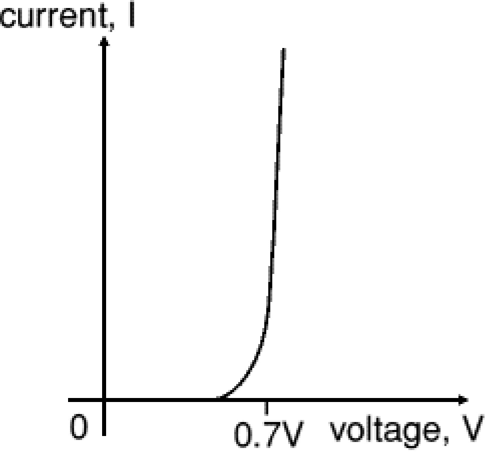
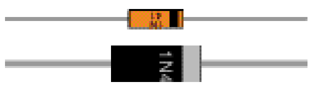
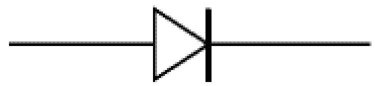


Characteristic of a Silicon Diode

Diodes

[Signal diodes](#) | [Rectifier diodes](#) | [Bridge rectifiers](#) | [Zener diodes](#)

Also see: [LEDs](#) | [AC and DC](#) | [Power Supplies](#)

Example:  Circuit symbol: 

Function

Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow. Diodes are the electrical version of a valve and early diodes were actually called valves.

Forward Voltage Drop

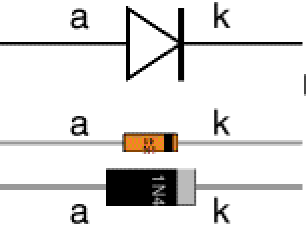
Electricity uses up a little energy pushing its way through the diode, rather like a person pushing through a door with a spring. This means that there is a small voltage across a conducting diode, it is called the **forward voltage drop** and is about 0.7V for all normal diodes which are made from silicon. The forward voltage drop of a diode is almost constant whatever the current passing through the diode so they have a very steep characteristic (current-voltage graph).

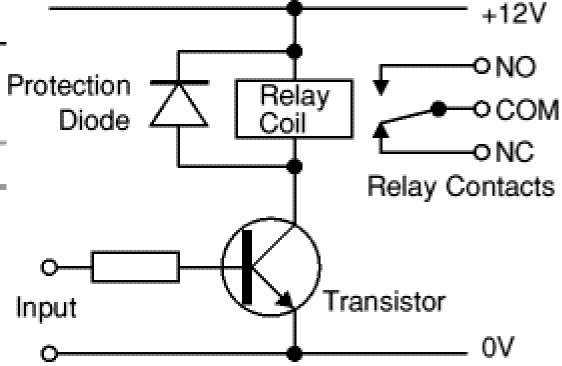
Reverse Voltage

When a reverse voltage is applied a perfect diode does not conduct, but all real diodes leak a very tiny current of a few µA or less. This can be ignored in most circuits because it will be very much smaller than the current flowing in the forward direction. However, all diodes have a **maximum reverse voltage** (usually 50V or more) and if this is exceeded the diode will fail and pass a large current in the reverse direction, this is called **breakdown**.

Ordinary diodes can be split into two types: [Signal diodes](#) which pass small currents of 100mA or less and [Rectifier diodes](#) which can pass large currents. In addition there are [LEDs](#) (which have their own page) and [Zener diodes](#) (at the bottom of this page).

Connecting and soldering





Diodes must be connected the correct way round, the diagram may be labelled **a** or **+** for anode and **k** or **-** for cathode (yes, it really is k, not c, for cathode!). The cathode is marked by a line painted on the body. Diodes are labelled with their code in small print, you may need a magnifying glass to read this on small signal diodes!

Small **signal diodes** can be damaged by heat when soldering, but the risk is small unless you are using a **germanium diode** (codes beginning OA...) in which case you should use a heat sink clipped to the lead between the joint and the diode body. A standard crocodile clip can be used as a heat sink.

Rectifier diodes are quite robust and no special precautions are needed for soldering them.

Testing diodes

You can use a multimeter or a simple tester (battery, resistor and LED) to check that a diode conducts in one direction but not the other. A lamp may be used to test a rectifier diode, but do NOT use a lamp to test a signal diode because the large current passed by the lamp will destroy the diode!

