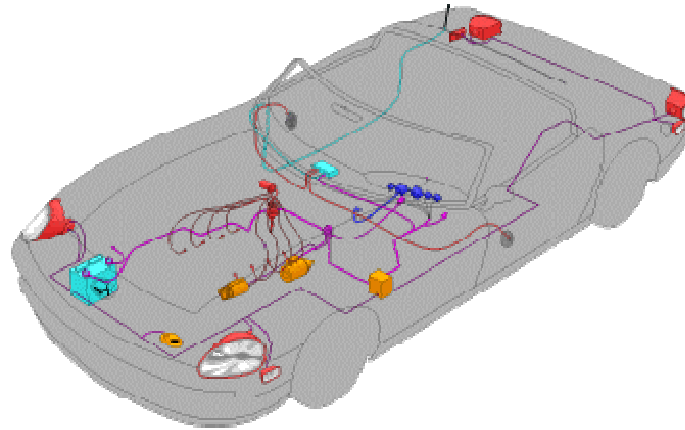


## Electrical System Overview



Below is an explanation of this system's operation

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### The Electrical System (An Overview)

When the automotive industry was in its infancy, it used electricity only to ignite the fuel inside the engine. By the late 1920's, the electric starter replaced the hand crank, electric headlights made acetylene lamps obsolete and the braying of the electric horn drowned out the squeak of the hand-squeezed air horn. Today, an automobile requires an elaborate electrical system of circuits just to produce, store, and distribute all the electricity it requires simply for everyday operation.

The first major component in the electrical system is the battery. The battery is used to store power for starting, and for running auxiliary devices such as clocks, radios and alarms when the engine is off. The next major component is the starter motor, which is used to start the engine. The third component is a charging device powered by the engine, known as the alternator. It powers the electrical system when the car is running, and restores the charge within the battery. With these basic components, the car maintains its supply of electricity. A device called the voltage regulator keeps the power level stabilized, and the fuse box keeps minor problems from becoming major ones.

Many different auxiliary electrical devices are used in modern cars, such as: radios, cellular phones, rear window defrosters and electric door locks, as well as a vast array of motors powering everything from the moonroof on down.

### Battery

The car's initial source of electricity is a battery, whose most important function is to start the engine. Once the engine is running, an alternator takes over to supply the car's electrical needs and to restore energy to the battery.

A 12-volt storage battery consists of layers of positively and negatively charged lead plates that, together with their insulated separators, make up each of six two-volt cells. The cells are filled with an electricity-conducting liquid (electrolyte) that is usually two-thirds distilled water and one-third sulfuric acid. Spaces between the immersed plates provide the most exposure to the electrolyte. The interaction of the plates and the electrolyte produces chemical energy that becomes electricity when a circuit is formed between the negative and positive battery terminals.

## **Starter**

The starter converts electricity to mechanical energy in two stages. Turning on the ignition switch releases a small amount of power from the battery to the solenoid above the starter. This creates a magnetic field that pulls the solenoid plunger forward, forcing the attached shift yoke to move the starter drive so that its pinion gear meshes with the engine's crankshaft flywheel. When the plunger completes its travels, it strikes a contact that permits a greater amount of current to flow from the battery to the starter motor. The motor then spins the drive and turns the meshed gears to provide power to the crankshaft, which prepares each cylinder for ignition. After the engine starts, the ignition key is released to break the starting circuit. The solenoid's magnetic field collapses and the return spring pulls the plunger back, automatically shutting off the starter motor and disengaging the starter drive.

When the starter is not in use, the drive unit is retracted so that its pinion is disengaged from the flywheel. As soon as the starter is activated, the forward movement of the solenoid plunger causes the shift yoke to move the drive in the opposite direction and engage the pinion and flywheel. The pinion is locked to its shaft by a clutch that unlocks if the engine starts up and the flywheel begins turning the pinion faster than its normal speed. By allowing the pinion to spin freely for a moment, the clutch protects the motor from damage until the drive is retracted.

## **Alternator or Generator**

The alternating-current generator, or alternator, is the electrical system's chief source of power while the engine is running. Its shaft is driven by the same belt that spins the fan. It converts mechanical energy into alternating-current electricity, which is then channeled through diodes that alter it to direct current for the electrical system and for recharging the battery.

