

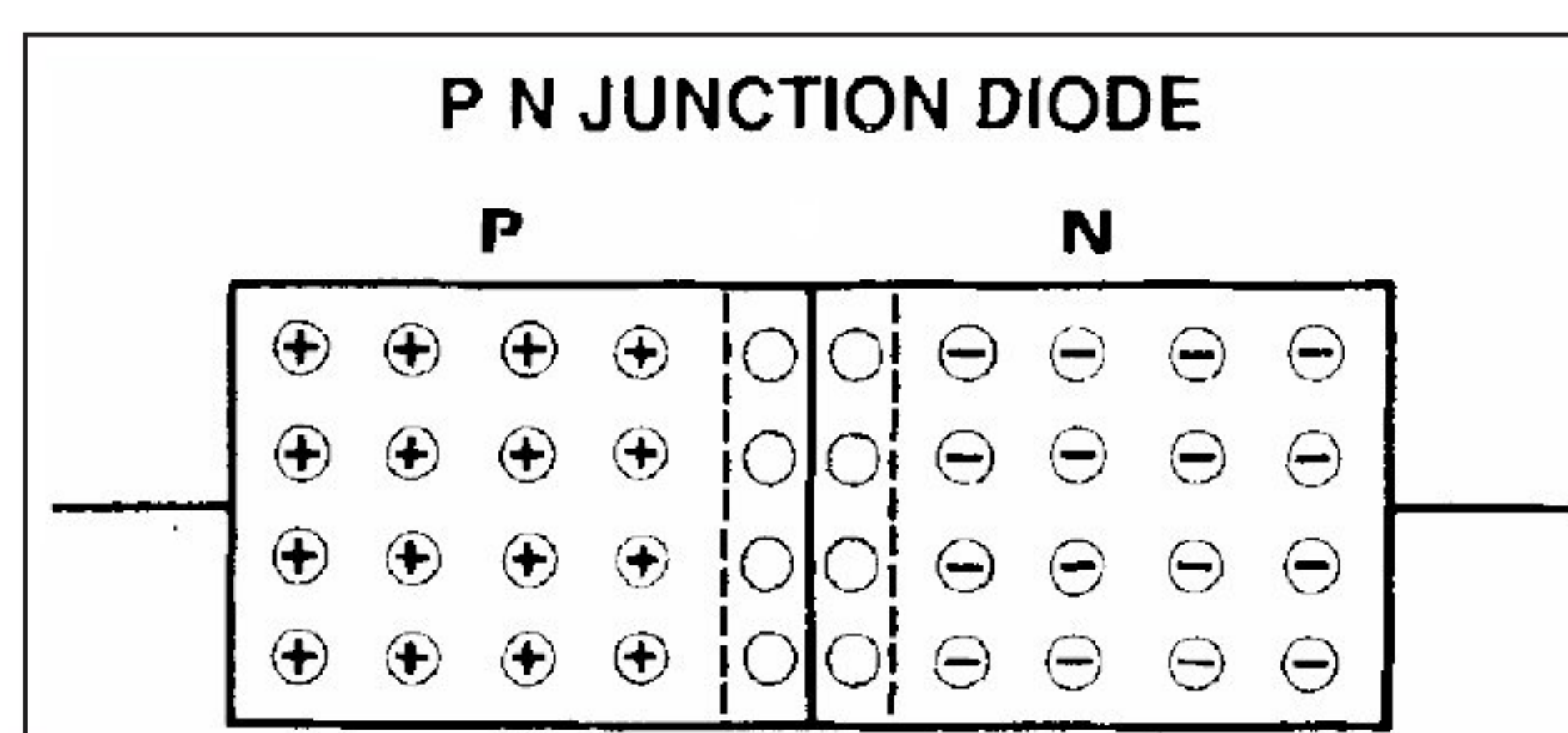
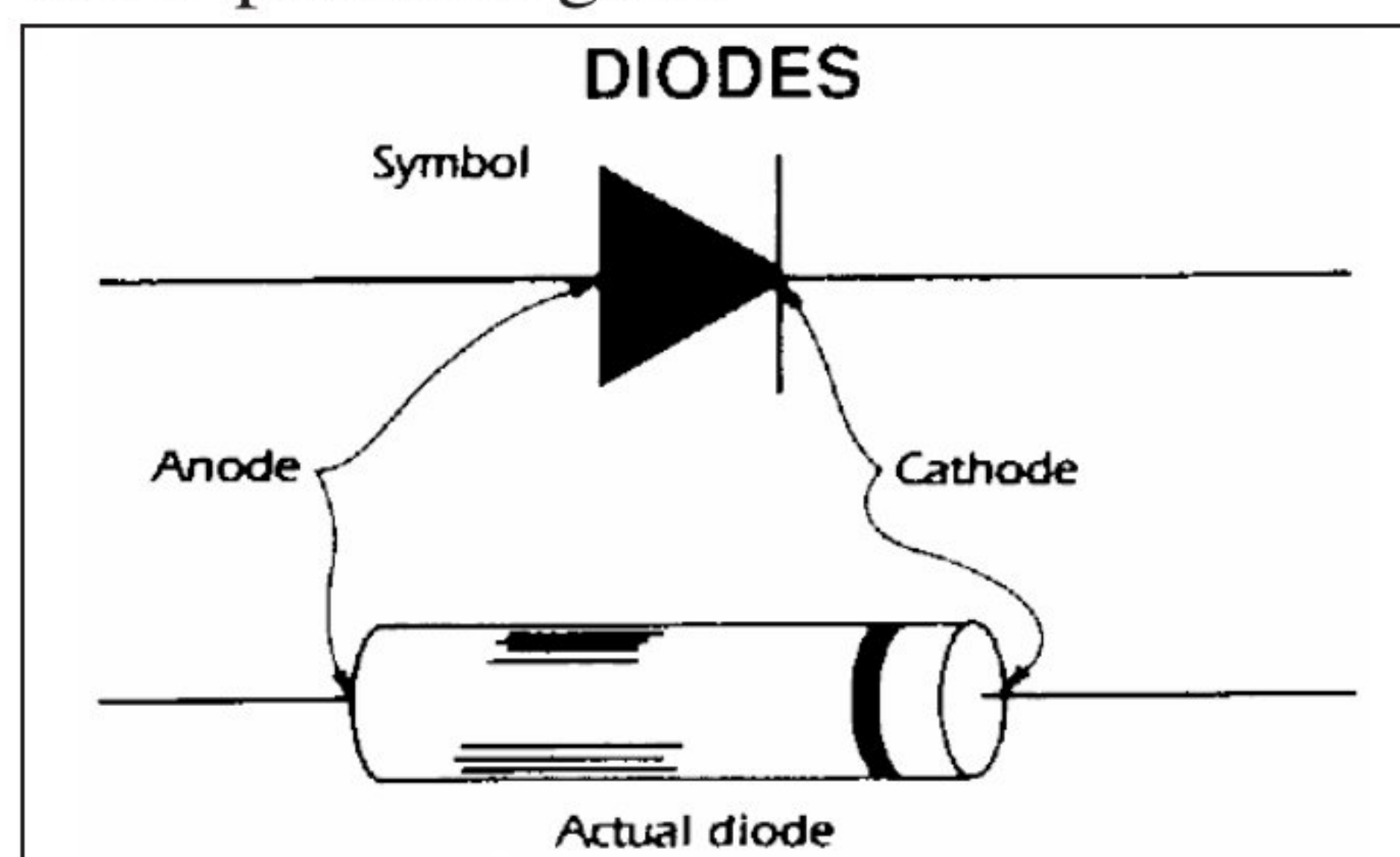
Semiconductors

Part II

From Toyota Motor Sales, Inc.

Diodes

Diodes block current flow in one direction and pass current in the opposite direction. This is accomplished by joining a layer of P-type material and a layer of N-type during manufacturing. Where they meet is called the PN junction. At the PN junction, some of the electrons of the N-type material move into some of the holes in the P-type material and create a neutral area at the junction. Another way of thinking of this is that the positive holes attract the negative electrons leaving no free electrons, so current is unable to flow past that point. This neutral area acts as a barrier, which is called the depletion region.

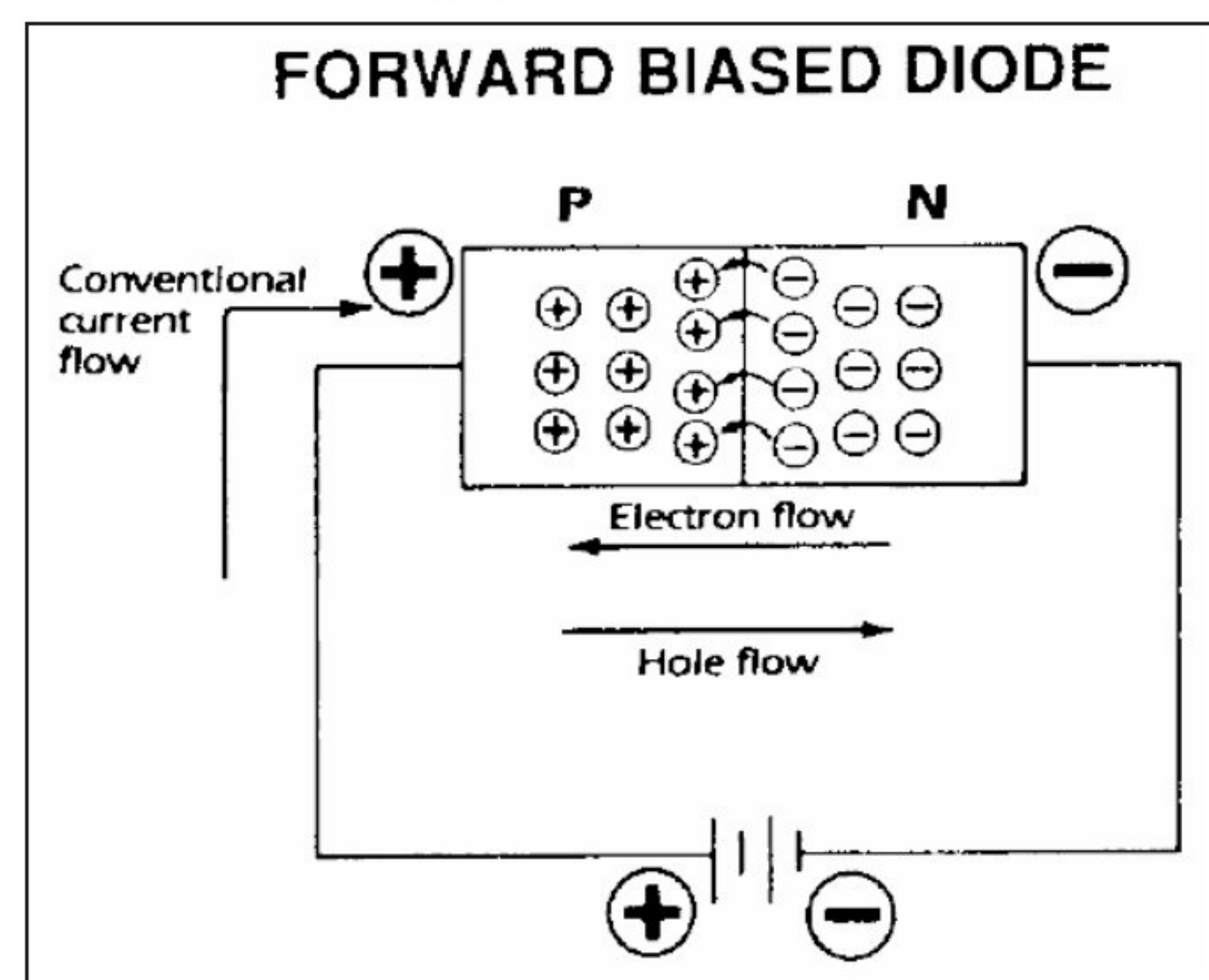


The depletion region is very thin and responds rapidly to voltage changes. It is here that current is either allowed to pass or is blocked.