Signal diodes (small current)

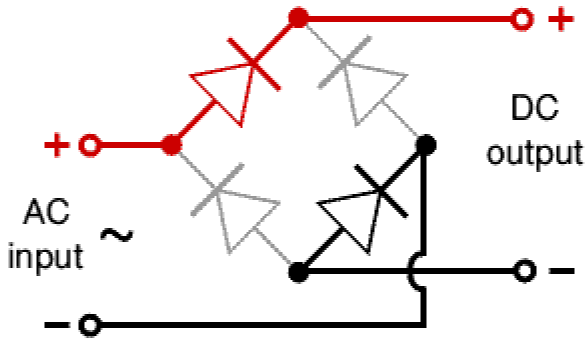
Signal diodes are used to process information (electrical signals) in circuits, so they are only required to pass small currents of up to 100mA.

General purpose signal diodes such as the 1N4148 are made from silicon and have a forward voltage drop of 0.7V.

Germanium diodes such as the OA90 have a lower forward voltage drop of 0.2V and this makes them suitable to use in radio circuits as detectors which extract the audio signal from the weak radio signal.

For general use, where the size of the forward voltage drop is less important, silicon diodes are better because they are less easily damaged by heat when soldering, they have a lower resistance when conducting, and they have very low leakage currents when a reverse voltage is applied.

Protection diodes for relays



Signal diodes are also used to protect transistors and ICs from the brief high voltage produced when a relay coil is switched off. The diagram shows how a protection diode is connected 'backwards' across the relay coil.

Current flowing through a relay coil creates a magnetic field which collapses suddenly when the current is switched off. The sudden collapse of the magnetic field induces a brief high voltage across the relay coil which is very likely to damage transistors and ICs. The protection diode allows the induced voltage to drive a brief current through the coil (and diode) so the magnetic field dies away quickly rather than instantly. This prevents the induced voltage becoming high enough to cause damage to transistors and ICs.

Rectifier diodes (large current)

Diode	Maximum Current	Maximum Reverse Voltage
1N4001	1A	50V
1N4002	1A	100V
1N4007	1A	1000V
1N5401	3A	100V
1N5408	3A	1000V

Rectifier diodes are used in power supplies to convert alternating current (AC) to direct current (DC), a process called rectification. They are also used elsewhere in circuits where a large current must pass through the diode.

All rectifier diodes are made from silicon and therefore have a forward voltage drop of 0.7V. The table shows maximum current and maximum reverse voltage for some popular rectifier diodes. The 1N4001 is suitable for most low voltage circuits with a current of less than 1A.

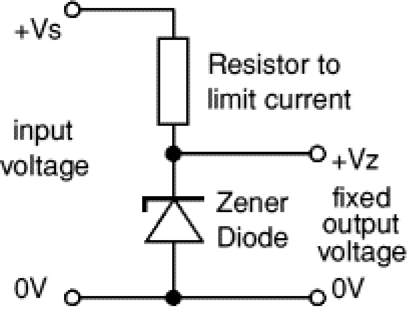
Also see: Power Supplies

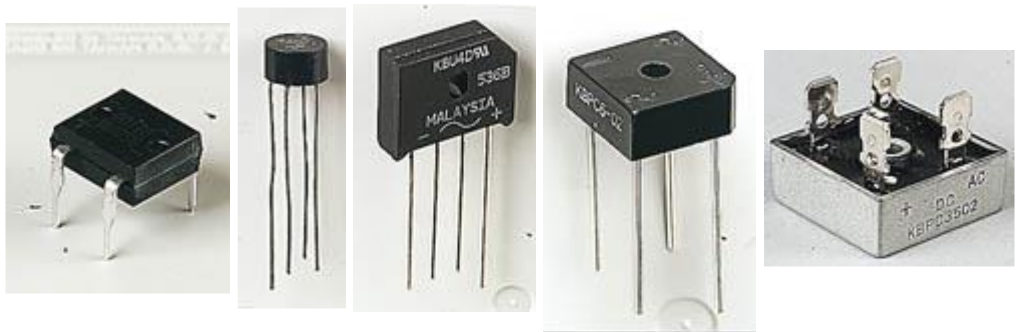
Bridge rectifiers

There are several ways of connecting diodes to make a rectifier to convert AC to DC. The bridge rectifier is one of them and it is available in special packages containing the four diodes required. Bridge rectifiers are rated by their maximum current and maximum reverse voltage. They have four leads or terminals: the two DC outputs are labelled + and -, the two AC inputs are labelled ~.

