Diodes

by R. Richards

A material such as metal is a good conductor with low resistivity and is only slightly affected by changes in temperature, materials such as plastics are good insulators with very high resistivity and are also only slightly affected by temperature changes. Semiconductor materials have a resistivity somewhere between that of a conductor and an insulator. The resistivity of this material can be accurately changed by adding small quantities of impurities and its conductivity approximately doubles for each 20 degree centigrade temperature change.

The commonest materials used in the manufacture of diodes are silicon and germanium. These are treated with impurities to alter the conductivity and this is known as doping. One half of the diode is treated with indium aluminium or gallium which forms the P region, the other half is treated with phosphorous arsenic or antimony to form the N region. The area where the P and N type materials are fused together is known as the P N junction or potential barrier. To understand how diodes behave in a circuit is simple, but one would require a sound knowledge of physics to fully understand the operation of semiconductors, so for simplicity we shall deal with basic principles only.

The P type material contains the positive carriers and the N type material the negative carriers, the potential barrier is formed between the two types and acts as a kind of insulator, see Figure 1a.

When the negative pole of a battery is connected to the P type region and the positive pole to the N type region, the carriers are drawn apart widening the depletion zone and preventing any flow of current. Under these conditions the diode is said to be reverse bias, see Figure 1c.

If, on the other hand, the positive pole of the battery is connected to the P region and the negative pole to the N region, the carriers will be drawn across the PN junction allowing current to flow. The diode is now said to be forward biased, see Figure 1b.

The P region of the diode is called the Anode (denoted as A) and the N region is called the Cathode (denoted as K), so from the previous explanation you will appreciate that the conventional current can only flow in one direction, i.e. from anode to cathode.

Diodes are used quite a lot in electronic circuits and rely on the unidirectional nature of the component and will repel the flow of current from cathode to anode until the pressure builds up to the breakdown voltage, and if heavy current is allowed to flow it will damage the diode. This breakdown voltage is known as the peak inverse voltage (P.i.v.), it is therefore essential when choosing diodes that the P.i.v. should be greater than the maximum voltage the diode is expected to carry.

It must also be noted that a diode will not conduct until a certain voltage is reached to overcome the junction barrier. These values are known as the potential barrier and are different for each type of material. Typical threshold voltages are silicon 0.5 to 0.7 volts and germanium 0.1 to 0.2 volts. Germanium diodes are used where a low forward voltage is required, but the P.i.v. is much lower than the silicon diode.

There are two kinds of diodes, namely the signal diode and the rectifier diode. Signal diodes are used for demodulation, clamping and gating. They have a very small junction which can only pass small amounts of current with low capacitance, which is a very desirable factor for use in high frequency circuits.

Rectifier diodes are used for power supplies of low frequency, normally used for rectifying AC voltages derived from mains transformers prior to smoothing and regulator circuits.

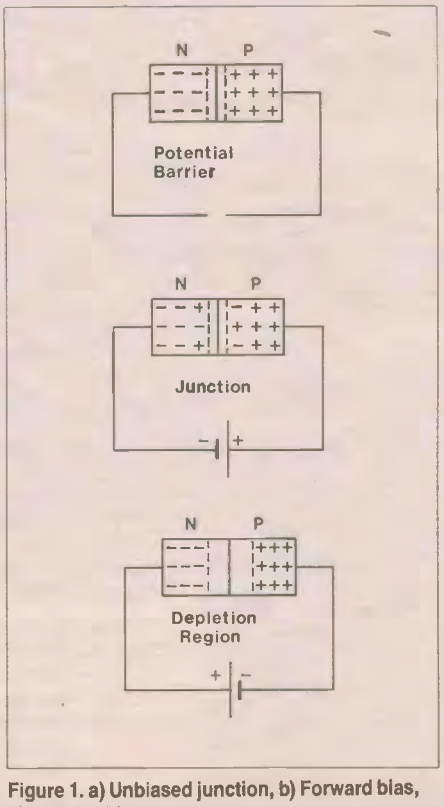

Figure 1. a) Unbiased junction, b) Forward bias, c) Reverse bias.

The modern types of diode are made from silicon and are encapsulated in plastics, but the larger types are encapsulated in a metal stud device, which has provision for mounting on a metal heatsink to dissipate the heat generated internally in the diode during operation. For example, the current flow and voltage drop across the diode causes a power loss which must be dissipated in the form of heat. Power diodes are therefore mounted on heatsinks to improve the cooling of the diode.

