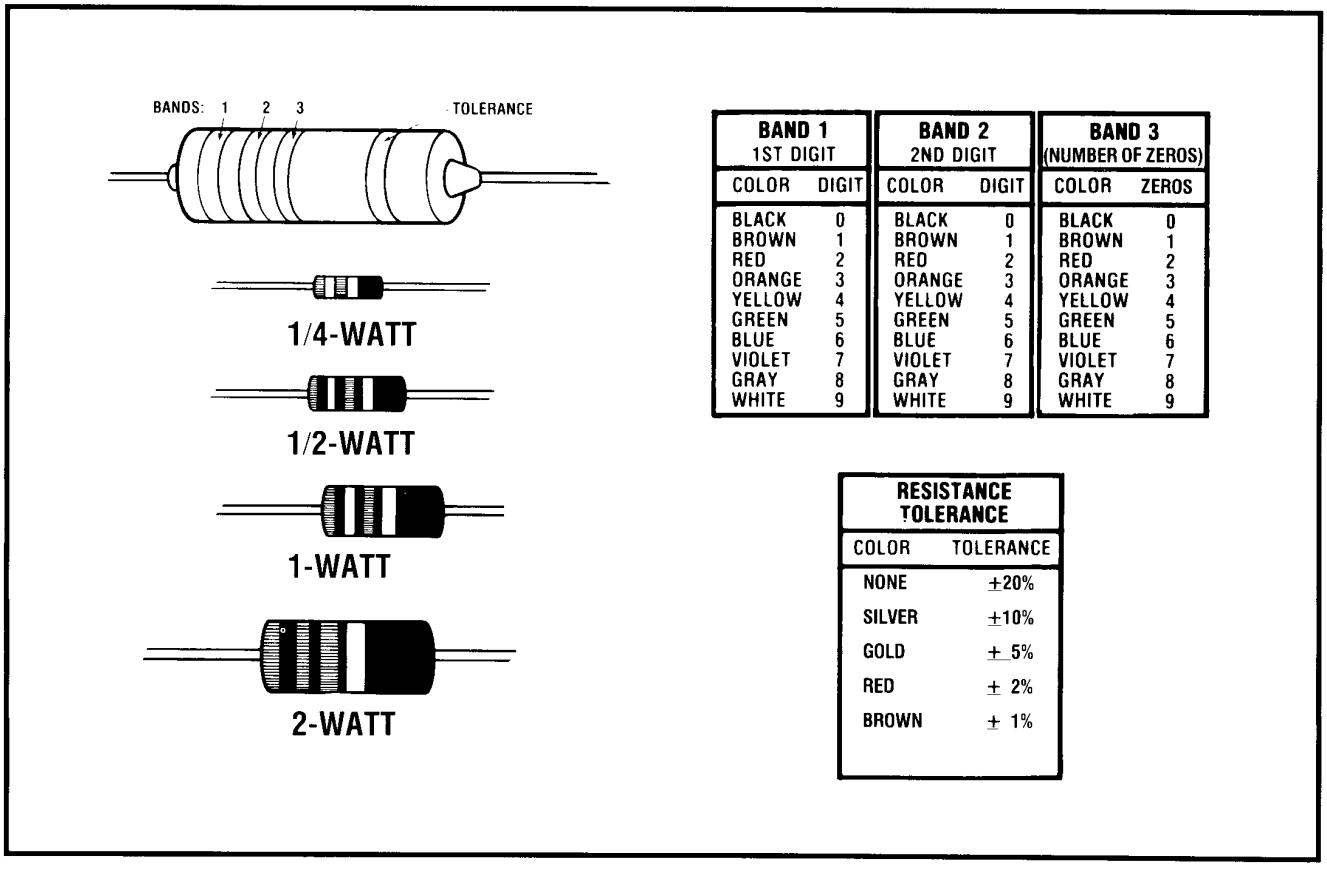
Wire-wound resistors are made with coils of resistance wire. Sometimes called power resistors, they are very accurate and heat stable. The resistance value is marked.



Carbon resistors are common in Toyota electronic systems. Carbon is mixed with binder; the more carbon, the lower the resistance. Some have the resistance value stamped on, others are rated by wafts of power; most have color-code bands to show the resistance value. Four bands are used ... the first two bands give the resistance digits, the next band is the number of zeros, and the last band gives the "tolerance."

A resistor with four bands - red, green, black, and brown from left to right - would be sized as follows:

- The first two bands set the digits ... red (2), green (5).
- The next band is the number of zeros. Black is "0" zeros. So the resistor has a base value of 25Ω.
- And, the last band is the tolerance ... brown (1 %). So, the resistance value is "25 ohms plus or minus .25 ohms" (24.75Ω to 25.25Ω).

