HOW DIODES WORK

Joe Knows Electronics™

IMPORTANT NOTE ON DIODE PACKAGES

Most of the diodes supplied in our semiconductor kit are in very small DO-35 glass cases. There is very little room on these cases to print identifying numbers and codes clearly. It would be best to keep track of the identities of parts from the moment they are removed from their envelopes until they are replaced.

There are several types of diode included in your Joe Knows Electronics Semiconductor Kit: general-purpose diodes, Zener diodes, Schottky diodes, PIN diodes, varicap (variable capacitance) diodes, and current regulation diodes.

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The best way to communicate with us is by email. This allows us to have a record of your correspondence and the ability to convey information like technical specifications more easily.

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Someone is available 24/7 to take your call at our toll free number. Your contact information will be taken and a member of our management team will contact you within normal business hours, 9am – 6pm EST M-F. Please note that our phone associates don't have the necessary information to discuss products or orders but will direct your call to the appropriate company representative.

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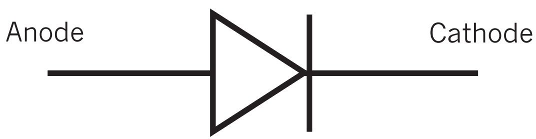
GENERAL-PURPOSE DIODES

The essence of how a simple diode operates is asymmetric conductance. While it shows very large resistance to current flow in one direction, there is very little resistance in the opposite direction. The electronic symbol for a diode appears below – the electrons in the low-resistance current flow opposite to the direction of the arrow, but the current flows in the direction the arrow points, because electrons have a negative charge.



Most diodes have a dot or a bar on them that shows which lead is the cathode:

1N4148
Comes in a DO-35 glass case 4mm long and 2mm diameter. A band at one end of the case indicates the cathode terminal.

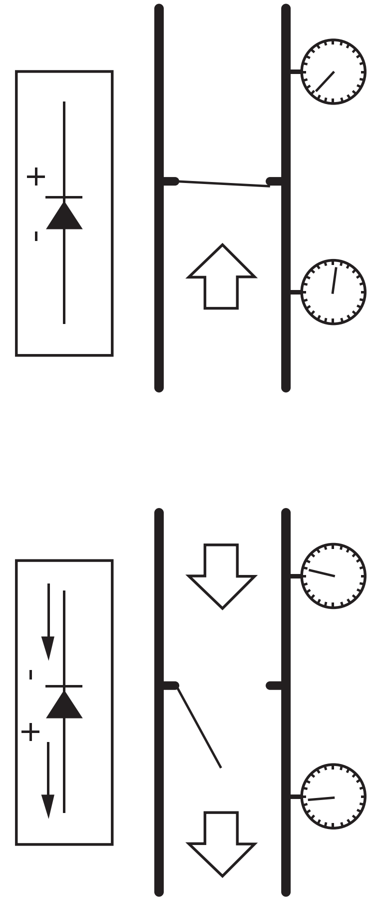
10A01-T
Comes in an R-6 plastic case 9mm long and 9mm diameter. Cathode band indicates the cathode terminal.

BY500-600
Comes in a DO-201AD epoxy case 9mm long and 5mm diameter. Cathode band indicates the cathode terminal.

RC205
Four diodes in a package making up a full wave rectifier for power supplies. Comes

in an RC-2 case 9mm diameter and 7mm high with four leads. The longest lead is the positive DC output lead. The lead opposite the positive DC output is the negative DC outputs. The other two leads are the AC input leads.