When the diode is connected in a circuit where the N-type material is connected to the negative terminal of the battery and the P-type material is connected to the positive terminal, the excess electrons in the N-type material are repelled by the negative potential of the battery. At the same time, the positively charged holes in the P-type material are repelled by the positive potential of the battery, resulting in a concentration of holes and electrons at the depletion region.

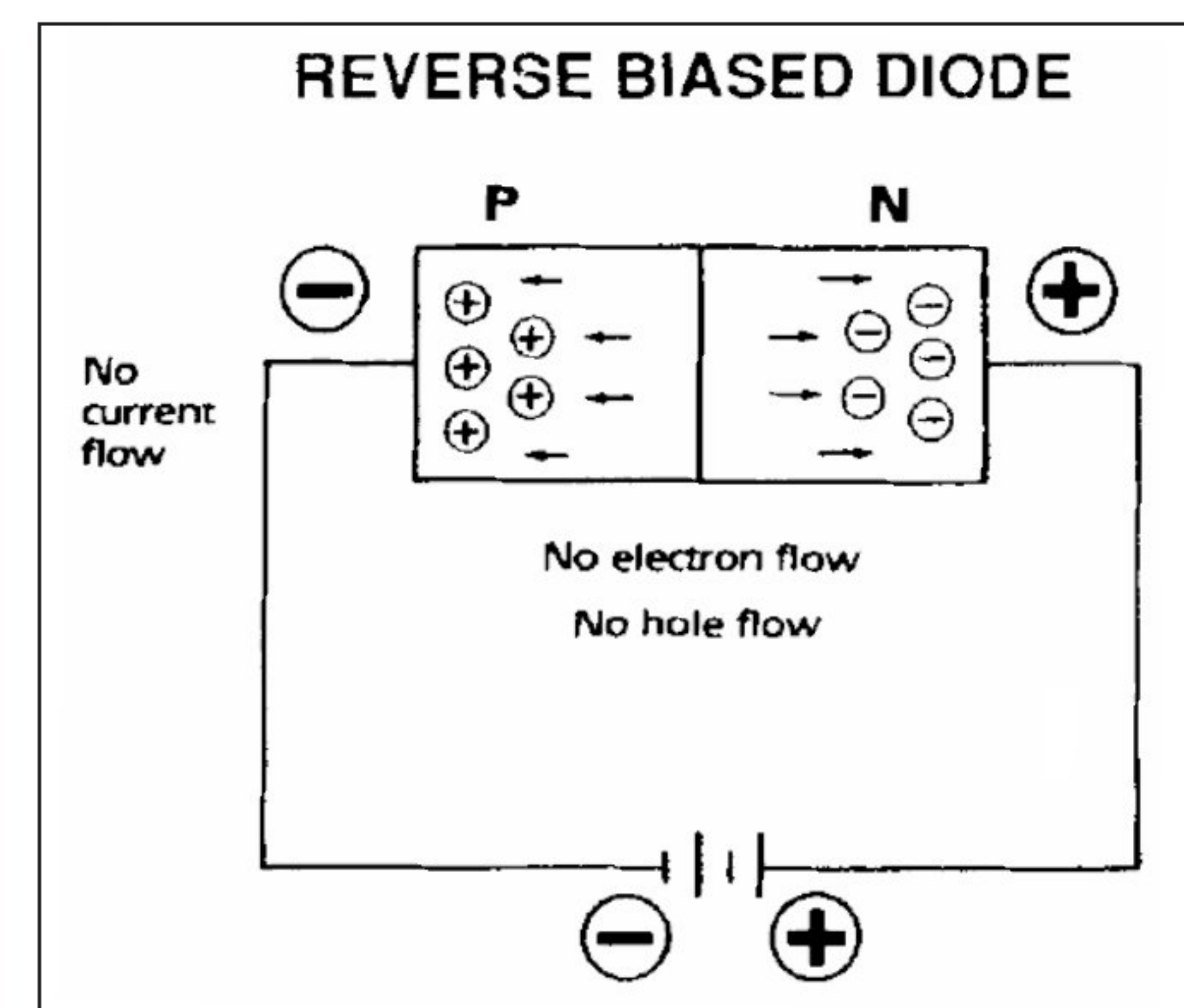
When voltage applied to the diode is great enough (.5 to .7 volts) elec-

trons in the N-type material will move across the depletion region at the junction, filling holes in the P-type material and leaving holes in the N-type material. Electrons move through the diode to the positive terminal of the battery and holes move through the diode to the negative terminal of the battery. When this happens the diode conducts current and is said to be forward biased.



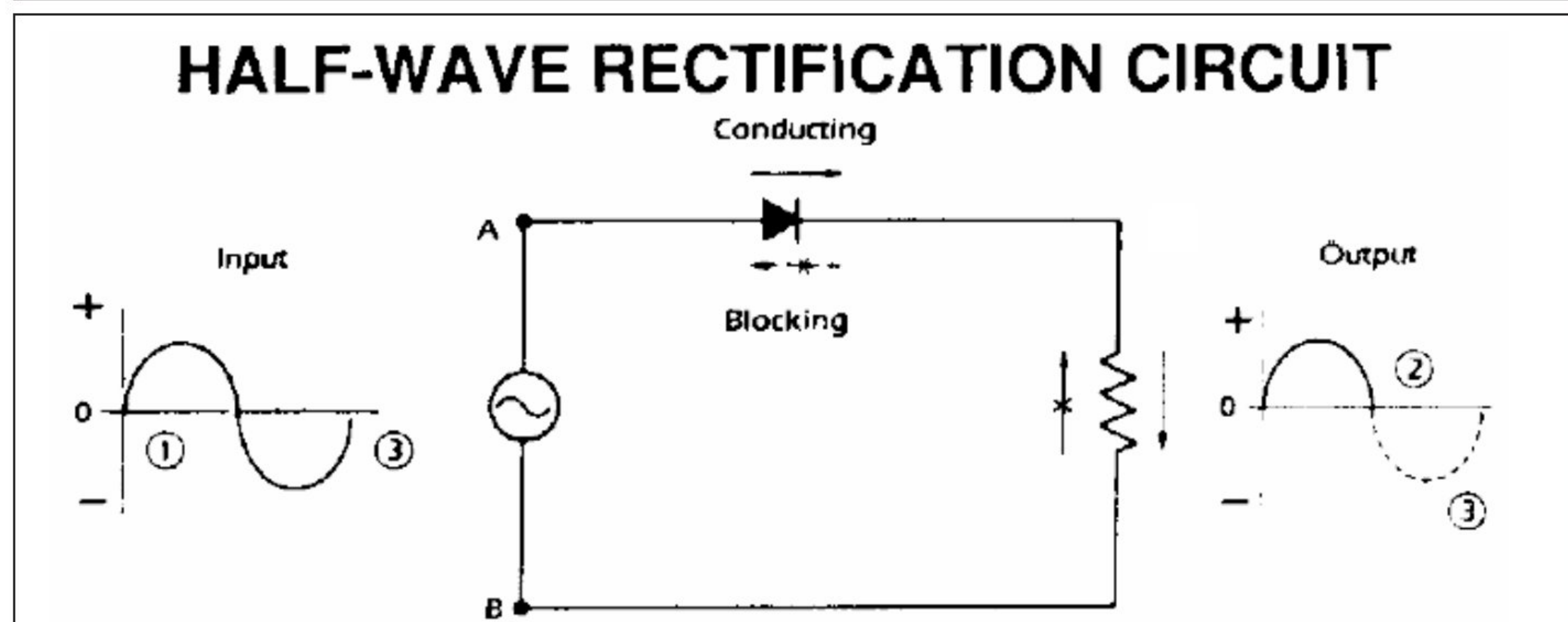
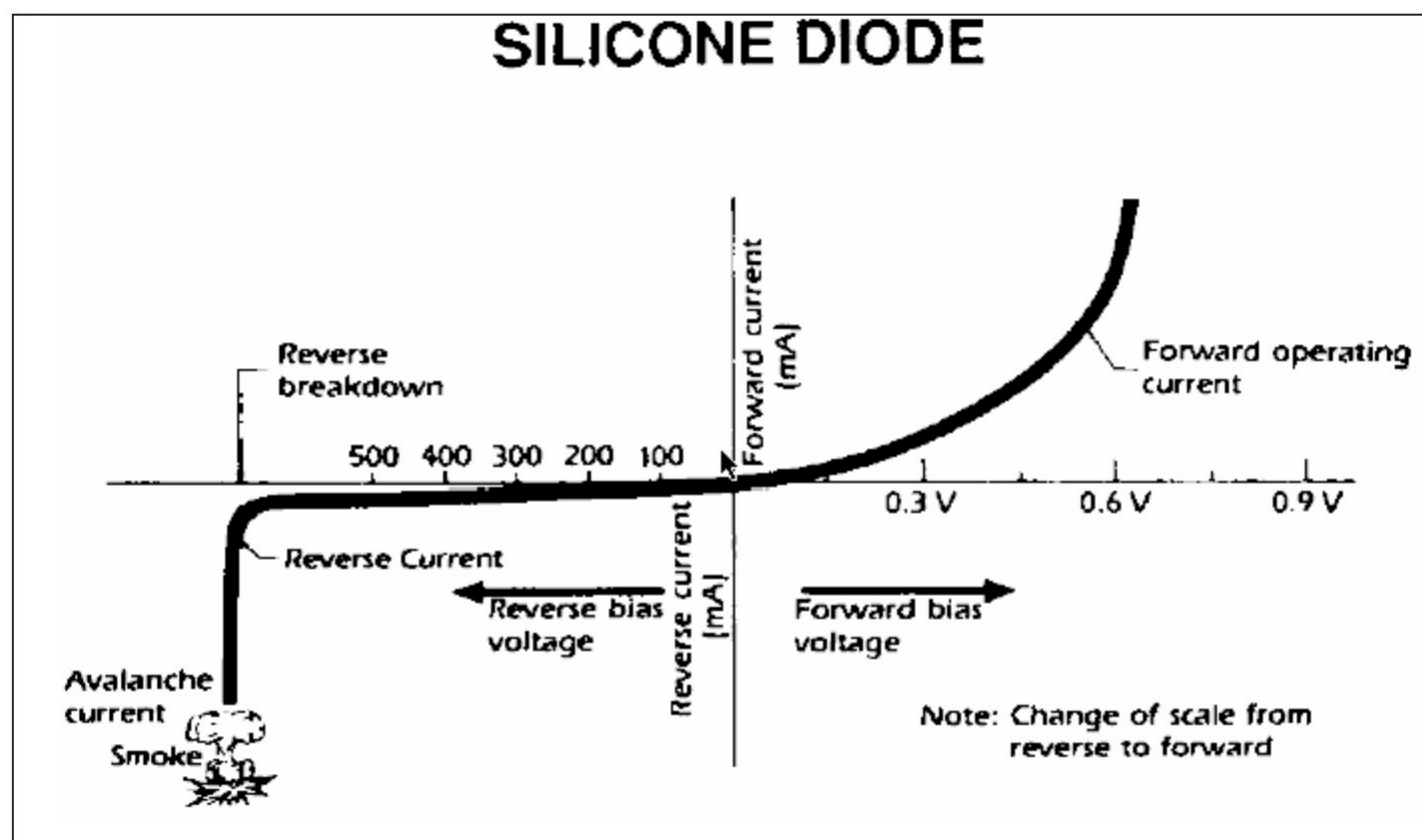
If the connection of the diode in the circuit is reversed, with the N-type material connected to the positive terminal of the battery and the P-type material connected to the negative terminal, the diode is reverse biased. In this case, the electrons in the N-type material are attracted to the positive

terminal of the battery and the holes in the P-type material are attracted to the negative terminal of the battery. This results in an increase in the depletion region or neutral zone so no current can flow through the diode. Whether the diode conducts or blocks current flow is determined by the voltage polarity applied to it.