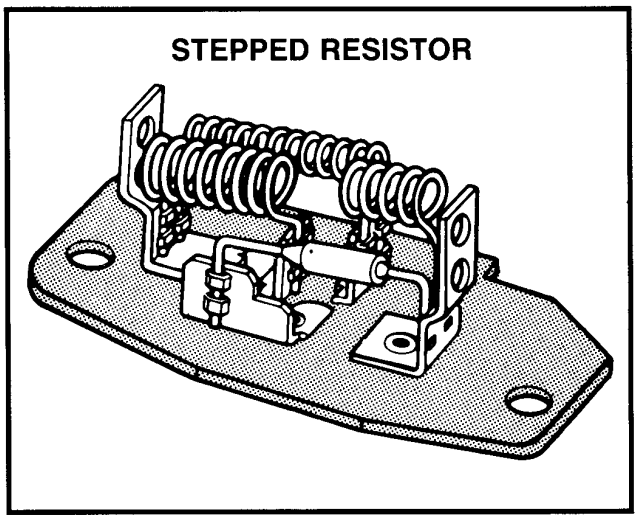


BAND 1 1ST DIGIT		BAND 2 2ND DIGIT		BAND 3 (NUMBER OF ZEROS)	
COLOR	DIGIT	COLOR	DIGIT	COLOR	ZEROS
BLACK	0	BLACK	0	BLACK	0
BROWN	1	BROWN	1	BROWN	1
RED	2	RED	2	RED	2
ORANGE	3	ORANGE	3	ORANGE	3
YELLOW	4	YELLOW	4	YELLOW	4
GREEN	5	GREEN	5	GREEN	5
BLUE	6	BLUE	6	BLUE	6
VIOLET	7	VIOLET	7	VIOLET	7
GRAY	8	GRAY	8	GRAY	8
WHITE	9	WHITE	9	WHITE	9

RESISTANCE TOLERANCE	
COLOR	TOLERANCE
NONE	±20%
SILVER	±10%
GOLD	± 5%
RED	± 2%
BROWN	± 1%

STEPPED OR TAPPED RESISTORS

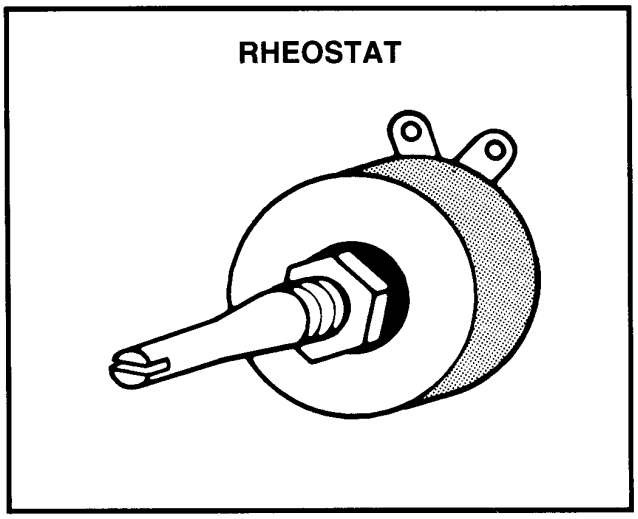
Stepped or tapped resistors have two or more fixed resistance values. The different resistances (carbon or wire) are connected to different terminals in a switch. As the switch is moved, different resistance values are placed in the circuit. A typical Toyota application is in the heater motor's blower-fan switch.

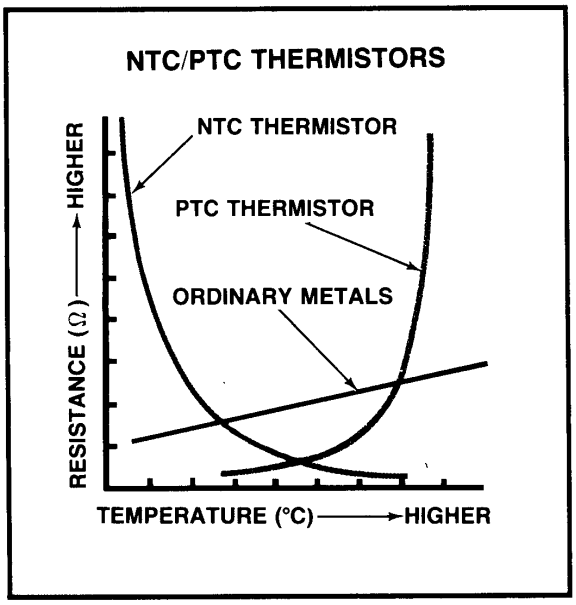


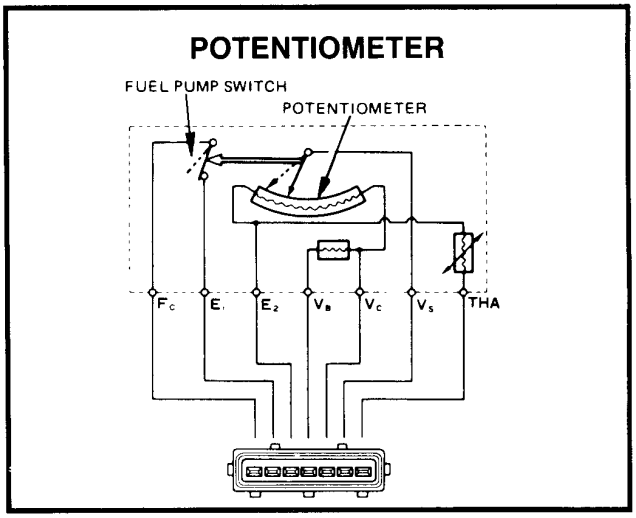
VARIABLE RESISTORS

Three types of variable resistors are used: rheostats, potentiometers, and thermistors.

- **RHEOSTAT** - Toyota uses a rheostat on the headlamp switch to dim or brighten dash panel lighting. Rheostats have two connections ... one to the fixed end of a resistor, one to a sliding contact on the resistor. Turning the control moves the sliding contact away from or toward the fixed end, increasing or decreasing the resistance.
- **POTENTIOMETER** - Toyota uses a potentiometer in the EFI airflow meter. Potentiometers have three connections ... one at each end of a resistor and one on a sliding contact. Turning the control places more or less resistance in the circuit.
- **THERMISTOR** - Toyota uses NTC (negative temperature coefficient) thermistors in temperature sensors and PTC (positive temperature coefficient) thermistors in the electric assist choke. Both types of thermistors change resistance with increasing temperature (NTC, resistance goes down as temperature goes up; PTC, resistance goes up as temperature go up.)