The operation of a diode can be imagined as similar to that of a check valve:



(b) Flow prohibited

(a) Flow permitted

Hydraulic Check Valve

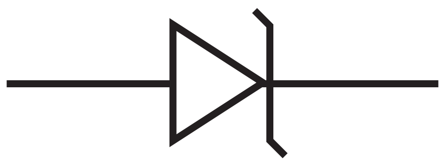
But the check valve isn't a perfect analogy – you get a better idea of the function if you assume that there is a little spring holding the flapper closed against the flow of electrons to the left, and that the flapper itself is elastic. You have to build up a little force (about 0.7 volts for a standard silicon diode) before the flapper will open. This is called the on-voltage, or more formally the diode forward voltage drop. A diode won't conduct in the forward direction unless the applied voltage is more than 0.7 volts, and thereafter the voltage drop across the diode will always be at least 0.7 volts (the exact value depends on the current flowing through the diode).

The elastic flapper has a similar effect when looking at reverse current flow. If the pressure on the left side of the check

valve becomes large enough, the flapper collapses, allowing a reverse flow to occur freely. The voltage at which this occurs is called the reverse breakdown voltage, and can be anywhere from a few volts to thousands, depending on the design details. With these basic ideas, you are equipped to understand what the diodes are doing in most circuits.

ZENER DIODES

Most special-purpose diodes are actually fairly normal diodes in which one or another of the normal characteristics of the general-purpose diode is exaggerated. In the case of Zener diodes, the reverse breakdown behavior (in which the flapper collapses) is the focal point.



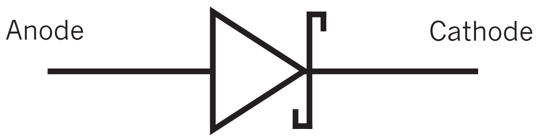
In the forward direction or when only small voltages are applied, a Zener diode works just as does a general-purpose diode. However, the Zener diode is designed so that the reverse breakdown takes place at a precise voltage, which can be as small as 1.8

volts in commercial Zeners (your kit contains values from 2.4 to 20 volts). In addition, once reverse conduction has begun, the resistance to the reverse flow is very small, so that the voltage across the diode remains very near to the Zener threshold regardless of the amount of reverse current flow. This characteristic makes the Zener diode well suited to voltage regulation. However, in design work it is important to remember that a Zener diode also provides the small-signal functions of a general-purpose diode, as they often serve two distinct roles in a circuit.

The Zener diodes in your semiconductor kit range in voltage from 2.4 to 20 volts, and all come in DO-35 glass cases as do the 1N4148 general purpose diodes described in that section.

SCHOTTKY DIODE

A Schottky diode has a metal-semiconductor contact rather than the p-n semiconducting junction of a general-purpose diode. The effect of this change in structure is to reduce the on-voltage of the diode from 0.7 volts to about 0.2-0.3 volts.

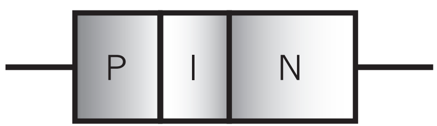


This also makes the Schottky diode capable of operating as a fast switch –the switching time for the 1N6263 Schottky diodes in your kit is about 100 picoseconds – fast enough to keep up

with a 5 GHz signal. Schottky diodes are a bit delicate: their reverse breakdown voltage is typically rather small, and their ability to dissipate power is dramatically reduced by having a metal side of the junction. As a result, they are also rather sensitive to electrostatic discharge, and static preventive handling methods are advisable. The 1N6263 is also in a DO-35 glass case.

PIN DIODE

A PIN diode replaces the p-n junction of a general-purpose diode with a semiconductor structure having three layers, although still only two electrodes. The layers are p- and n-type silicon separated by a thin layer of lightly doped, or near-intrinsic silicon. The p and n layers are heavily doped, to the extent that these layers are simply good conductors. The action of the PIN diode takes place at the surfaces and with the near-intrinsic layer.



When a PIN diode is forward biased, the intrinsic layer is injected with very large

numbers of carriers from the adjoining highly doped layers. This dramatically decreases the resistance of the diode, from 10 kohms at a microamp of forward current to about 20 ohms at a milliamp of forward current for the BA479 PIN diodes in your kit. These come in the DO-35 glass case.