The circuit symbol for a diode is shown in Figure 2a. It will be noted that the arrow part of the symbol points in the direction of conventional current flow. Figure 2b illustrates the identification for plastic diodes with the ring marking the cathode end, usually this type is used for currents up to 1 ampere. Diodes from 1 to 3 amperes are also encapsulated in plastic but are generally larger, see Figure 2c. Diodes above 5 amperes are usually metal stud types and the screw end is normally the cathode and the diode symbol is often marked on the body, see Figure 2d.

There are many different diodes available, varying with peak inverse voltages from 8 to 1250 volts and capable of dealing with currents from 30mA to 20A. The most popular ones are listed in Table 1.

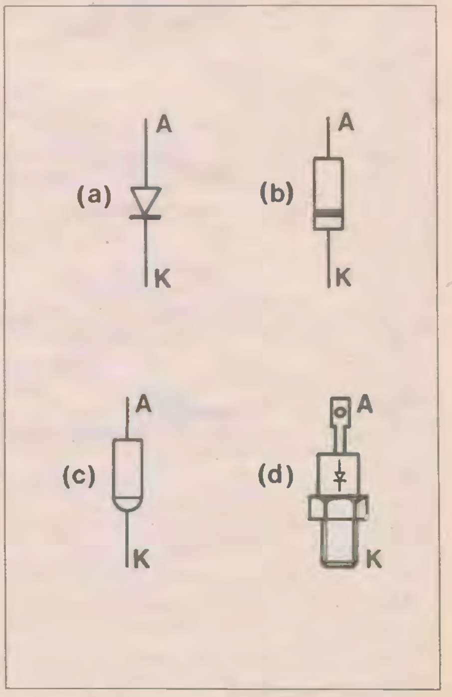

Figure 2. a) Diode symbol, b) 1 amp case, c) 3 amp case, d) Stud mounted, over 5 amp.

Low Power (signal) Germanium

Device	Volts	Amperes
OA47	25	0.11
OA90	30	0.03
OA91	115	0.05

Low Power (signal) Silicon

Device	Volts	Amperes
OA202	150	0.08
1N4148	75	0.075
1N914	75	0.075
BA154	50	0.03
BA155	100	0.1

Power Rectifier Diodes

Device	Volts	Amperes
1N4001	150	1
1N4002	100	1
1N4003	200	1
1N4004	400	1
1N4005	600	1
1N4006	800	1
1N4007	1000	1
1N5400	50	3
1N5401	100	3
1N5402	200	3
1N5403	300	3
1N5404	400	3
1N5405	500	3
1N5406	600	3
1N5407	800	3
1N5408	1000	3
BYX71-350	350	7
BYX71-600	600	7

Table 1. The commonest diodes in use.

Zener Diodes

The most common way of providing a fixed reference voltage is with a zener diode. Ordinary diodes will break down if the reverse voltage increases to the breakdown point. This occurs at a precise voltage which can be varied by adding specific amounts of dope to the semiconductor material. It is therefore possible to manufacture diodes which will break down at a fixed and predictable voltage. Zener diodes are made in such a way that the breakdown region is not damaged at the breakdown voltage providing the current is limited by a series resistor to a safe value.

The zener diode forms an excellent constant voltage source because in the breakdown region of operation the voltage drop across the diode remains constant and independent of the current flowing through it.

Zeners are specified by their breakdown voltage and their power rating, so by dividing the power rating by the breakdown voltage, the maximum current that can be safely allowed to flow can be deduced and is expressed in formula as I = P/V. For example, if we wish to know what is the safe current allowed to flow in a BZX61C5V6 where P = 1.3 and V = 5.6 we get I = 1.3/5.6 = 0.232 or 232mA.

Figure 3a illustrates the circuit symbol used for a zener diode. It should be noted that the arrow part always points towards the positive supply rail. Low powered zener diodes are encapsulated in plastic with a ring marking the cathode. The body is usually marked with the series code and the breakdown voltage, see Figure 3b. High current zeners are normally stud mounted in a similar fashion to their silicon cousins, see Figure 3c.

The most common use of zener diodes is for voltage stabilizing and so they are manufactured in a number of standard power ratings and breakdown voltages as shown in Table 2.