## **Lighting Circuit**

The automobile lighting circuit includes the wiring harness, all the lights, and the various switches that control their use. The complete circuit of the modern passenger car can be broken down into individual circuits, each having one or more lights and switches. In each separate circuit, the lights are connected in parallel, and the controlling switch is in series between the group of lights and the fuse box. The parking lights, are connected in parallel and controlled by a single switch. In some installations, one switch controls the connection to the fuse box, while a selector switch determines which of two circuits is energized. The headlights, with their upper and lower beams, are an example of this type of switch. Again, in some cases, such as the courtesy lights, several switches may be connected in parallel so that any switch may be used to turn on the lights.

## **Main Lighting Switch**

The main lighting switch (sometimes called the headlight switch) is the heart of the lighting system. It controls the headlights, parking lights, side marker lights, taillights, license plate light, instrument panel lights, and interior lights. Individual switches are provided for special purpose lights such as directional signals, hazard warning flashers, back up lights, and courtesy lights. The main lighting switch may be of either the "push-pull" or "push-pull with rotary contact" types. A typical switch will have three positions: off, parking, and headlamps. Some switches also contain a rheostat to control the brightness of the instrument panel lights. The rheostat is operated by rotating the control knob, separating it from the push-pull action of the main lighting switch.

When the main lighting switch completes the circuit to the headlamps, the low beam lights the way for city driving and for use when meeting oncoming traffic on the highway. When the dimmer switch is actuated, the single filament headlamps go "on," along with the high beam of the two filament headlamps. The next actuation of the dimmer switch returns the headlighting system to low beams only on the two filament lamps. Some cars are equipped with an electronic headlight dimming device, which automatically switches the headlights from high beam to low in response to light from an approaching vehicle or light from the taillight of a vehicle being overtaken. The dimmer switch in the automatic headlamp dimming system is a special override type. It is located in the steering column as part of a combination dimmer, horn, and turn signal switch. The override action occurs when a slight pull toward the driver on the switch lever provides high beam headlights regardless of the amount of light on the sensor-amplifier.

For some years there has been discussion about the advantages of a polarized headlight system. Such a system comprises headlights which produce polarized light in a particular plane. The windscreens of all cars would be fitted with polarizing glass, which would be oriented so that glare from an approaching vehicle would be essentially eliminated, while the forward vision would still be kept at the present levels. The advantages the system appear attractive, but the practical problems of making the transition are very great, since it would not be practical to convert all existing vehicles to this type of lighting. Also, any benefits would only be marginal because glare itself is not a frequent cause of accidents. However, many cars now have refracting or colored glass to cut down on glare.

Due to recent legislation, newer cars in Texas with the dimmer switch mounted on the steering column will have to be refurbished with standard floor-mounted dimmers. Too many Aggies are being found in the ditch with their legs caught in the steering wheel.

## **Directional Signal Switch**

The directional signal switch is installed just below the hub of the steering wheel. A manually controlled lever projecting from the switch permits the driver to signal the direction in which he wants to turn. Moving the switch handle down will light the "turn signal" lamps on the left front and left rear of the car, signaling a left turn. Moving the switch upward will light the turn signal lamps on the right (front and rear), signaling a right turn. With the switch in a position to signal a turn, lights are alternately turned "on" and "off" by a turn signal flasher. Incorporated in the

directional signal switch is a "lane change switch mechanism." This feature provides the driver the opportunity to signal a lane change by holding the turn lever against a detent, then releasing it to cancel the signal immediately after the maneuver is completed.

## **Stoplight Switch**

In order to signal a stop, a brake pedal operated "stoplight switch" is provided to operate the vehicle's stop lamps. In addition to lighting the conventional rear lights, the switch also operates the center high-mounted stop lamp, that became mandatory on later models. Cruise control equipped vehicles may also utilize a vacuum release valve. In this case, both the vacuum release valve and the stoplight switch are actuated by movement of the brake pedal.