If the reverse bias voltage applied to a diode is great enough, the voltage can overcome the depletion region at the junction and the diode will conduct for a short period before burning open. When this happens the diode is destroyed.

The three main uses for diodes in the automobile are rectification, de-spiking, and isolation.



Rectification—Since a diode will allow current to flow in one direction and not the other, it can be used to turn alternating current into direct current. This is called rectification. Diodes can provide either full-wave or half-wave rectification, depending on the number of diodes and how they are connected.

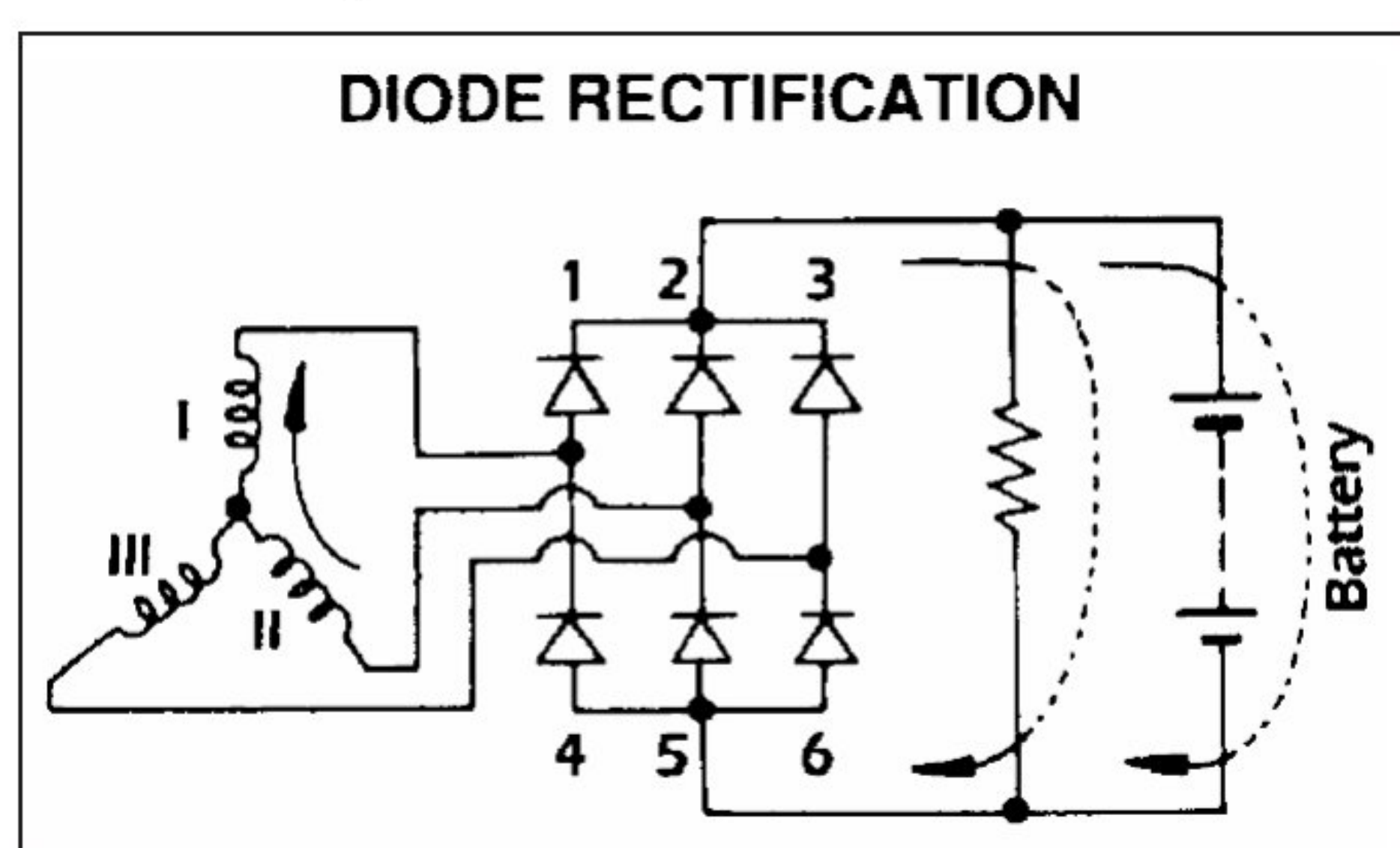
A half-wave rectifier consisting of one diode will have an output voltage that is approximately one half of the AC source. Since the output from an AC power source continually changes or alternates from positive to negative, the diode is forward biased for part of the output and reverse biased for the other. The diode will allow current to flow in the circuit when it is forward biased but will block the flow of current when it is reverse biased. The result is that only half of the wave is output while the other half is blocked by the diode. This type of rectifier is not commonly found in an automotive application since it is not an efficient way to rectify AC to DC to charge a battery.

A full-wave rectifier uses a four-diode network to rectify both halves of an AC output. In such a system, current flows from the first half of the phase of the AC power source through the first diode in forward bias, through the external circuit, through the second diode, then completes the circuit. On the second half of the phase, the current flows through the third diode, through the external circuit, through the fourth