Controls

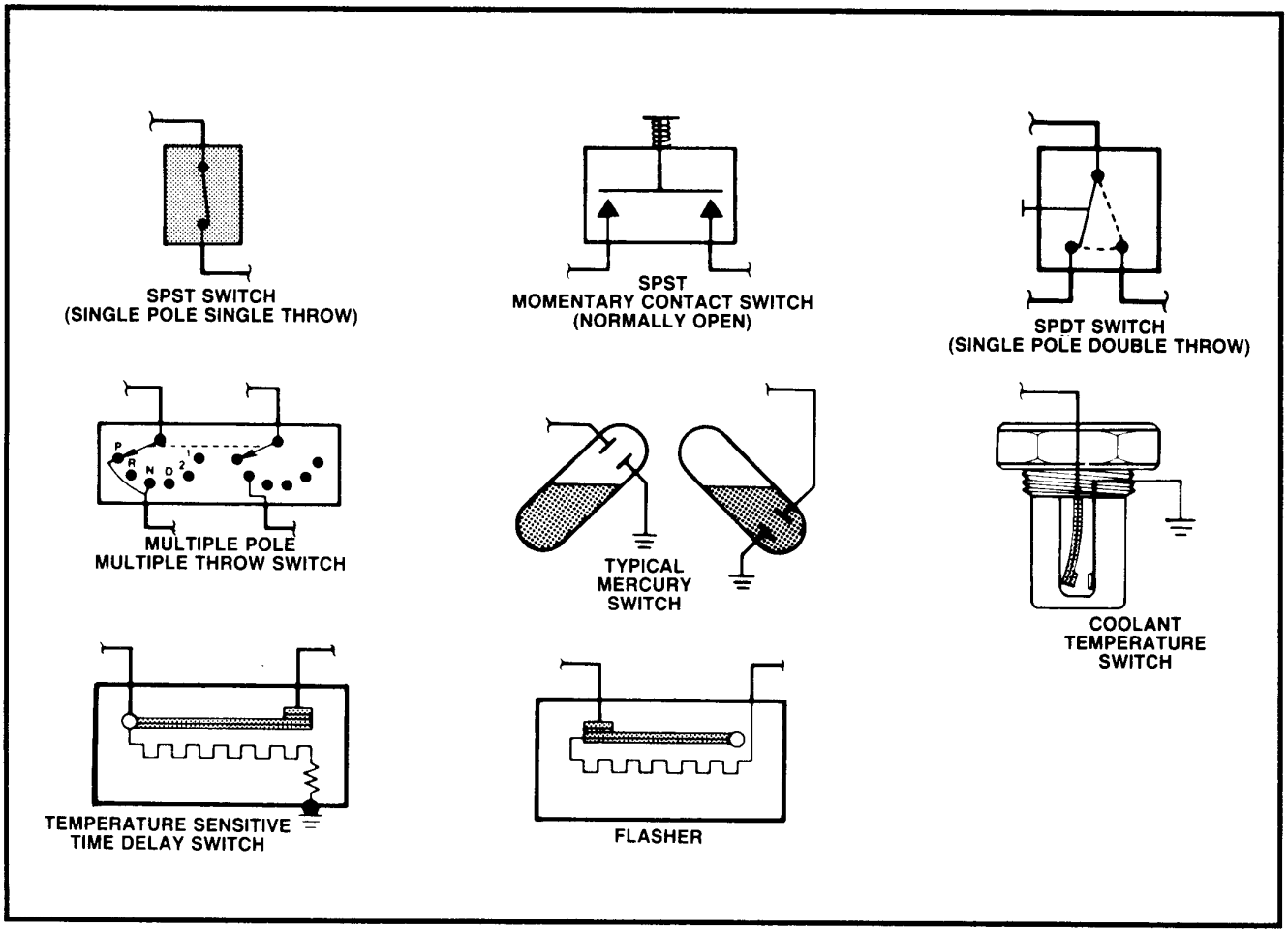
Control devices used in electrical circuits on Toyota vehicles include a variety of switches, relays, and solenoids. Electronic control devices include capacitors, diodes, and transistors. Controls are needed to start, stop, or redirect current flow. Most switches require physical movement for operation, relays and solenoids are operated with electromagnetism, electronic controls are operated electrically.

SWITCHES

Switches are the most common circuit control device. They usually have two or more sets of contacts. Opening the contacts is called "opening" or "breaking the circuit," while closing the contacts is called "closing" or "making" the circuit. "Poles" refer to the number of input circuit terminals. "Throws" refer to the number of output circuits. Such switches are referred to as SPST (single-pole, single-throw), SPDT (single-pole, double-throw), and MPMT (multiple-pole, multiple-throw).

The various types of switches include:

- **Hinged pawl** - a simple SPST switch to make or break a circuit.
- **Momentary contact** - another SPST switch, normally open or closed, which makes or breaks the circuit when pressed ... typically used for the horn switch.
- **SPDT** - one wire in, two wires out ... commonly used in high-beam / low-beam headlamp circuits.
- **MPMT** - movable contacts are linked to sets of output terminals ... may be used for the transmission neutral start switch.
- **Mercury switch** - liquid mercury flows between contacts to make circuit ... commonly used to turn engine compartment and trunk lamps on and off.
- **Temperature-sensitive switch** - a bimetal element bends when heated to make contact completing a circuit or to break contact opening a circuit. The same principle is also used in time-delay switches and flashers.



RELAYS

A relay is simply a remote-control switch, which uses a small amount of current to control a large amount of current. A typical relay has a control circuit and a power circuit. The control circuit is fed current by the power source, and the current flows through a switch and an electromagnetic coil to ground. The power circuit is also fed current from the power source, and the current flows to an armature which can be attracted by the magnetic force on the coil.