The diagram shows the operation of a bridge rectifier as it converts AC to DC. Notice how alternate pairs of diodes conduct.

Also see: Power Supplies





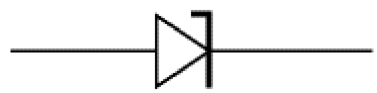
Various types of Bridge Rectifiers
Note that some have a hole through their centre for attaching to a heat sink

Photographs © Rapid Electronics

Zener diodes

Example: 

a = anode, k = cathode

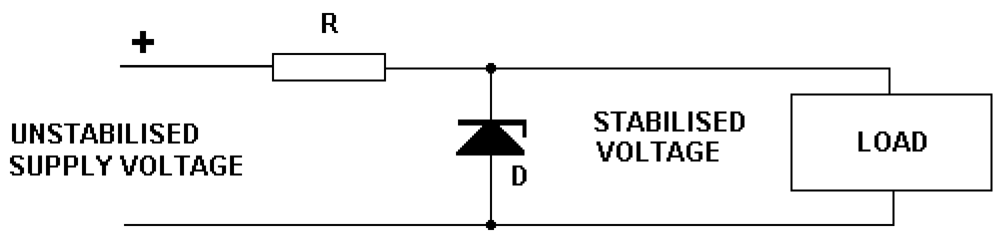
Circuit symbol: 

Zener diodes are used to maintain a fixed voltage. They are designed to 'breakdown' in a reliable and non-destructive way so that they can be used **in reverse** to maintain a fixed voltage across their terminals. The diagram shows how they are connected, with a resistor in series to limit the current.

Zener diodes can be distinguished from ordinary diodes by their code and breakdown voltage which are printed on them. Zener diode codes begin BZX... or BZY... Their breakdown voltage is printed with V in place of a decimal point, so 4V7 means 4.7V for example.

Zener diodes are rated by their breakdown voltage and maximum power:

- The minimum voltage available is 2.4V.
- Power ratings of 400mW and 1.3W are common.



The Zener diode is operated in reverse bias mode (positive on its cathode).
It relies on the reverse breakdown voltage occurring at a specified value.
This value is printed on it.

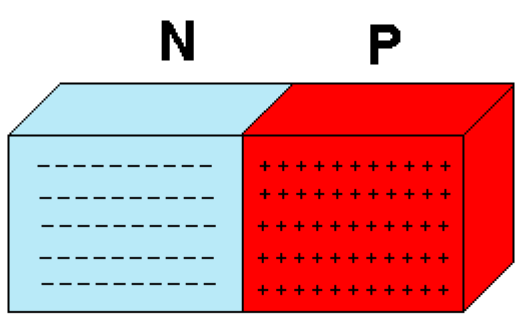
It has two main applications.

1. as a reference source, where the voltage across it is compared with another voltage.

2. as a voltage regulator, smoothing out any voltages variations occurring in the supply voltage across the load.

When being used a voltage regulator, if the voltage across the load tries to rise then the Zener takes more current.
The increase in current through the resistor causes an increase in voltage dropped across the resistor.
This increase in voltage across the resistor causes the voltage across the load to remain at its correct value.