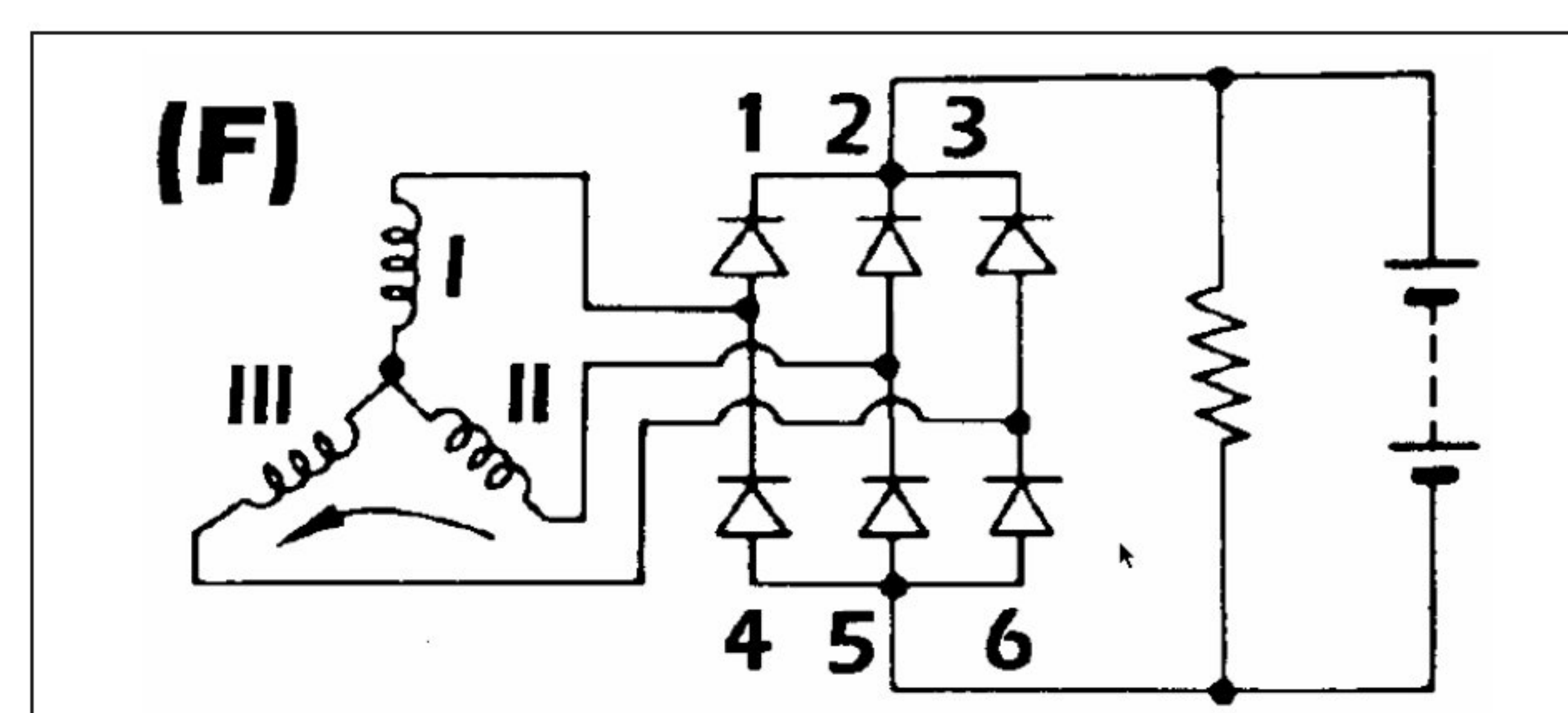
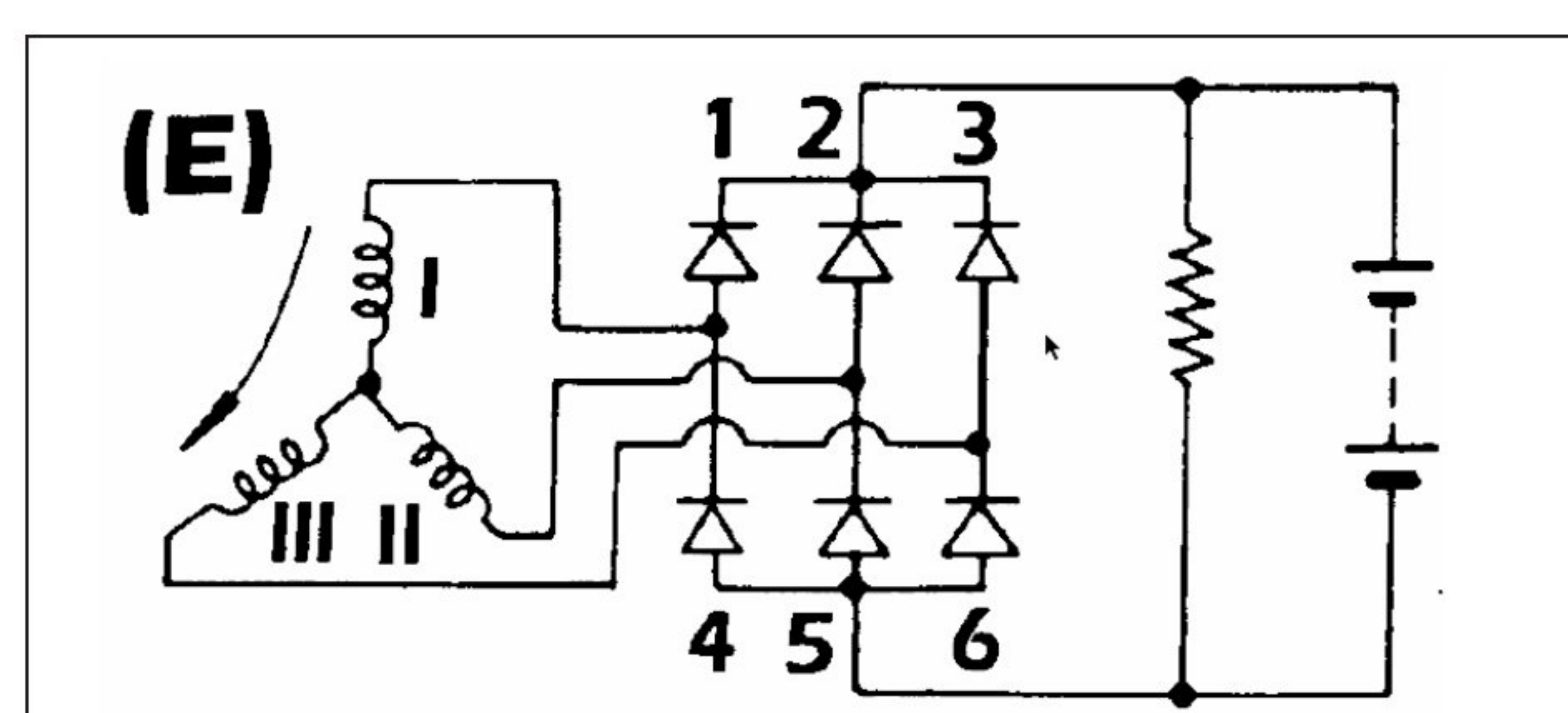
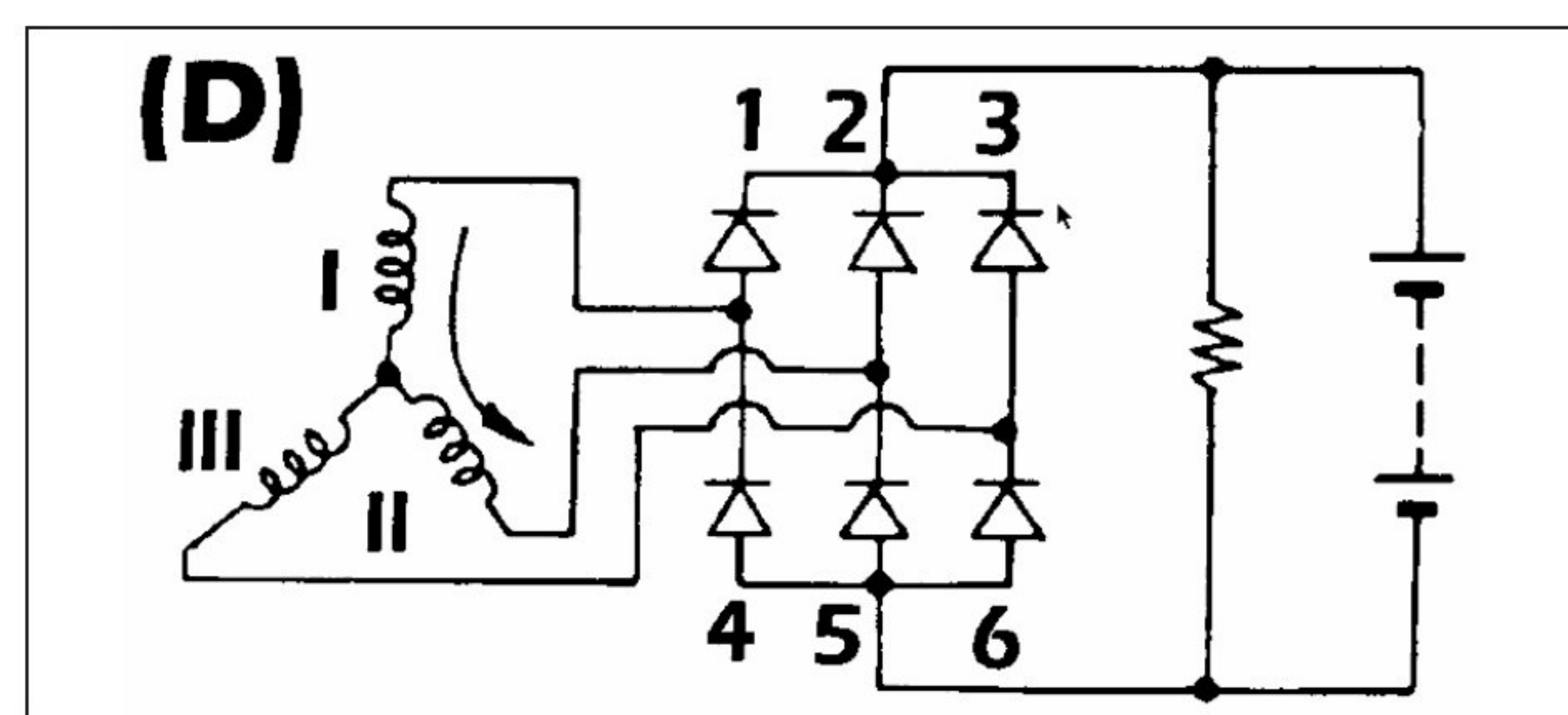
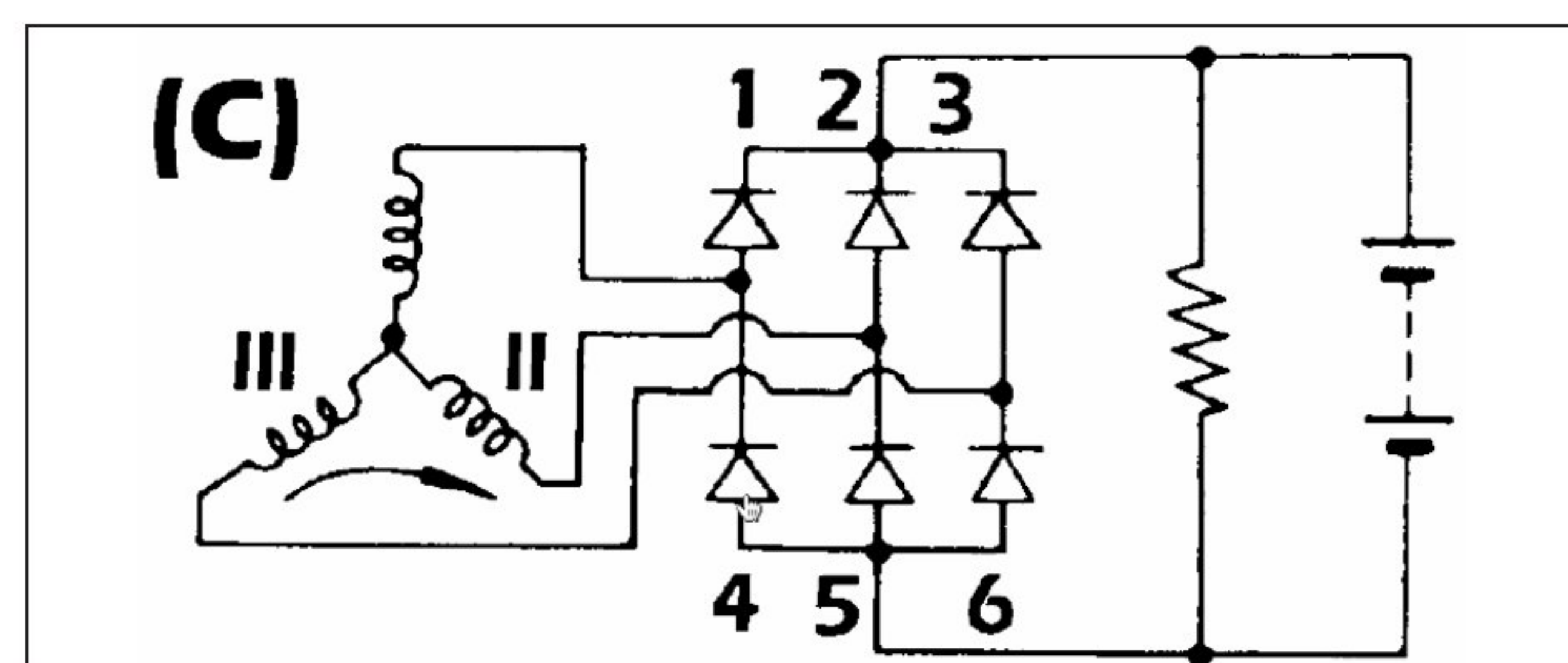
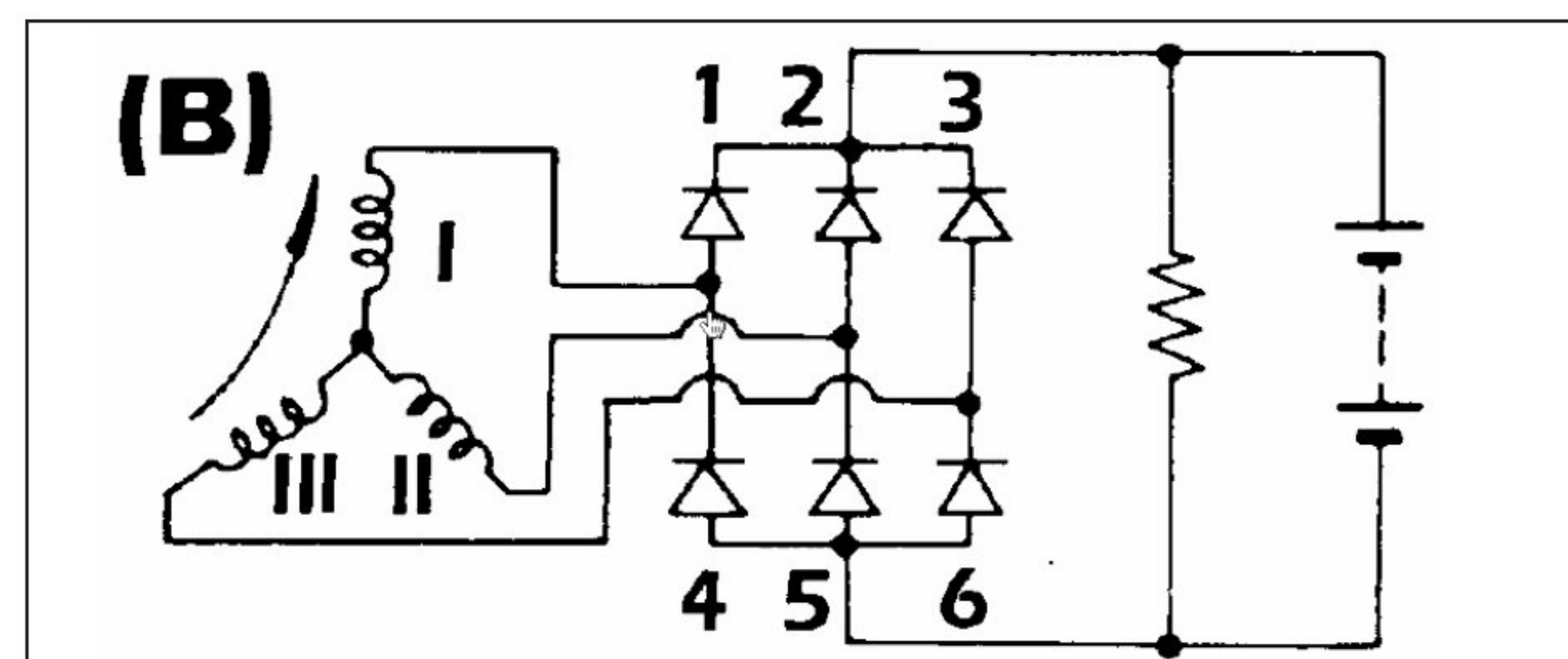
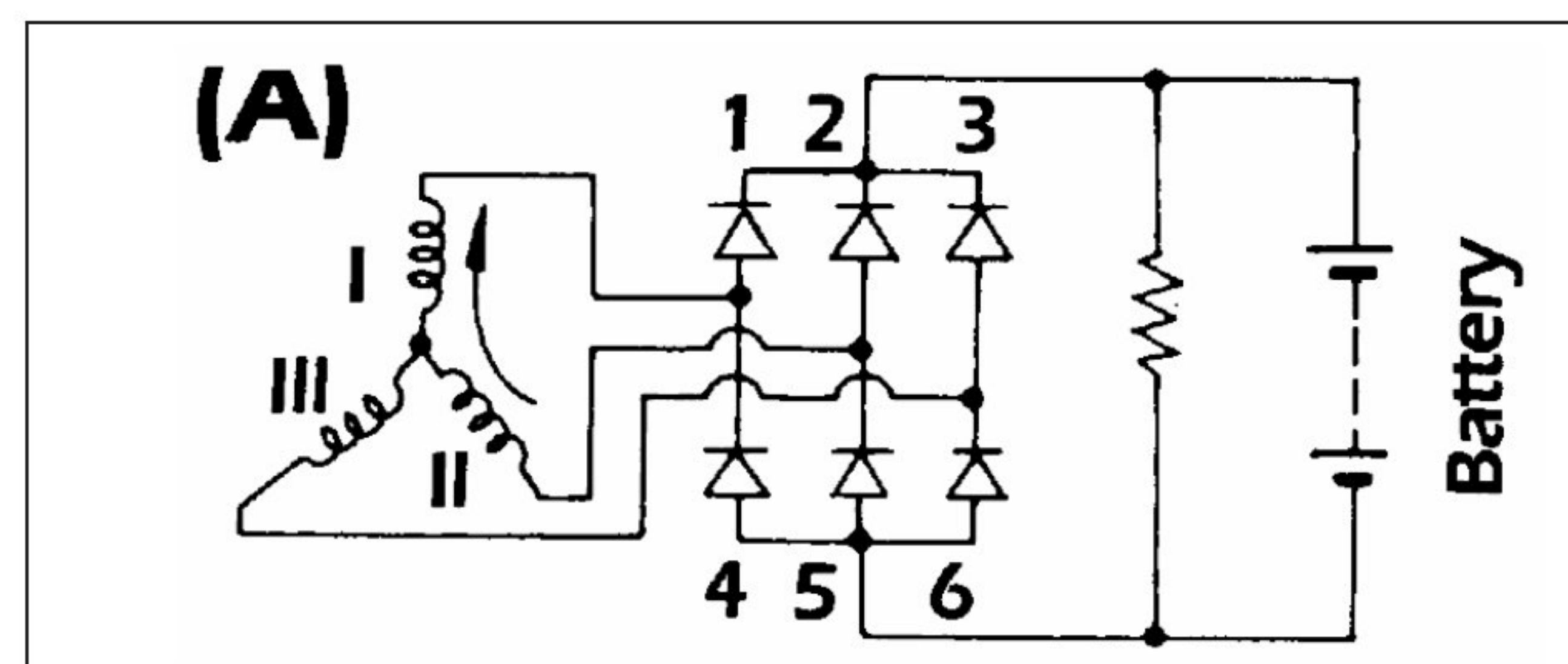
diode and completes the circuit.