In operation, when the control circuit switch is open, no current flows to the relay. The coil is not energized, the contacts are open, and no power goes to the load. When the control circuit switch is closed, however, current flows to the relay and energizes the coil. The resulting magnetic field pulls the armature down, closing the contacts and allowing power to the load.

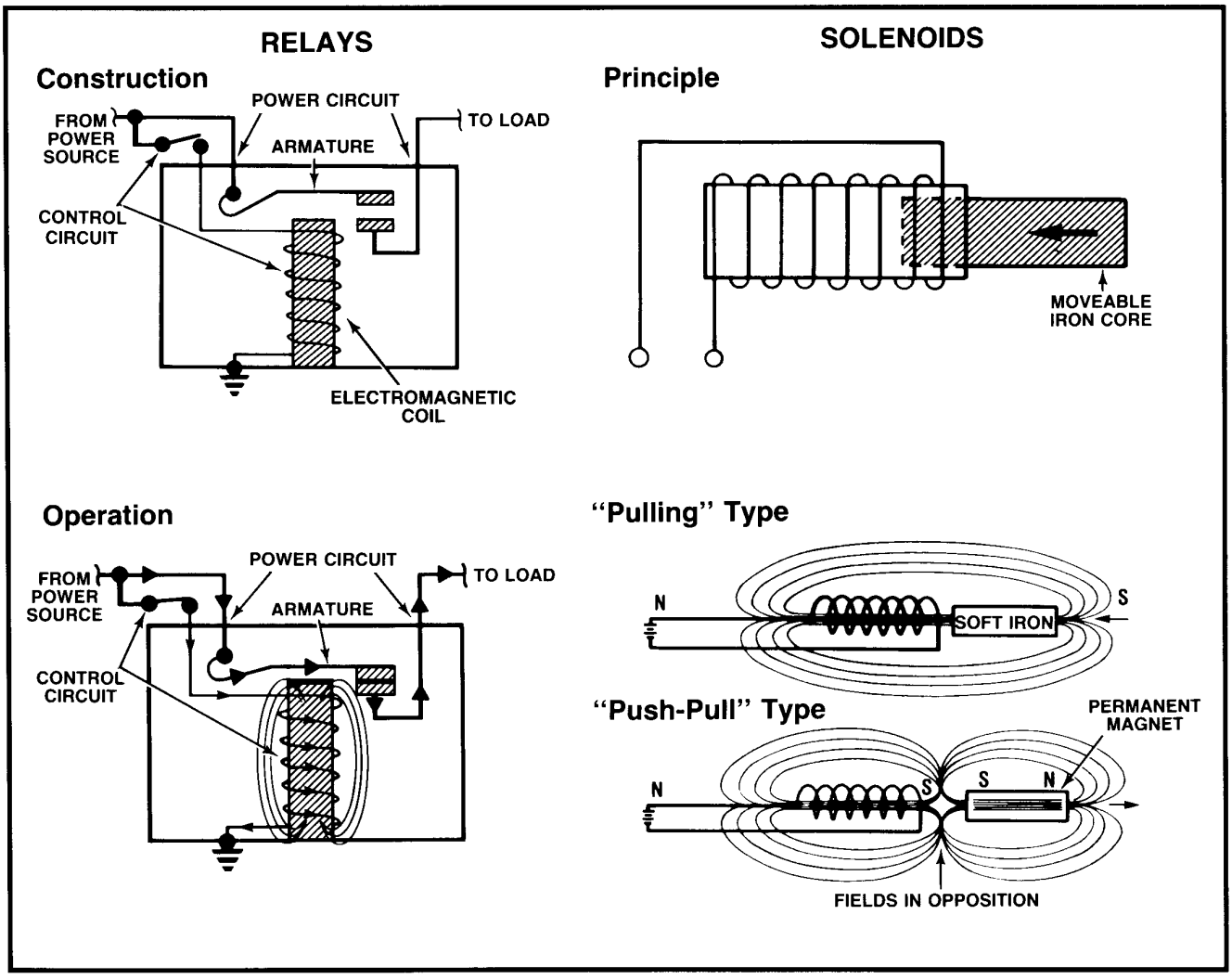
Many relays are used on Toyotas for controlling high current in one circuit with low current in another circuit. The relay control circuit can be switched from the power supply side or, more common in Toyotas, from the ground side.