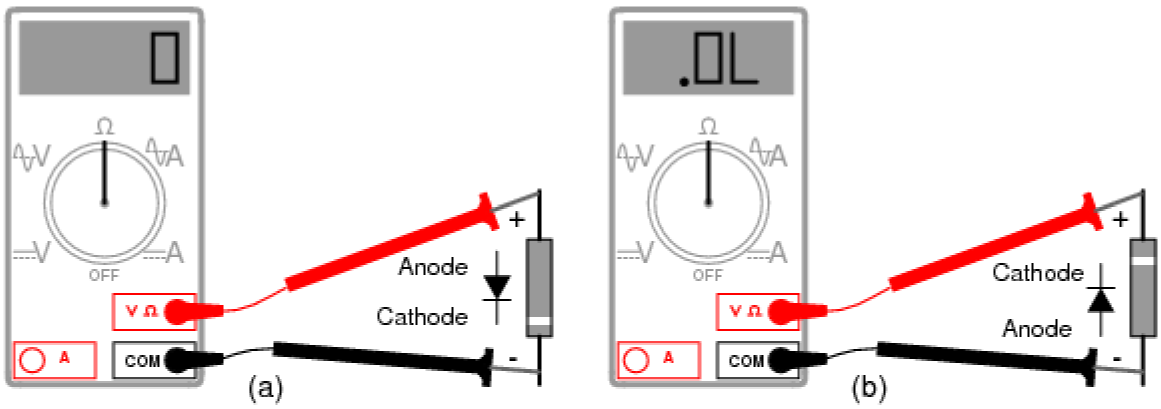
In a similar manner, if the voltage across the load tries to fall, then the Zener takes less current.
The current through the resistor and the voltage across the resistor both fall.
The voltage across the load remains at its correct value.



The P-N junction is made from a single crystal with the impurities diffused into it.

The N end has a surplus of negative electrons.
The P end has a surplus of holes.

Being able to determine the polarity (cathode versus anode) and basic functionality of a diode is a very important skill for the electronics hobbyist or technician to have. Since we know that a diode is essentially nothing more than a one-way valve for electricity, it makes sense we should be able to verify its one-way nature using a DC (battery-powered) ohmmeter as in Figure below. Connected one way across the diode, the meter should show a very low resistance at (a). Connected the other way across the diode, it should show a very high resistance at (b) ("OL" on some digital meter models).

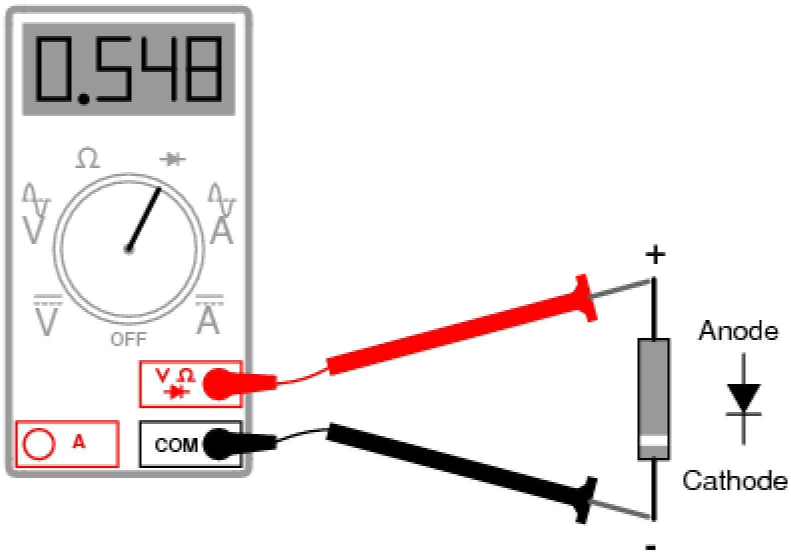


Determination of diode polarity: (a) Low resistance indicates forward bias, black lead is cathode and red lead anode (for most meters) (b) Reversing leads shows high resistance indicating reverse bias.

Of course, to determine which end of the diode is the cathode and which is the anode, you must know with certainty which test lead of the meter is positive (+) and which is negative (-) when set to the "resistance" or "Ω" function. With most digital multimeters I've seen, the red lead becomes positive and the black lead negative when set to measure resistance, in accordance with standard electronics color-code convention. However, this is not guaranteed for all meters. Many analog multimeters, for example, actually make their black leads positive (+) and their red leads negative (-) when switched to the "resistance" function, because it is easier to manufacture it that way!