By using four diodes in the full-wave rectifier, all of the current flows to the DC part of the circuit and the current in the DC part always flows the same direction even though the current flow in the AC power source changes directions.

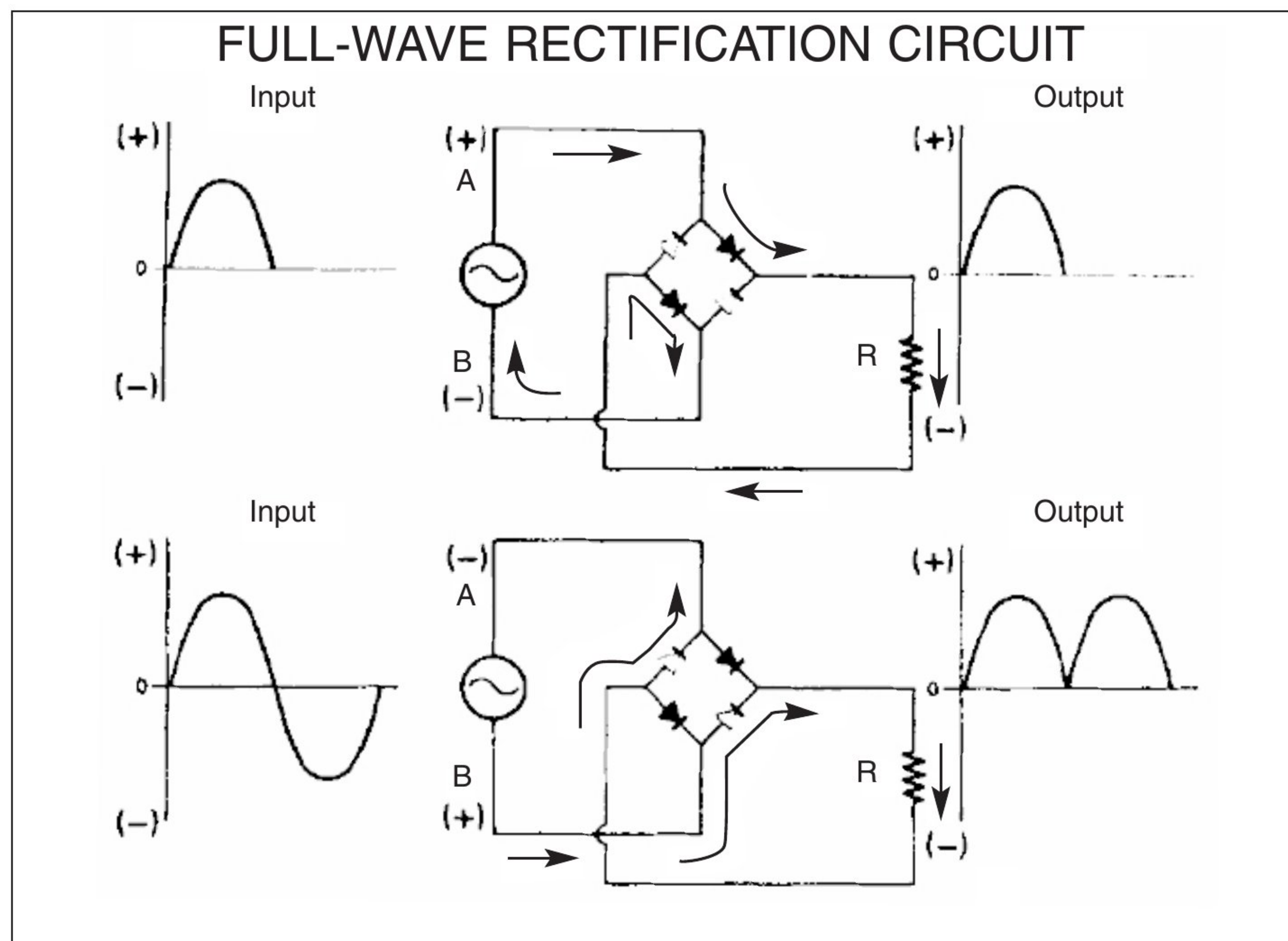
The full-wave, three-phase rectifier found in an automotive alternator goes a step further. Because the alternator uses three coils that produce three overlapping AC sine waves staggered at 120 degree intervals, six diodes are required to achieve full-wave rectification. Each coil uses four of the diodes to rectify the output, achieving full-wave rectification (as in the full-wave, single-phase rectifier discussed earlier). Because the coils and diodes are interconnected, the same diodes are used by different coils at different times. Due to the overlap of the waves, output from each coil in this type of alternator produces a smooth output to the DC system.



The illustrations below show how the six diodes can rectify the output of all three coils.

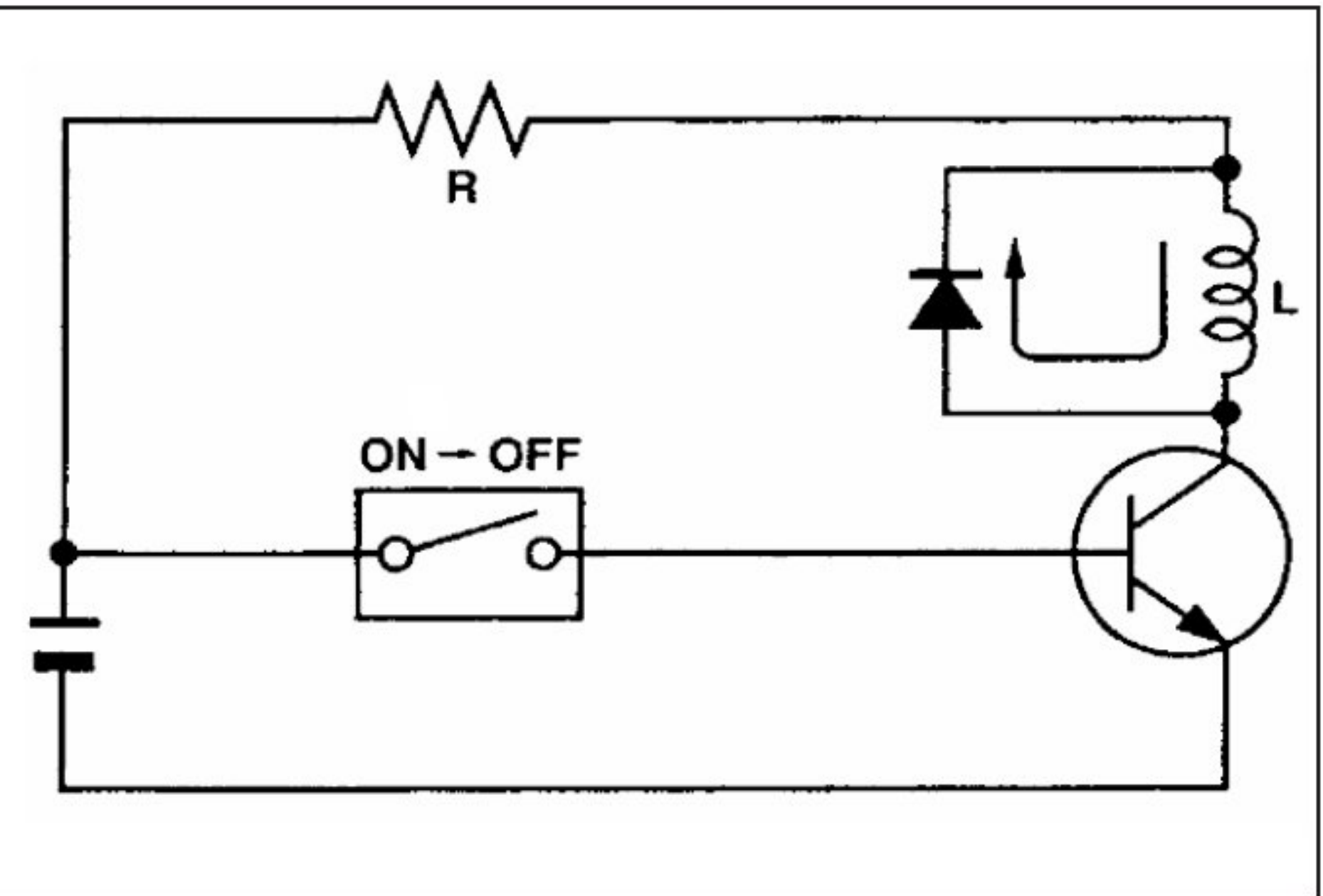


In each of the these illustrations, trace the path of the current flow through the stator coils, the corresponding diodes and the DC circuit. The arrows in the illustrations next to the stator coils show the direction of conventional current flow.