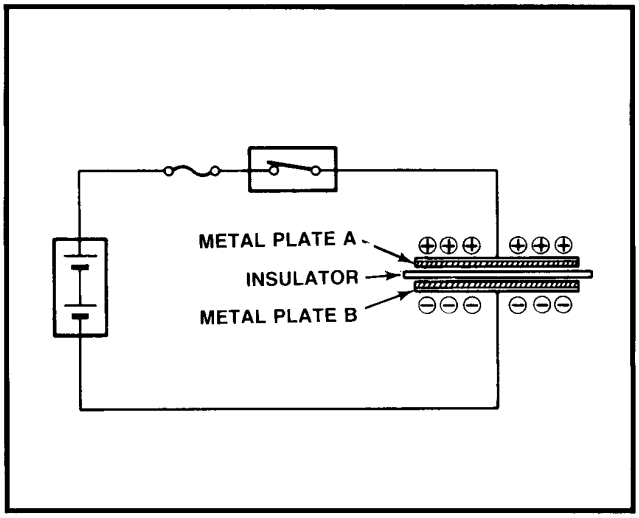
SOLENOIDS

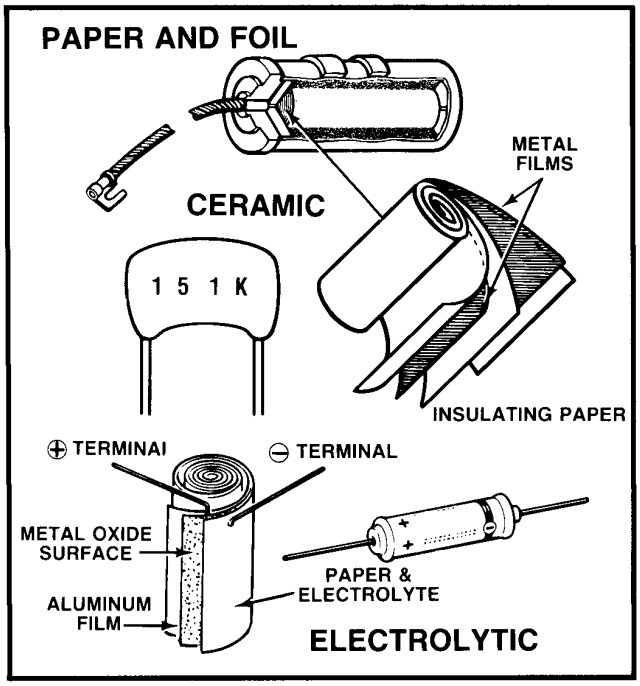
Solenoids are electromagnetic switches with a movable core that converts current flow into mechanical movement.

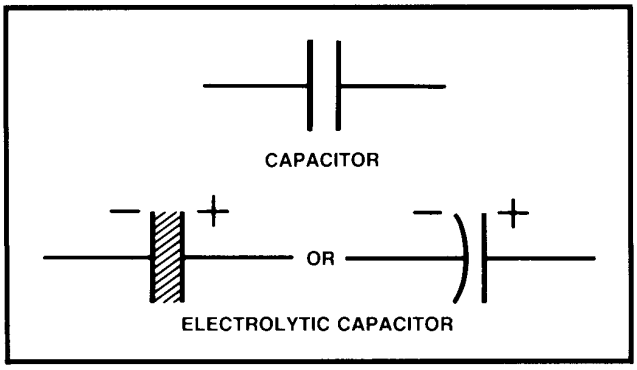
In a "pulling" type solenoid, the magnetic field pulls a core into a coil. These solenoids are called magnetic switches on Toyota starters. A pull-in coil "pulls" the core into the coil, and a hold-in coil "holds" the core in place.

In a "push-pull" type solenoid, a permanent magnet is used for the core. By changing the direction of current flow, the core is "pulled in" or "pushed out." A typical use is on electric door locks.









CAPACITORS

Capacitors use an electrostatic field to "soak up" or store an electrical charge. In a circuit, a capacitor will build up a charge on its negative plate. Current flows until the capacitor charge is the same as that of the power source. It will hold this charge until it is discharged through another circuit (such as ground). Always handle capacitors with care; once charged, they can be quite shocking long after the power is removed.

• TYPES

A capacitor has two conducting plates separated by an insulating material or **dielectric**. Three types are used: **ceramic** for electronic circuits, **paper and foil** for noise suppression in charging and ignition systems, and **electrolytic** for turn-signal flashers. Different symbols are used for ordinary and electrolytic capacitors.

• RATINGS

Automotive capacitors are rated in microfarads, and the rating is usually stamped on the case. Always choose a capacitor rated for the maximum expected voltage.

Capacitance	Basic Unit	Units for Small Values	
Symbol	F	μF	pF
Pronounced As	Farad	Microfarad	Picofarad
Multiplier	1	1×10^{-6} (1/1,000,000)	1×10^{-12} (1/1,000,000,000,000)

• DIAGNOSIS / TESTING

Capacitors can be tested for short circuits using an ohmmeter. Connect one test lead to the capacitor mounting clip and the other test lead to the capacitor pigtail connector. The meter needle will first show some continuity as the meter's battery charges the capacitor, then will swing to infinite resistance (∞). If only continuity is seen, the capacitor is most likely shorted.

Electronics

"Electronic" devices and systems provide today's vehicles with added comfort, convenience, safety, and performance.

These devices and systems, like their "electrical" counterparts, control electricity to do work. The current flows through a **semiconductor** - rather than through wires. The movement usually produces an electrical signal - rather than heat, light, or motion. And, this signal may be transmitted, amplified, or used in special circuits to perform logical decision-making functions.

Since there are seldom any moving (electromechanical) parts, these devices and systems are often called solid-state electronics.

SEMICONDUCTORS

Semiconductors can act like conductors or insulators. They have a resistance higher than that of conductors like copper or iron, but lower than that of insulators like glass or rubber. They have special electrical properties:

- Conductivity can be increased by mixing in certain substances;
- Resistance can be changed by light, temperature, or mechanical pressure; and,
- Light can be produced by passing current through them.