## **Horn**

The car horn on passenger cars provides the driver with a means of sounding an audible warning signal. The horn electrical circuit generally includes: battery, fuse or fusible link, horn relay, horn(s), steering column wiring harness, horn switch, and body sheet metal. Often, a cadmium plated screw is used to ground the horn to the body of the vehicle. Horns usually are located in the forward part of the engine compartment or in the front fender well. The horn switch is built into the steering wheel or incorporated into the multi-functional switch lever, which includes turn signal and dimmer switch.

## **Electricity At Rest**

The ancient Greeks had a word for it. Records show that as early as 600 BC the attractive properties of amber were known. Thales of Miletus (640-546 BC), one of the "seven wise men" of ancient Greece, is credited with having observed the attraction of amber for small fibrous materials and bits of straw. Amber was used by these people, even as it is now, for ornamental purposes. Just as the precious metals had their names of gold and silver, so amber had its name: "electron." It was later shown that the same effect can be obtained by rubbing a rod of glass or hard rubber with a handkerchief. Many other nonmetallic materials are found to have this property, which is known as "static electricity."

All electrified materials behave either as glass or rubber. Glass has a "positive" charge and hard rubber has a "negative" charge. If you electrify two strips of hard rubber by rubbing them with fur, they will repel each other. Two glass rods will behave the same way. But, if you electrify a rod of rubber and suspend it near an electrified rod of glass, they will attract each other. One of the most important laws of electricity is "Bodies with similar charges repel each other; bodies with opposite charges attract each other." A positive charge is designated with a (+); a negative charge by the sign (-).

Although people have controlled electricity for many years, no one can explain exactly what it is. Many different theories have been given as to the nature of electricity through the years, but the modern one is the "Electron theory." In short, the electron theory proposes that all matter consists of tiny particles called molecules. These molecules are made up of two or more smaller particles called

atoms. The atoms are then divided into smaller particles called protons, neutrons, and electrons. These particles are all the same in matter, whether in gas, liquid, or solid. The different properties or characteristics of the matter take form according to the arrangement and numbers of these particles which make up the atom. The proton has a natural positive charge of electricity; the electron has a negative charge; and the neutron has no charge at all, but just adds weight to the matter.

Protons and neutrons form the central core of the atoms about which the electrons rotate. The electrons carry small negative charges of electricity, which neutralize the positive charges of the protons. The simplest atom of all is the hydrogen atom. It consists of one positive proton and one negative electron. Other atoms, such as those forming copper, iron, or silicon, are much more complicated. Copper, for example, has 29 electrons circling about its nucleus in four different orbits. While protons are much smaller than electrons in size, they contain the bulk of the mass of every atom. One proton, for example, weighs nearly two thousand times as much as an electron. The electrons therefore are light particles or objects around a small but relatively heavy nucleus.

It is difficult to conceive the size of the atom. Research by physicists has established that the mass on one electron is about .000,000,000,000,000,000,000,000,911 of a gram. If you assume that one proton in a hydrogen atom is the size of a baseball in Kansas City, then the electron would have an orbit which would reach from the Atlantic coast to the Pacific. Along with the extremely small size of electrons and protons, they are separated by relatively vast distances.

## **Conductors and Insulators**

Not all substances are good conductors of electricity. As a general rule, metals are good conductors whereas nonmetals are poor conductors. The poorest of conductors are commonly called "insulators," or "nonconductors." Aluminum, copper, gold, iron, mercury, nickel, platinum, and silver are examples of good conductors. Amber, glass, mica, paper, porcelain, rubber, silk, and sulfur are all nonconductors. The difference between a conductor and an insulator is that in a conductor, there are free electrons, whereas in an insulator, all of the electrons are tightly bound to their respective atoms. In an uncharged body, there are an equal number of positive and negative charges. In metals, a few of the electrons are free to move from atom to atom, so that when a negatively charged rod is brought to the end of the conductor, it repels nearby free electrons in the conductor, causing them to move. They in turn repel free electrons in front of them, giving rise to a flow of electrons all along the conductor. There are a large number of substances that are neither good conductors of electricity nor good insulators. These substances are called "semi-conductors." In them, electrons are capable of being moved only with some difficulty, i.e., with considerable force.