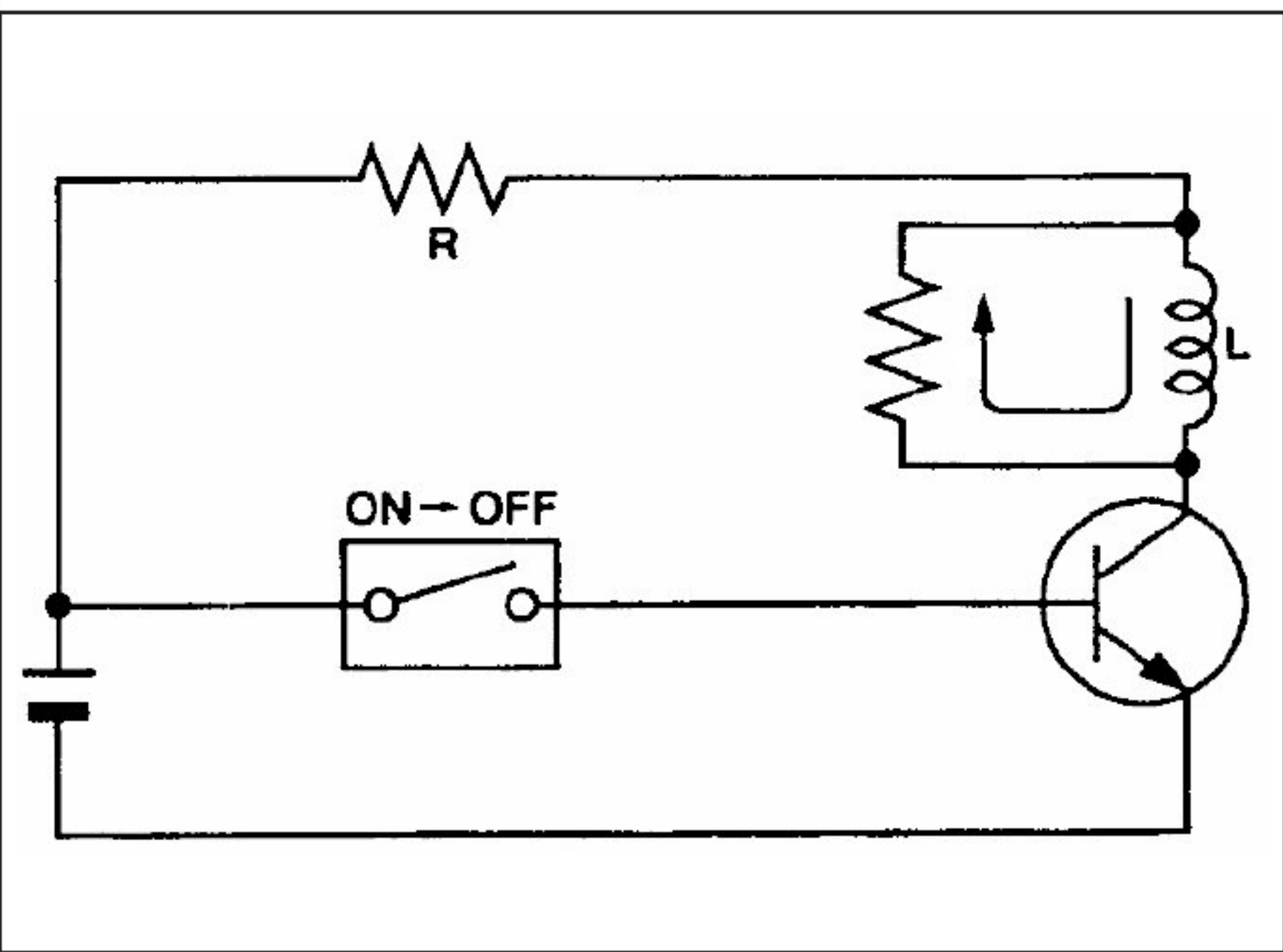


De-Spiking—Diodes are used on some relay coils to suppress voltage spikes. These spikes can damage components such as transistors in the control circuit of the relay. The voltage spike is produced by the collapsing magnetic field in the relay coil which occurs whenever current flow through the coil is stopped suddenly. The voltage induced in the relay coil is similar to the way an ignition coil operates. The induced voltage in a relay coil can be several times more than the system voltage.

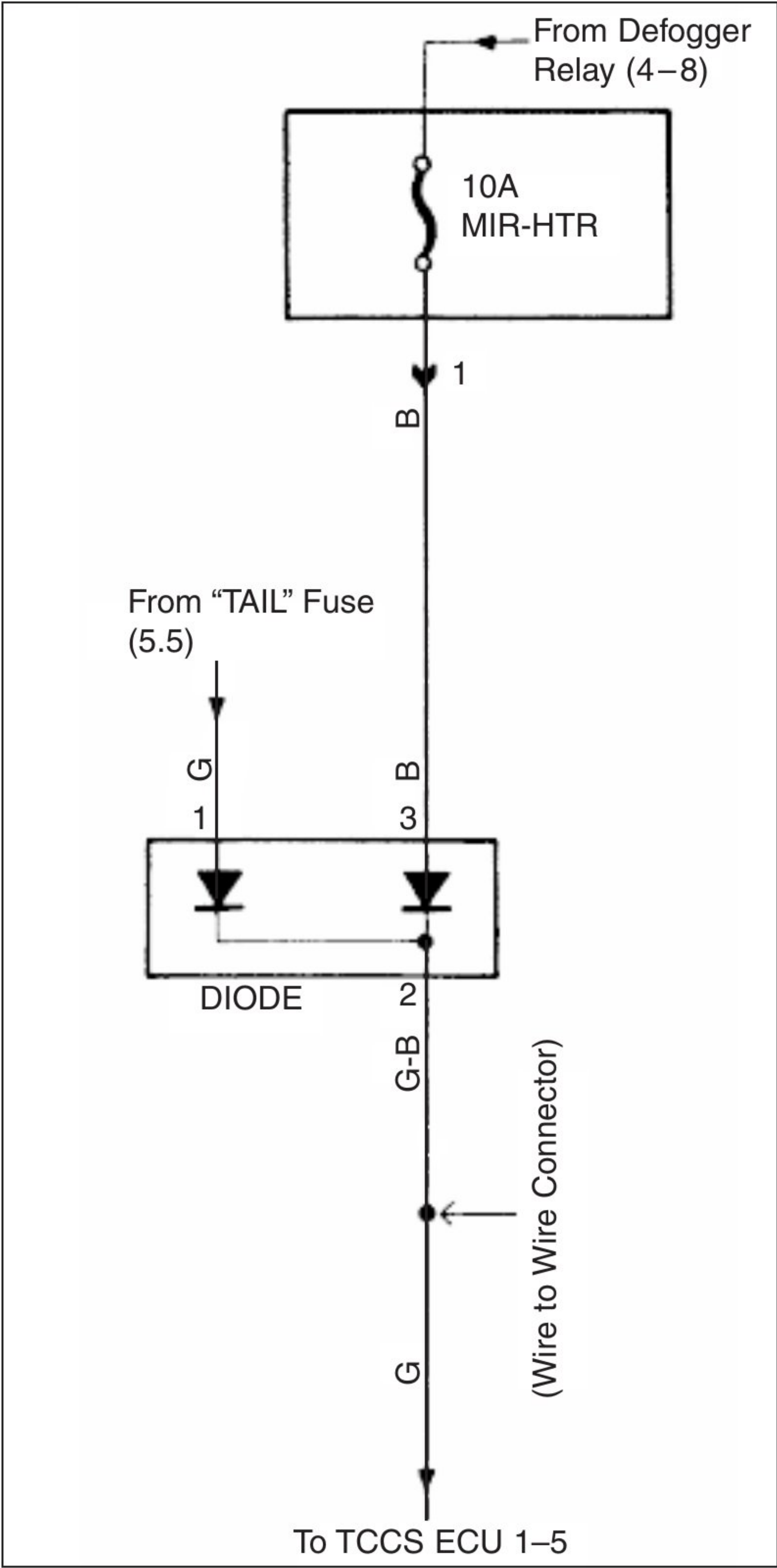
A de-spiking diode is connected in parallel with the relay coil. It is reverse biased when the relay is turned on, therefore no current will flow through the diode. When the relay control circuit is opened, current stops flowing through the coil, causing the magnetic field to collapse. The magnetic lines of force cut through the coil and induce a voltage. Since the circuit is open, no current flows. The voltage builds until it reaches about .7 volts, enough to forward bias the diode, completing the circuit to the other end of the coil. The current flows around in the diode and coil circuit until the voltage is dissipated.