DIODES

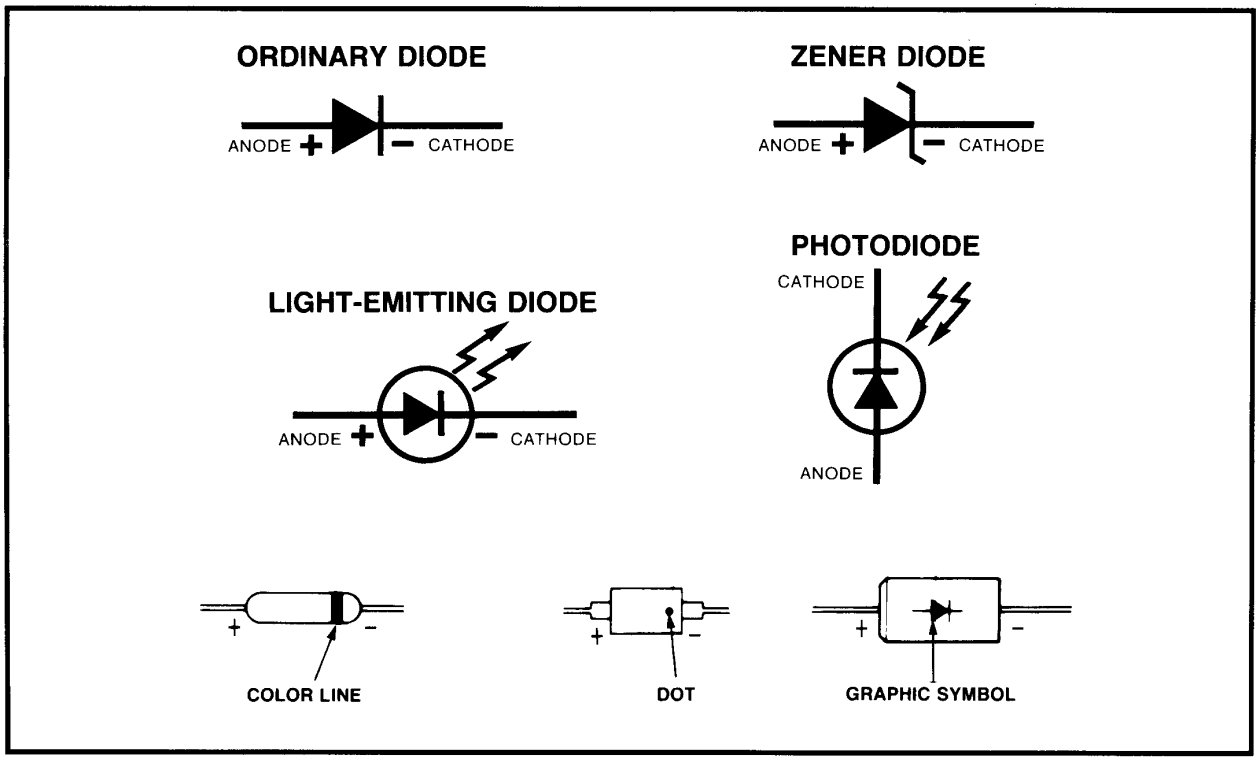
Diodes are semiconductor devices which act as one way electrical check valves. Diodes will allow current flow in one direction (anode to cathode), but block it in the reverse direction (cathode to anode).

• TYPES / USES

There are several types of diodes. **Rectifying diodes** change low-current AC to DC in the charging system. **Power rectifiers** can handle larger currents in electronic power supplies. **Zener diodes** can function as voltage sensitive switches. They turn "on" to allow current flow once a certain voltage is reached. They are often used in voltage regulation applications. **Light-emitting diodes** (LEDs) are used for indicator lights and digital displays. And, photodiodes detect light for sensors.

• SYMBOLS

Symbols for various diodes are shown. The arrow points in the "forward" direction of current flow (anode to cathode). Zener diodes have a "Z" shaped bar on the cathode side. LEDs and photodiodes are enclosed in a circle with incoming or outgoing light indicated.



Transistors

Transistors are semiconductor devices for controlling current flow. A "transistor" (transformer + resistor) transfers signals across the resistance of two semiconductor materials.

• TYPES / USES

There are many types of transistors. **Ordinary** or bipolar transistors are most common for switching and amplifying. **Power transistors** are a variation for larger currents; exposed metal carries away heat. **Phototransistors** are another variation, used as light-sensitive switches in speedometer and headlamp systems.

Field-effect transistors (FETs) are quite different. They are used as switches, amplifiers, and voltage controlled resistors.

• SYMBOLS

Bipolar transistors are shown with a line and arrow for the **emitter**, a heavy T-shaped line for the **base**, and a line without an arrow for the **collector**. The emitter arrow points to the circuit's negative side. Phototransistors have incoming light arrows added. And, FETs have an arrow showing negative (N) or positive (P) voltage.

• OPERATION

In bipolar transistors, a small base current (I b) between the emitter-base "turns on" the transistor and causes a larger current (I c) to flow between the emitter-collector. In phototransistors, light striking the base "turns on" the transistor. This switches on a second transistor which amplifies the signal.

ELECTRONIC CIRCUITS AND SYSTEMS

Individual semiconductor devices are called **discrete devices**, a number of them may be used in a circuit. Such devices are common in charging, ignition, and headlamp circuits that handle large amounts of power.