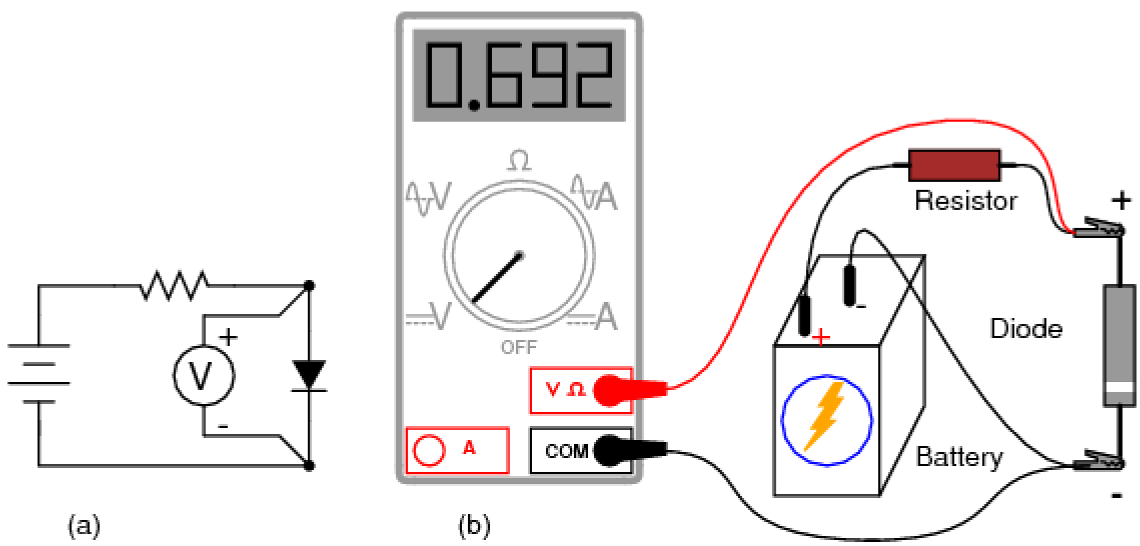
One problem with using an ohmmeter to check a diode is that the readings obtained only have qualitative value, not quantitative. In other words, an ohmmeter only tells you which way the diode conducts; the low-value resistance indication obtained while conducting is useless. If an ohmmeter shows a value of "1.73 ohms" while forward-biasing a diode, that figure of 1.73 Ω doesn't represent any real-world quantity useful to us as technicians or circuit designers. It neither represents the forward voltage drop nor any "bulk" resistance in the semiconductor material of the diode itself, but rather is a figure dependent upon both quantities and will vary substantially with the particular ohmmeter used to take the reading.

For this reason, some digital multimeter manufacturers equip their meters with a special "diode check" function which displays the actual forward voltage drop of the diode in volts, rather than a "resistance" figure in ohms. These meters work by forcing a small current through the diode and measuring the voltage dropped between the two test leads. (Figure below)



Meter with a "Diode check" function displays the forward voltage drop of 0.548 volts instead of a low resistance.

The forward voltage reading obtained with such a meter will typically be less than the "normal" drop of 0.7 volts for silicon and 0.3 volts for germanium, because the current provided by the meter is of trivial proportions. If a multimeter with diode-check function isn't available, or you would like to measure a diode's forward voltage drop at some non-trivial current, the circuit of Figure below may be constructed using a battery, resistor, and voltmeter



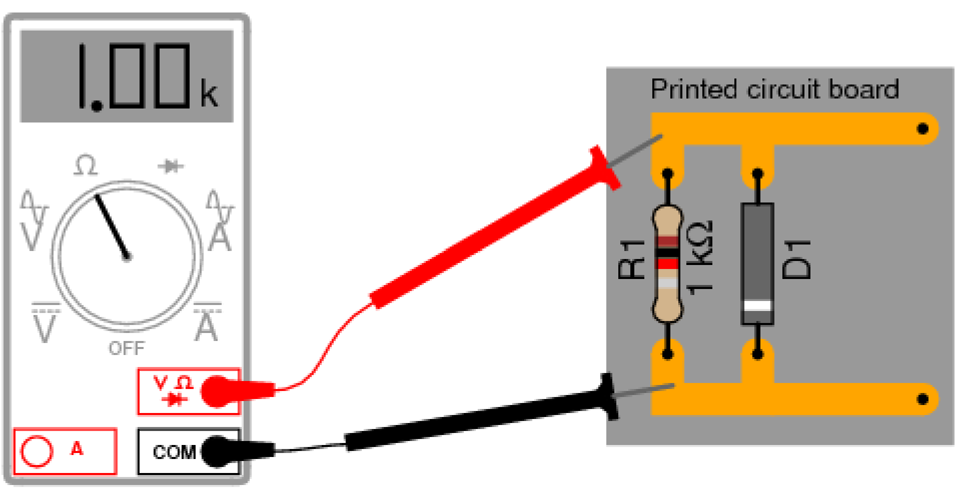
Measuring forward voltage of a diode without "diode check" meter function: (a) Schematic diagram. (b) Pictorial diagram.