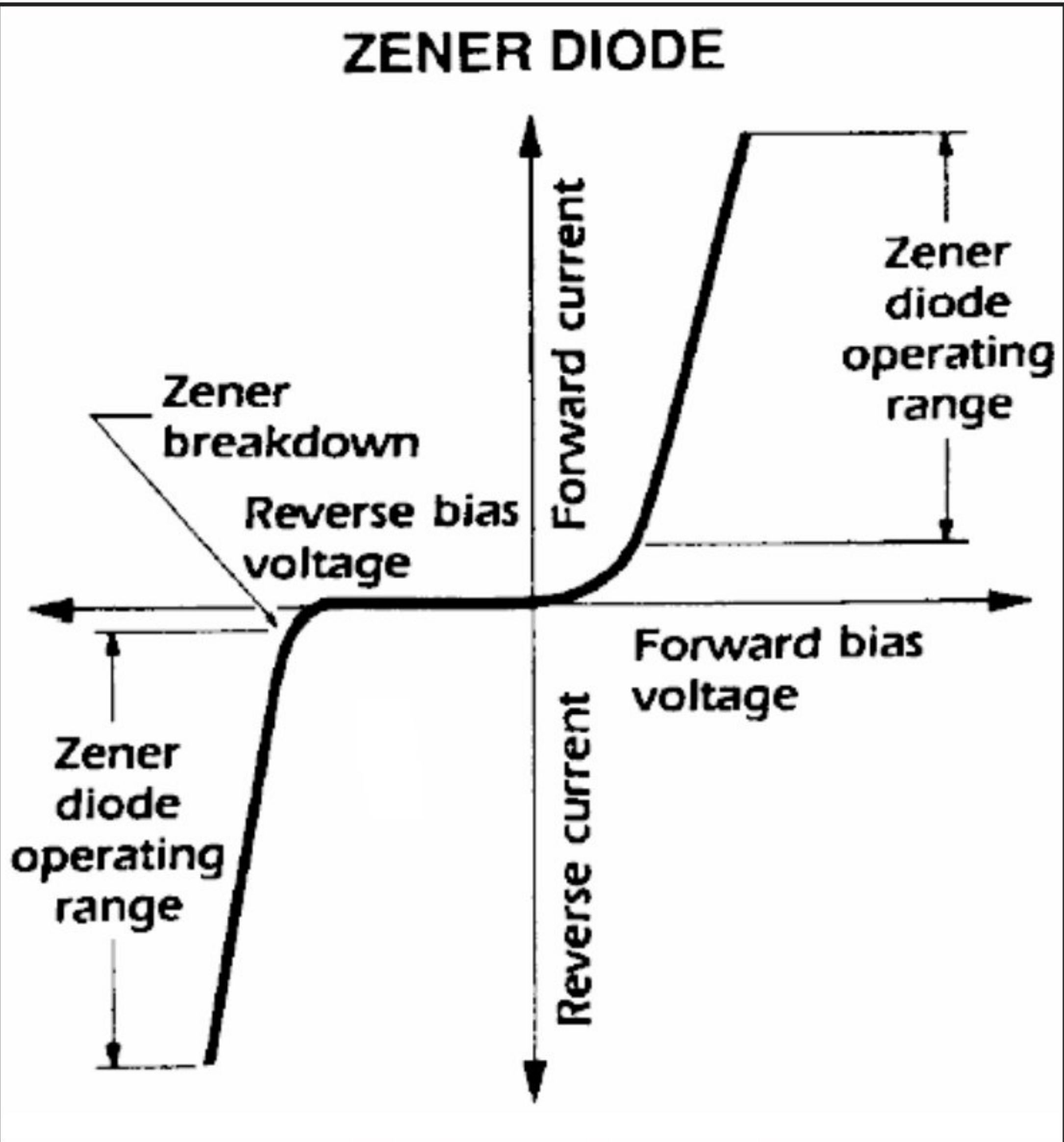
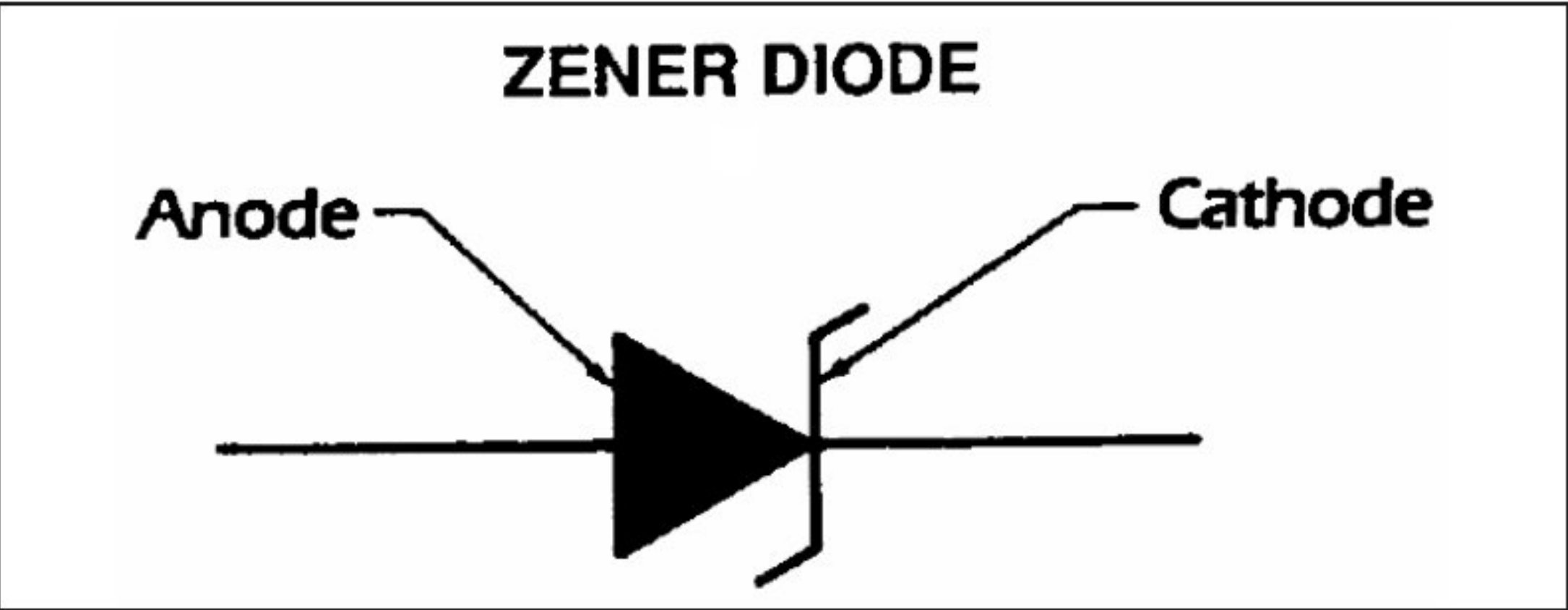
Because some relays located in very hot environments where de-spiking diodes can fail prematurely, resistors are sometimes used instead. The resistor is more durable and can suppress voltage spikes in much the same way as the diode, but the resistor will allow current to flow through it whenever the relay is on. Therefore resistance of the resistor must be fairly high (400 to 600 ohms) to prevent too much current flow in the circuit. Because of resistors' high resistance, they are not quite as efficient at suppressing a voltage spike as diodes.



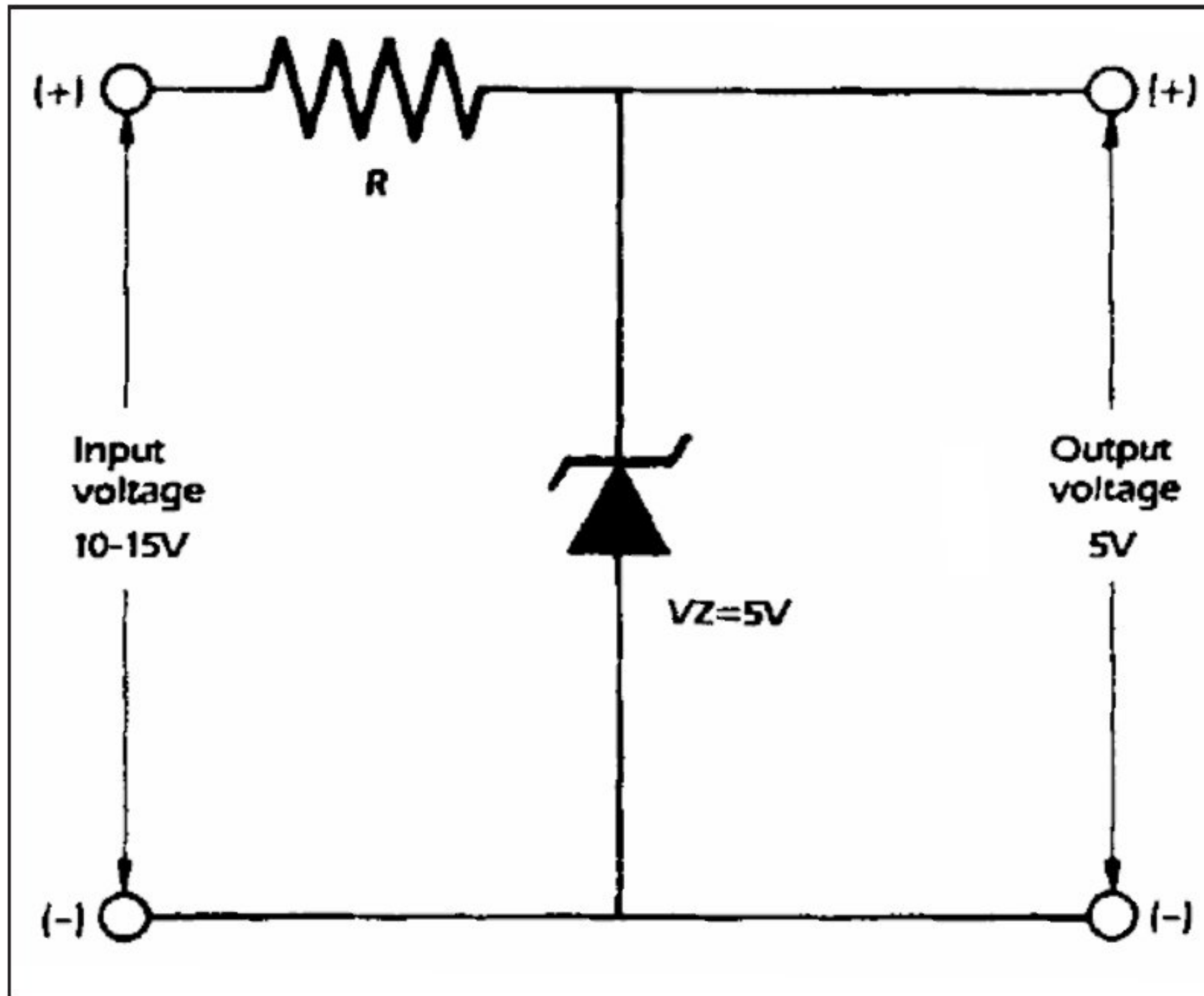
Isolation—A diode can be used to separate two circuits. Diodes are used in this way on many Toyota models. The Electronic Load Sense (ELS) circuit used on a Camry is a good example. This system signals the ECU to increase the idle speed when certain electrical loads are turned on. It uses two diodes so two different circuits can provide a voltage signal to the same terminal on the ECU. Without diodes, whenever either of the systems were turned on, voltage would also be applied to the other circuit causing it to operate.



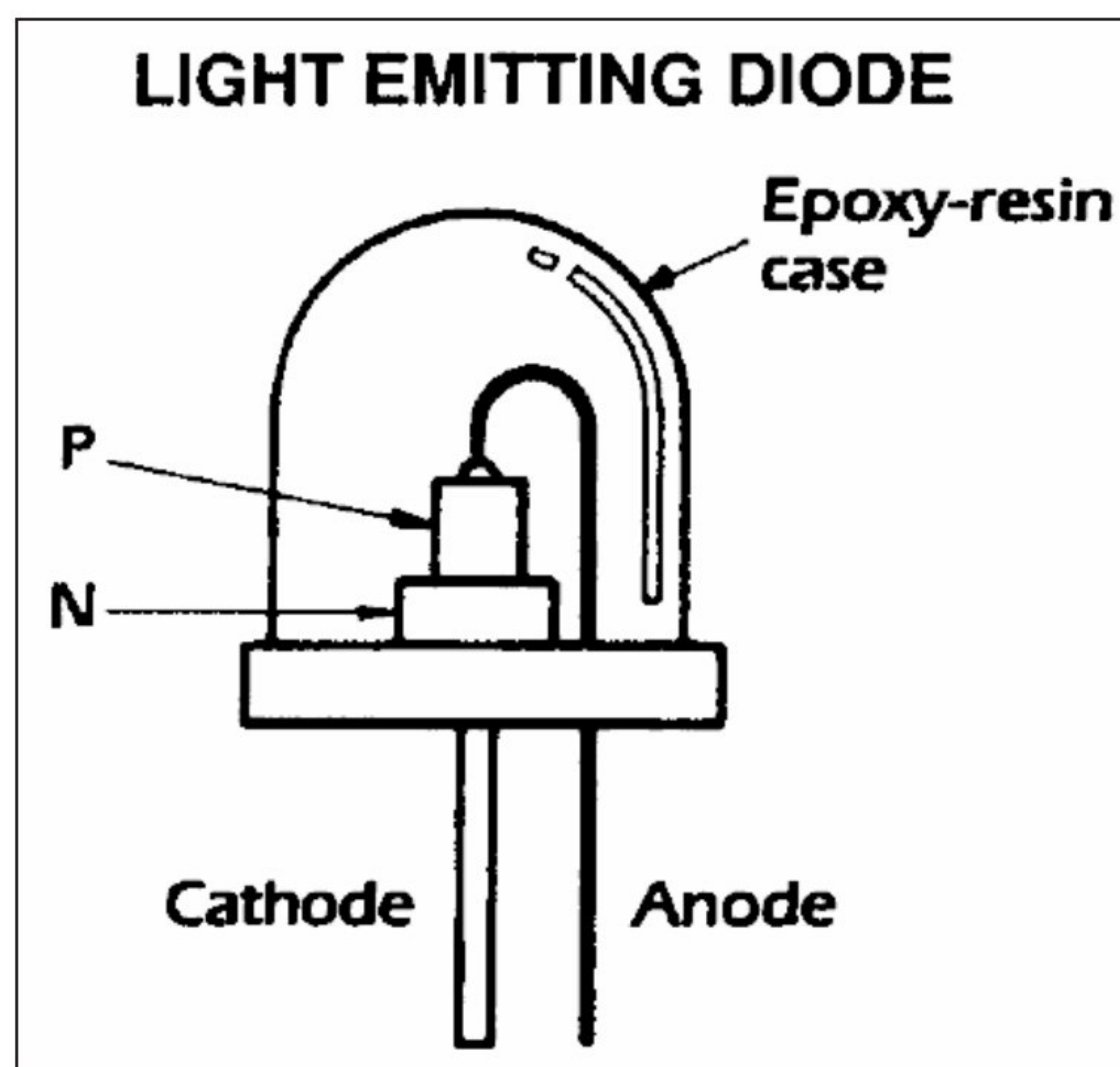
Zener diode—A zener diode acts like an ordinary silicon diode when in the forward bias direction, but it has been specially doped to act very differently in reverse bias. A zener diode allows current to flow in reverse bias at a specific voltage without damage over and over again. The reverse bias voltage at which the zener will conduct, sometimes called the zener point, differs from one zener to another as each zener diode is doped to have a zener point at a specific voltage.