## **Electricity In Motion (Electrical Current)**

When an electric charge is at rest it is spoken of as "static electricity," but when it is in motion, it is referred to as an "electric current." In most cases, an electric current is described as a flow of electric charge along a conductor. To make an electron current flow continuously along a wire, a continuous supply of electrons must be available at one end and a continuous supply of positive charges at the other. This is like the flow of water through a pipe: to obtain a continuous flow, a continuous

supply of water must be provided at one end and an opening for its escape into some receptacle at the other. The continuous supply of positive charge at the one end of a wire offers a means of escape for the electrons. If this is not provided, electrons will accumulate at the end of the wire and the repulsion back along the wire will stop the current flow.

The rate at which the free electrons drift from atom to atom determines the amount of electrical current. In order to create a drift of electrons through a circuit, it is necessary to have an electrical pressure, or "voltage." Electric current, then, is the flow of electrons. The more electrons in motion, the stronger the current. In terms of automotive applications, the greater the concentration of electrons at a battery or generator terminal, the higher the pressure between the electrons. The greater this pressure (voltage) is, the greater the flow of electrons.

In modern electric car designs, the drive motors are often used as the brakes also, allowing them to switch over into performing as generators, which charge the batteries with the energy generated.

## **Electromagnetic Principles**

The connection between electricity and magnetism was made by Oersted, a Danish scientist, in 1820. He had frequently demonstrated the nonexistence of a connection between electricity and magnetism. His usual procedure was to place a current-carrying wire at right angles to, and directly over, a compass needle to show that there was no effect of one on the other. One occasion, at the end of his lecture, he placed the wire parallel to the compass needle and saw the needle move to one side. When he reversed the current in the wire, the needle, to his amazement, deviated in the opposite direction. Thus a great discovery concerning electromagnetism was made quite by accident.

There is no actual knowledge as to why some materials have magnetic properties and others have not. The "electron theory" generally is accepted as the best explanation of magnetism. It is also known as the "domain theory."

According to the theory, an electron moving in a fixed circular orbit around the proton creates a magnetic field with the north pole on one side of the orbit and a south pole on the other side. It is assumed that the orbiting electron carries a negative charge of electricity, which is the same as electrical current flowing through a conductor. Current flow, then, is from negative to positive. When a number of magnetized orbiting electrons exist in a material, they interact with each other and form "domains," or groups of atoms having the same magnetic polarity. However, these domains are scattered in random patterns throughout and the material is, in effect, demagnetized. Under the influence of a strong external magnetic field, domains become aligned and the total material is magnetized. The strength of its magnetic field depends on the number of domains that are aligned. In magnetic substances, the domains align themselves in parallel planes and in the same direction when placed in a magnetic field. This arrangement of the electron-created magnets produces a strong magnetic effect.

If you stroke a piece of hardened steel with a magnet, the piece of steel itself will become a magnet. (Steel railroad tracks laid in a north-to-south direction become magnetized because they lie parallel to the magnetic lines of the earth.) Much

stronger magnets and magnetic fields can be produced by electrical means. Placing a piece of steel in any strong magnetic field will cause it to become magnetized.

A magnetized field surrounds any conductor carrying an electrical current. The discovery of that fact resulted in the development of much of our electrical equipment. The "field of force" is always at right angles to the conductor. Since the magnetic force is the only force known to attract a compass needle, it is obvious that a flow of electric current produces a magnetic field similar to that produced by a permanent magnet. Not only is the field of force at right angles to the conductor, but the field also forms concentric circles about the conductor. When the current in the conductor increases, the field of force is increased. Doubling the current will double the strength of the field of force.

### **The Left-Hand Rule (Magnetic Effect)**

Oersted's experiment has been interpreted to mean that "around every wire carrying an electric current there is a magnetic field." The direction of this field at every point, like that around a bar magnet, can be mapped by means of a small compass or by iron filings. If a wire is mounted vertically through a hole in a plate of glass or other suitable nonconductor, and then iron filings are sprinkled on the plate, there will be a lining-up of the filings parallel to the magnetic field. The result shows that the magnetic lines of force or "lines of induction" are concentric circles whose planes are at right angles to the current.

The "left-hand rule" used in electromagnetism can always be relied upon to give the direction of the magnetic field due to an electron current in a wire. Derived from experiment, the rule states: "if the current-carrying wire were to be grasped in the left hand, the thumb pointing in the direction of the electron current, negative (-) to positive (+), the fingers will point in the direction of the magnetic induction."