Connecting the diode backwards to this testing circuit will simply result in the voltmeter indicating the full voltage of the battery.

If this circuit were designed to provide a constant or nearly constant current through the diode despite changes in forward voltage drop, it could be used as the basis of a temperature-measurement instrument, the voltage measured across the diode being inversely proportional to diode junction temperature. Of course, diode current should be kept to a minimum to avoid self-heating (the diode dissipating substantial amounts of heat energy), which would interfere with temperature measurement.

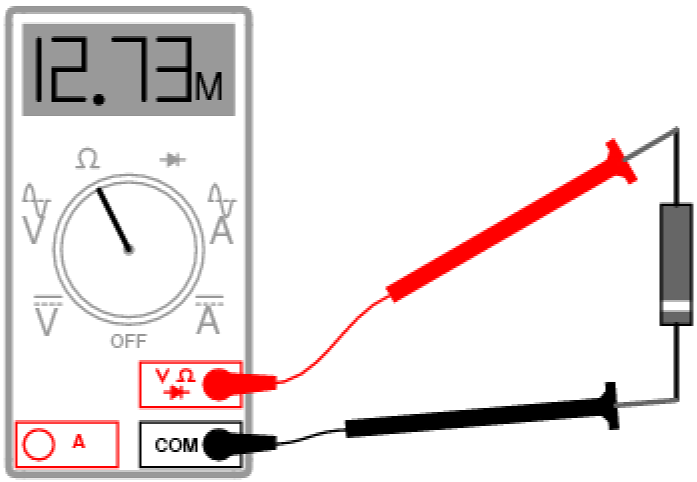
Beware that some digital multimeters equipped with a "diode check" function may output a very low test voltage (less than 0.3 volts) when set to the regular "resistance" (Ω) function: too low to fully collapse the depletion region of a PN junction. The philosophy here is that the "diode check" function is to be used for testing semiconductor devices, and the "resistance" function for anything else. By using a very low test voltage to measure resistance, it is easier for a technician to measure the resistance of non-semiconductor components connected to semiconductor components, since the semiconductor component junctions will not become forward-biased with such low voltages.

Consider the example of a resistor and diode connected in parallel, soldered in place on a printed circuit board (PCB). Normally, one would have to unsolder the resistor from the circuit (disconnect it from all other components) before measuring its resistance, otherwise any parallel-connected components would affect the reading obtained. When using a multimeter which outputs a very low test voltage to the probes in the "resistance" function mode, the diode's PN junction will not have enough voltage impressed across it to become forward-biased, and will only pass negligible current. Consequently, the meter "sees" the diode as an open (no continuity), and only registers the resistor's resistance. (Figure below)



Ohmmeter equipped with a low test voltage (<0.7 V) does not see diodes allowing it to measure parallel resistors.

If such an ohmmeter were used to test a diode, it would indicate a very high resistance (many mega-ohms) even if connected to the diode in the "correct" (forward-biased) direction. (Figure below)



Ohmmeter equipped with a low test voltage, too low to forward bias diodes, does not see diodes.

Reverse voltage strength of a diode is not as easily tested, because exceeding a normal diode's PIV usually results in destruction of the diode. Special types of diodes, though, which are designed to "break down" in reverse-bias mode without damage (called *zener diodes*), which are tested with the same voltage source / resistor / voltmeter circuit, provided that the voltage source is of high enough value to force the diode into its breakdown region. More on this subject in a later section of this chapter.

- **REVIEW:**
- An ohmmeter may be used to qualitatively check diode function. There should be low resistance measured one way and very high resistance measured the other way. When using an ohmmeter for this purpose, be sure you know which test lead is positive and which is negative! The actual polarity may not follow the colors of the leads as you might expect, depending on the particular design of meter.
- Some multimeters provide a "diode check" function that displays the actual forward voltage of the diode when its conducting current. Such meters typically indicate a slightly lower forward voltage than what is "nominal" for a diode, due to the very small amount of current used during the check.