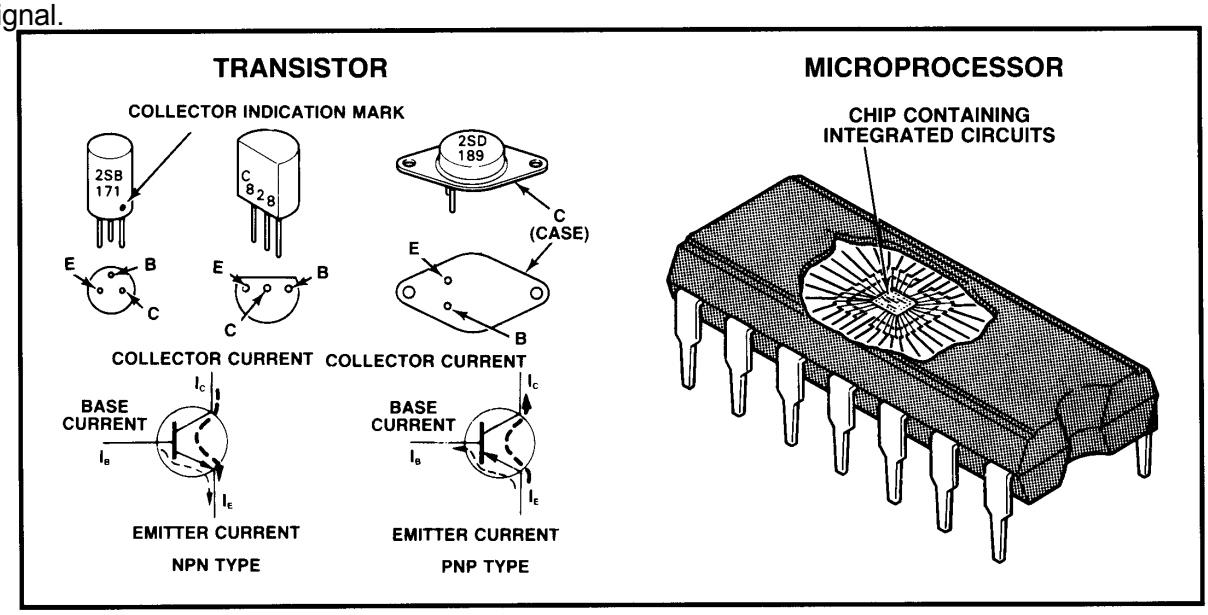
The more sophisticated electronic control systems now being used on the vehicle, however, make use of **integrated circuit**s and **microprocessors** or onboard computers.

• INTEGRATED CIRCUITS

An integrated circuit (IC) has hundreds, even thousands, of discrete devices on a single silicon chip. These include diodes, transistors, resistors, and capacitors. The IC is usually packaged in ceramic or plastic and each tiny device inside is connected to one or more leads that plug into a larger on-vehicle circuit. One type can process **analog signals** - those that change continuously with time. Another type can process **digital signals** - those that change intermittently "on" or "off" with time.

• MICROPROCESSORS

Microprocessors, or on-board computers, are used on various electronic control systems. Such systems have three basic parts: 1) **sensors** tell what is happening; 2) the **microprocessor** computes the data and decides what to do; and 3) the **actuators** or controls respond to change or display the condition. The ECS and ABS are examples of such systems.



Protective Devices

Electrical circuits are protected from too much current by fuses, fusible links, and circuit breakers. Such devices will interrupt a circuit to prevent high current from melting conductors and damaging loads. Each of these circuit protection devices is sensitive to current, not voltage, and is rated by current-carrying capacity. They are usually located at, or near, the power source for the circuit being protected. As such, they are usually a good starting point during electrical problem troubleshooting. Remember, though, these devices "blow" or open a circuit because of a problem. Always locate and correct the problem **before** replacing a fuse or fusible link or resetting a circuit breaker.