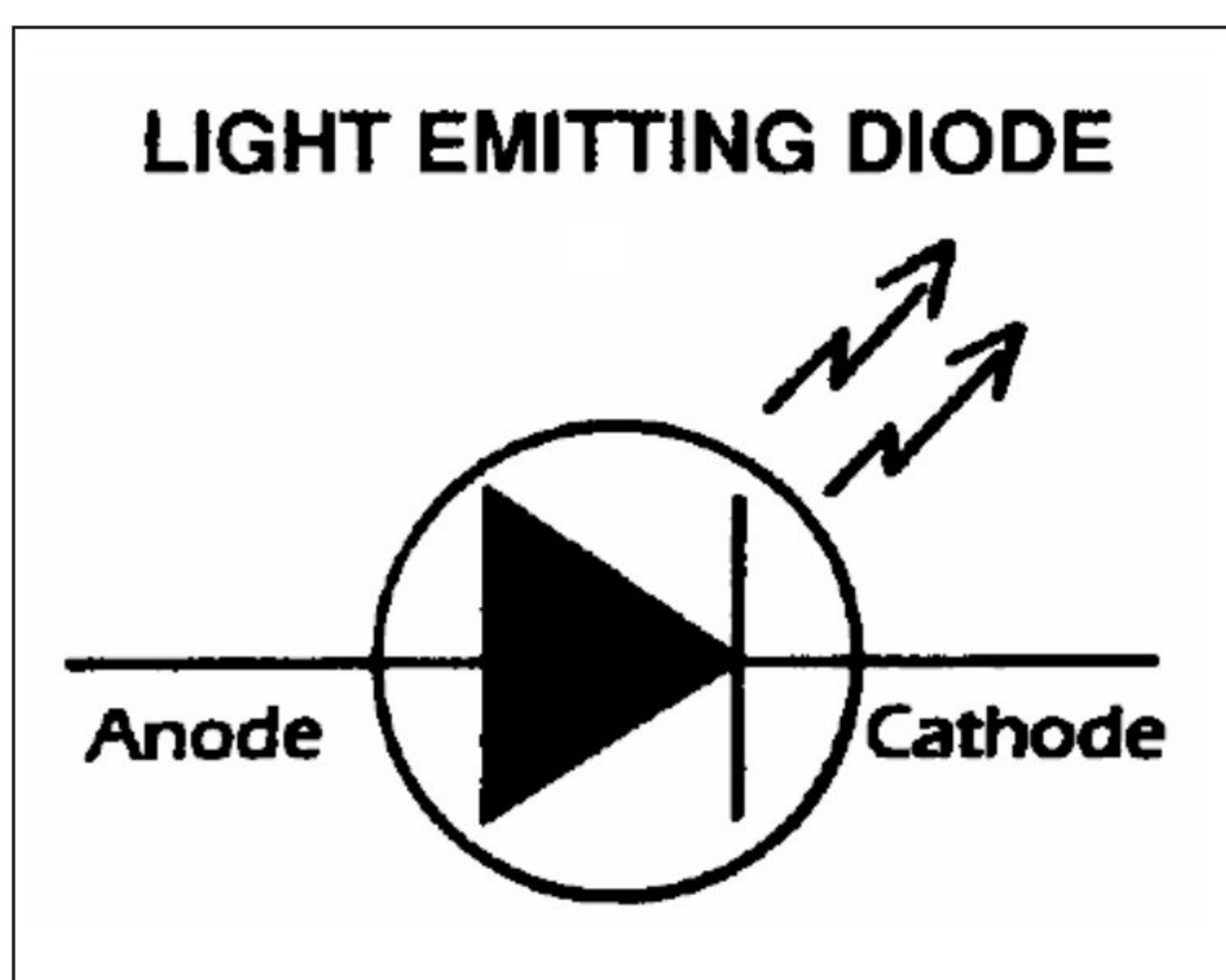
A zener diode can be used to suppress spikes by connecting it between the circuit and ground with the diode reverse biased. When a voltage spike exceeds the zener point of the diode, it completes the circuit to ground and prevents the spike from damaging anything.



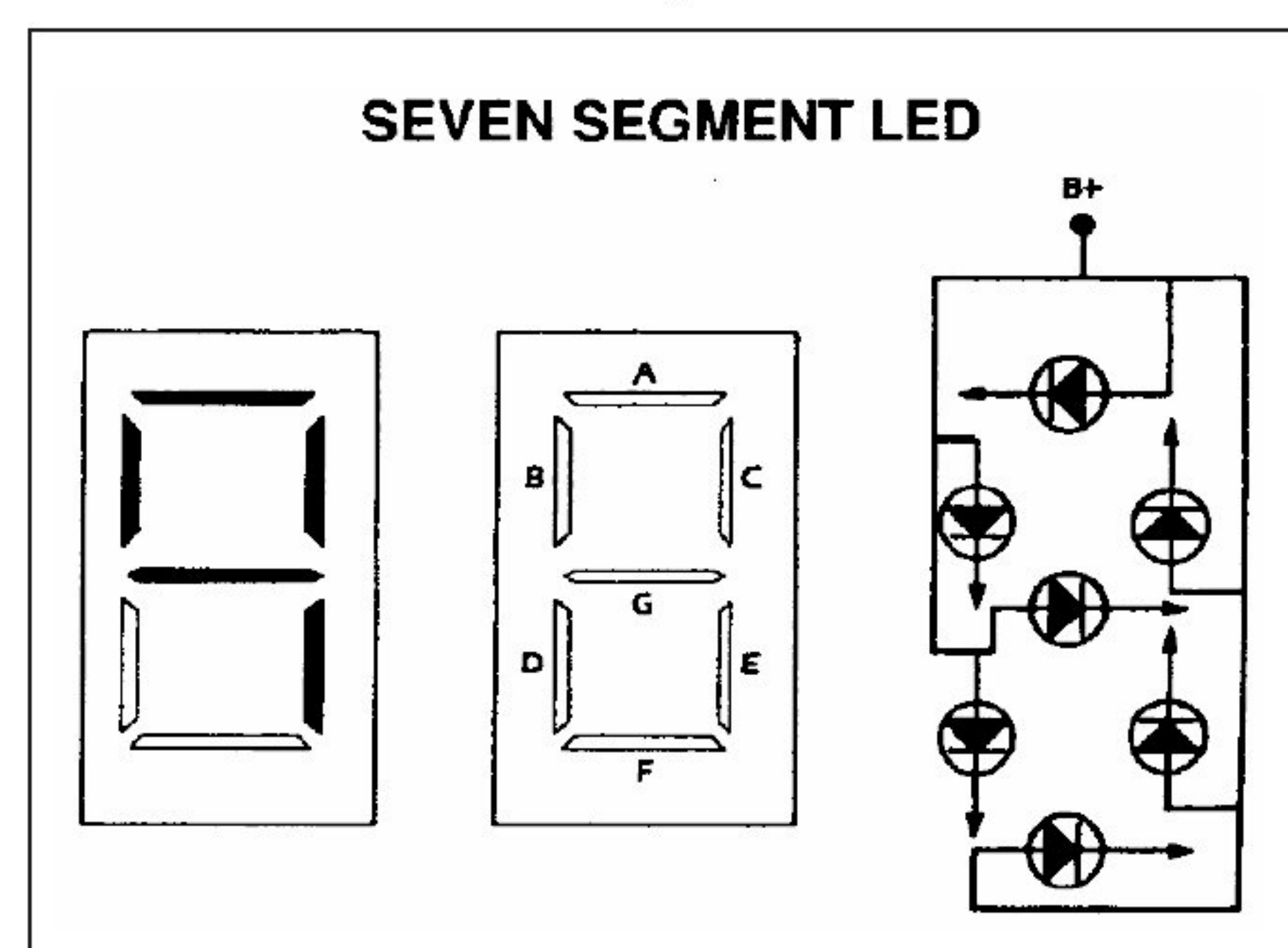
A more common use of a zener diode in an automobile is to sense the charging system voltage. By connecting the zener between the base of a transistor and the positive side of the charging system, the zener can allow current to flow to the base of the transistor when its zener point is reached. If the zener point is 14.5 volts and the transistor to which the zener is connected turns off alternator field current when the transistor is turned on, a constant charging system voltage can be maintained. As soon as the system voltage drops below the zener point, the diode stops conducting and the transistor turns off, allowing field current to flow.



In vehicles, LEDs are used in a variety of ways, including displays and indicators. LEDs are also used in conjunction with phototransistors, which convert light to electrical current. A vehicle speed sensor, known as a photo-coupler or light-activated switch, is a good example. In a speed sensor, the speedometer cable is connected to a slotted wheel which separates the LED from the phototransistor. As the wheel turns, it constantly breaks the beam of light emitted from the LED to the phototransistor, thereby turning the phototransistor on and off. The pulsed signal goes to the computer and is used to determine vehicle speed.



Light emitting diodes (LEDs)—An LED is a diode that is specially designed to produce light. LEDs are made with a transparent epoxy case so they can emit the light they produce when forward biased. The color of the light given off by an LED can be red, green or infrared, depending on how the material is doped. An LED, like a standard silicon diode, will conduct current in only one direction. The forward bias voltage drop of an LED (1.5 to 2 volts) is much higher than a silicon diode. The forward bias current through an LED must be controlled, as with any other semiconductor, or damage will result. LEDs have advantages over ordinary bulbs, such as longer life, cooler operation, lower voltage requirements, and the ability to produce the same amount of light as an incandescent bulb while consuming less power.



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