### **Magnetic Properties of A Solenoid**

Shortly after Oersted discovered the magnetic effect of a current-carrying wire, Ampere found that a loop or coil of wire (a single loop or a coil of several turns of wire) acted as a magnet. A coil of wire of this kind is sometimes referred as a "solenoid," or as a "helix." The magnetic lines of force in a solenoid are such that one side or end of the coil acts like a "N" magnetic pole and the other side or end like a "S" magnetic pole. At all points in the region around a coil of wire carrying a current, the direction of the magnetic field, as shown by a compass, can be predicted by the left-hand rule. Inside each loop or turn of wire, the lines point in one direction, whereas outside they point oppositely. Outside the coil, the lines go the same way they do about a permanent bar magnet, whereas inside the coil they go from "S" to "N". Not only does one coil of wire act like a magnet, but two coils will demonstrate the repulsion and attraction of like and unlike poles.

### **Electronics (Solid State)**

Electronics refers to any electrical component, assembly, circuit, or system that uses solid state devices. "Solid state" means that these devices have no moving parts, other than electrons. Examples of solid state devices include semiconductor diodes,

transistors, and silicon controlled rectifiers. These and many more have broad application in automotive electronics.

## **Semiconductors and Diodes**

Semiconductors are made from material somewhere between the ranges of conductors and nonconductors. Semiconductors, basically, are designed to do one of three things: (1) stop the flow of electrons, (2) start the flow of electrons, or (3) control the amount of electron flow. A semiconductor diode is a two-element solid state electronic device. It contains what is termed a "P" type material connected to a piece of "N" material. The union of the "P" and "N" materials forms a PN junction with two connections. The "anode" is connected to the P material; the "cathode" is connected to the N material. A diode is, in effect, a one-way valve. It will conduct current in one direction and remain non conductive in the reverse direction. When current flows through the diode, it is said to be "forward biased." When current flow is blocked by the diode, it is "reverse biased." When a diode is reverse biased, there is an extremely small current flow; actually, the current flow is said to be "negligible." When the P and N are fused together to form a diode, it can be placed in a circuit. The P material is connected to the positive side of the battery and the N material is connected to the negative side of the battery. Connected in this manner, current will flow. If connected in the reverse manner, current will not flow.

## **Transistors and Resistors**

A transistor is a solid state device used to switch and/or amplify the flow of electrons in a circuit. A typical automotive switching application would be a transistorized ignition system in which the transistor switches the primary system off and on. An amplifying application could be in a stereo system where a radio signal needed strengthening.

A transistor is a three-element device made of two semiconductor materials. The three elements are called "emitter," "base," and "collector." The outer two elements (collector and emitter) are made of the same material; the other element (base) is different. Each has a conductor attached. The materials used are labeled for their properties: "P" for positive, meaning a lack of electrons. It has "holes" ready to receive electrons. "N" is for negative, which means the materials has a surplus of electrons. The movement of a free electron from atom to atom leaves a hole in the atom it left. This hole is quickly filled by another free electron. As this movement is transmitted throughout the conductor, an electric current is created from the negative to the positive. At the same time, the "hole" has been moved backward in the conductor as one free electron after another takes its place in a sort of chain reaction. "Hole flow" is from positive to negative. Current flow in a transistor, then, may be either electron movement or hole flow, depending on the type of material, and this determines the type of transistor it is as well.

In most 12 volt systems, a resistor is connected in series with the primary circuit of the ignition coil. During the cranking period, the resistor is cut out of the circuit so that full voltage is applied to the coil. This insures a strong spark during cranking, and quicker starting is provided. The starting circuit is designed so that as long as the starter motor is in use, full battery voltage is applied to the coil. When the starter is not cranking, the resistance wire is cut into the circuit to reduce the voltage applied to the coil. If the engine starts when the ignition switch is turned on, but



stops when the switch is released to the run position, it can indicate that a resistor is bad and should be replaced.

At no time should the resistor be bypassed out of the circuit, as that would supply constant battery voltage and burn out the coil. The resistor and resistor wires should always be checked when the breaker points are burned, or when the ignition coil is bad.