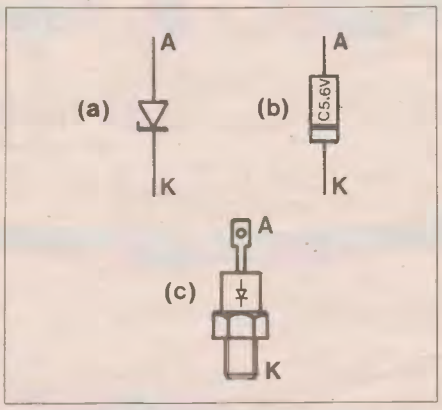

Figure 3. a) Zener diode symbol, b) Plastic case, c) Metal stud.

Series Code	Volts	Power in Watts
BZY88	2.7 to 33	0.4
BZX85	2.7 to 6.8	1.3
BZX61	7.5 to 72	1.3
1N5333	3.3 to 24	5
BZY93	9.1 to 75	20

Table 2. Zener diode ratings.

Light Emitting Diodes

These diodes (which are often abbreviated to LED) are made of transparent semiconductor material which has the property of emitting light when forward biased. When the electrons cross the potential barrier in a forward bias the energy they lose will appear in the form of light. This is achieved by making the diode with gallium arsenide phosphide which produces light in the visible region when forward biased. The voltage drop across the LED is rather higher than that of a normal diode. Forward current of 10 to 50 milliamperes can produce a voltage drop of 1.5 to 2 volts. An LED is usually a two terminal device which will only allow current to flow in one direction, i.e. anode to cathode, see Figure 4a.

The P.i.v. of the LED is very low and if the device is subject to any reverse voltage then it should be protected by fitting an ordinary diode with reversed polarity and connected in parallel with it, see Figure 4c.

The current flow through the LED must not exceed 50mA. To achieve this a resistor is inserted in series with the LED. The value of the resistor is calculated by the following formula:

$$R = \frac{E - 2}{I}$$

Where R = resistance, E = battery voltage, 2 = the voltage drop across the LED and I = the current flowing through the LED. See Figure 4d for example.

The circuit symbol for the LED is illustrated in Figure 4b. Note that the arrow part again points in the direction of conventional current flow. Apart from the single LED, arrays of LEDs can be combined to form a 7 segment LED display, as used in calculators and electronic recording devices for example. Single LEDs are manufactured in many colours although red, green and yellow are the most common, and are used for multitudious purposes. Basic LED details are shown in Table 3.

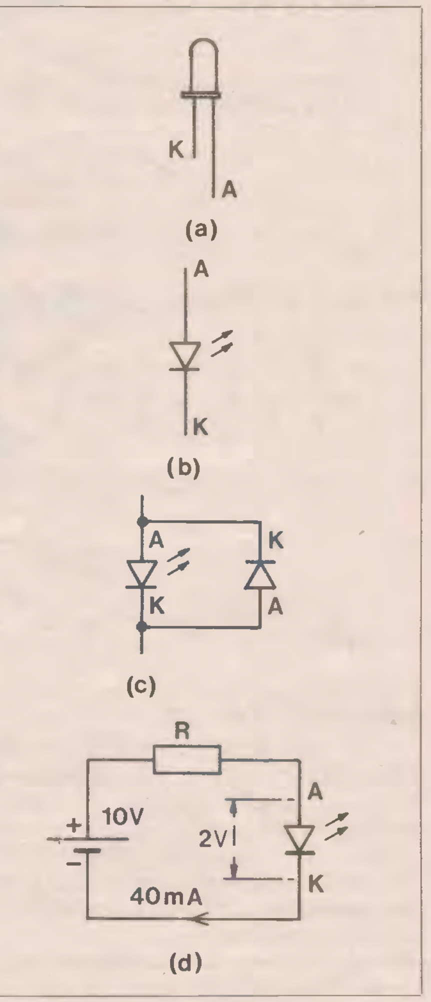

Figure 4. a) LED outline, b) symbol, c) Protected LED, d) Calculation for series resistor.

Colour	Diameter	Forward volts	Reverse volts	Max current	Max power
Red	0.2"	2V	5V	40mA	125mW
Green	0.2"	2V	5V	40mA	125mW
Yellow	0.2"	2V	5V	40mA	85mW

Table 3. LEDs.