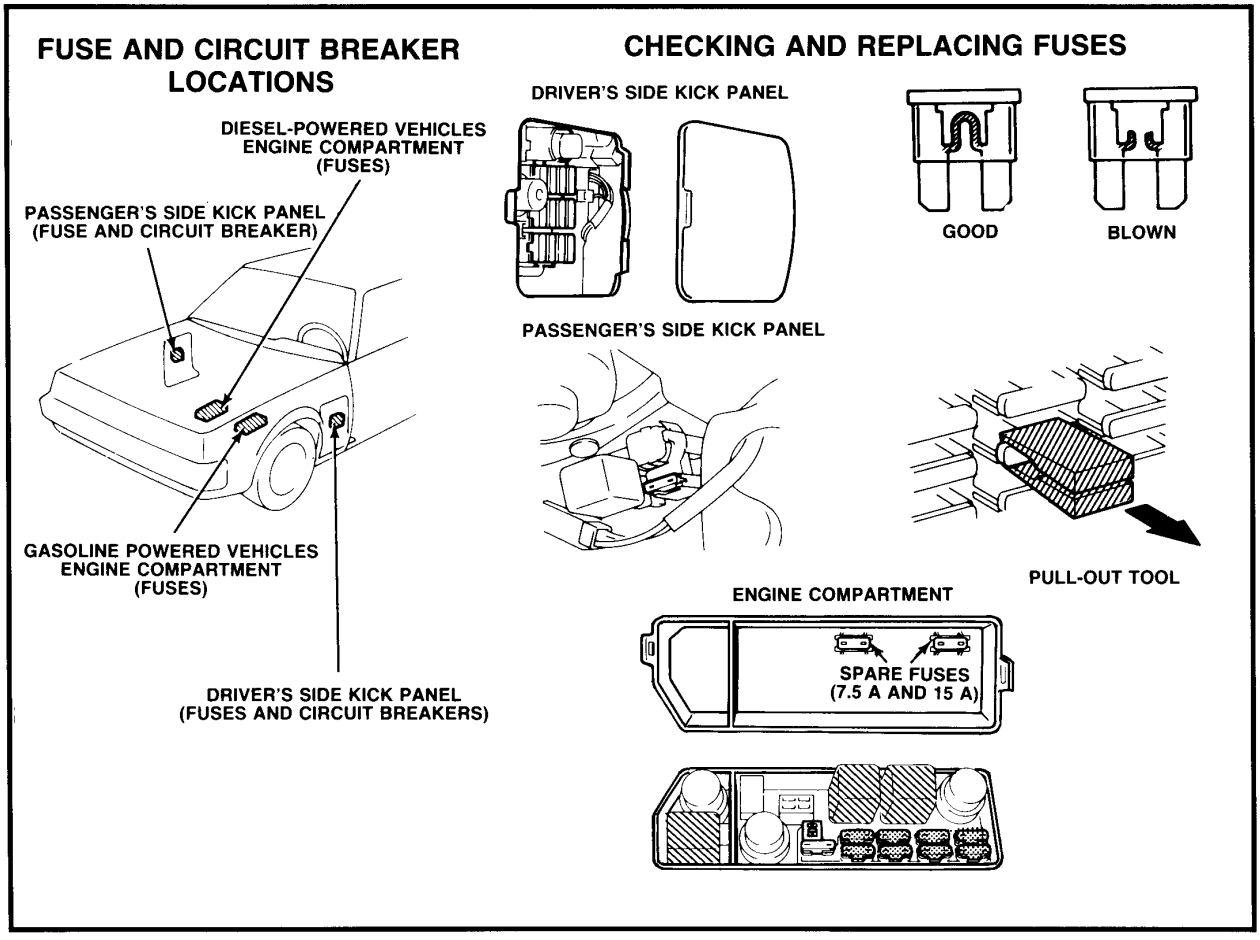
FUSES

Fuses are the most common circuit protection device. Fuses have a fusible element, or low-melting-point metal strip, in a glass tube or plug-in plastic cartridge. These fuses are located in a fuse block under the dash or behind a kick panel. Most circuits - other than the headlamp, starter, and ignition systems - receive power through the fuse block. Battery voltage is supplied to a **buss bar** in the block. One end of each fuse is connected to this bar, the other end to the circuit it protects.

Fuse ratings range from 0.5 to 35 amps, but 7.5 - amp to 20-amp fuses are most common.

— CAUTION —

1. **Turn off all electrical components and the ignition switch before replacing a fuse. Do not exceed the fuse amp rating.**
2. **Always use a fuse puller for removing and inserting a fuse. Remove and insert straight in and out without twisting. Twisting could force open the terminals too much, resulting in a bad connection.**



FUSIBLE LINKS

Some circuits use fusible links, or fuse links, for overload protection. Toyotas can have as many as six fusible links protecting circuits for charging, starting, ignition, and certain accessories. Check the "Power Source" page in the Electrical Wiring Diagram manual for the specific vehicle.

A fusible link is a short length of smaller gauge wire installed in a circuit with larger conductors. High current will melt the link before it melts the circuit wiring. Such fuse links have special insulation that blisters or bubbles when the link melts. A melted link must be replaced with one of the same size after the cause of the overload has been identified and the problem corrected.

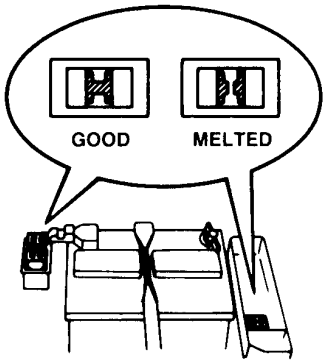
CIRCUIT BREAKERS

Circuit breakers are used for protecting circuits temporary overloads may occur and where power must be quickly restored. A bimetal strip is used, similar to that in a temperature-sensitive switch. When heated, the two metals expand differently and cause the strip to bend. The "breaker" is normally closed and it opens when the bimetal element bends. Some circuit breakers are self-resetting, others must be manually reset.

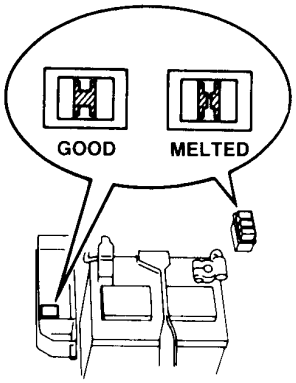
Circuit breakers are used on Toyota vehicles to protect circuits for the defogger, heater, air conditioner, power windows, power door locks, and sun roof.

CHECKING THE FUSIBLE LINKS

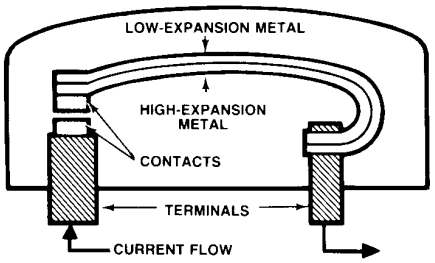
GASOLINE-POWERED VEHICLES



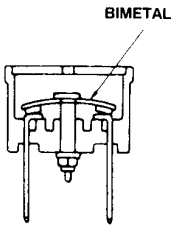
DIESEL-POWERED VEHICLES



CHECKING CIRCUIT BREAKERS



AUTOMATICALLY RESET TYPE



MANUALLY RESET TYPE

Resetting manually-reset type circuit breakers

(a) Insert a pin into the reset hole and push it.

(b) Using an ohmmeter, check that there is continuity between both terminals of the circuit breaker.

If there is no continuity, replace the circuit breaker.

ASSIGNMENT ***NAME:*** _____

1. Describe two power sources used in a vehicle.
2. Explain the term “load” and how it is used in a circuit.
3. Describe the two types of resistors and how each is used.
4. Explain the color code of a resistor that is: “Brown, Orange, Red, Silver.
5. Describe a “stepped resistor “ and how it differs from a “fixed resister”.
6. List and describe three types of “variable resistors”.
7. Explain how a “NTC” thermistor differs from a “PTC” thermistor.
8. List six types of switches used in automobiles.
9. Describe the two circuits used in a relay.
10 Explain how a “relay” differs from a “solenoid”.
11. Explain how current flows into a “capacitor”.
12. Explain the term “semiconductor”.
13. Draw, label, and describe the basic function of a “diode”.
14. Draw, label, and describe the basic function of a “bi-polar transistor”.
15. Explain the term “Integrated Circuit”.
16. List three types of “circuit protective devices”.
17. Describe the basic construction of a “fuse” or “fuse element”.
18. Explain how a “fuse element” differs from a “fusible link”.
19. Describe the basic construction of a “circuit breaker”.