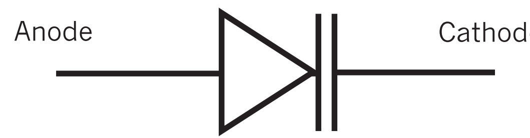
Another attribute is that the intrinsic layer is rather thick, meaning that it takes quite a while for the injected carriers to escape after the forward bias is removed. This means that, while for low frequencies a PIN diode functions just as a general-purpose diode, at high frequencies the intrinsic layer does not have time to respond to the fluctuating current.

It essentially works as a variable resistor at high frequencies – 1-1000 MHz for the BA479 diodes. The control signal that determines the resistance is a DC current applied across the PIN diode, which implies that a very small amount of DC power can control a very large output signal from a PIN diode circuit, making possible very efficient RF switches, amplifiers, and modulators (or equivalently attenuators).

A PIN diode can also be used as a photodetector. When a PIN diode is reverse-biased well below the reverse breakdown voltage, there is only a very tiny current flow, called a dark current. If a photon is absorbed by the silicon in the intrinsic layer, it frees a charge carrier from the silicon. This charge carrier is then swept along by the electric field driven by the reverse bias, which can then be detected as a pulse of current. PIN photodiodes are used in preference to p-n junction photodiodes in optical communication.

VARICAP DIODES (VARIABLE CAPACITANCE)

Also called varicap, varactor, or tuning diodes, these devices exhibit a capacitance that depends on the voltage supplied across the diode, making them extremely tunable in RF circuits such as radio receivers and transmitters.



The operating principle of a varicap diode can be illustrated through the check valve analogy. When a diode is reverse-biased (as in the second part of the check valve picture), initially electrons are pressed up against the flapper of the check valve, holding it closed. These electrons, of course, are charged, and act to repel any electrons from the other side of the flapper. (Holes are pulled toward the flapper, but are thereby removed from the region just behind the flapper.)

The net result is that there is a region, called the depletion layer, just behind a reverse-biased p-n interface in which there are essentially no current carriers. The depletion layer is an insulator that lies between a pair of conductive slabs – a configuration which sounds rather like a capacitor.

Of course, this does make up a capacitor. As the thickness of the depletion layer increases with larger reverse voltages, the capacitance of the diode becomes

smaller, roughly inversely proportional to the square root of the applied voltage. While the effect is fairly small in conventional diodes, designs capable of relatively large capacitance ranges have been developed.

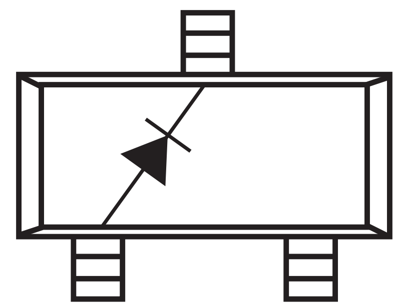
The SMV1249 varicaps in your kit have a capacitance range between 37 and 2 picofarads as the reverse-bias voltage varies between 0 and 8 volts.

As varicaps generally are used in tuned circuits, it is often necessary to keep the DC voltage that determines their capacitance separate from the RF energy being manipulated by the tuned circuit. This is often accomplished by putting the varicap in series with a larger capacitor that blocks the DC voltage from entering the tuned circuit, and feeding the DC tuning voltage through a large resistor. Varicaps also have a property that can either be a curse or a blessing, depending on what you want your circuit to accomplish. The capacitance of a varicap depends on the applied voltage. As a result, if the RF voltage in your tuned tank circuit becomes too large, it will change the resonant frequency of the tank during each current oscillation, introducing potentially huge distortion into the RF output from the circuit.

This is usually a bad thing, but nonlinear effects such as these offer opportunities to those prepared to take advantage. For example, a varicap can be used as a frequency mixer by using a voltage at one frequency to set the capacitance of a tuned circuit through which a voltage

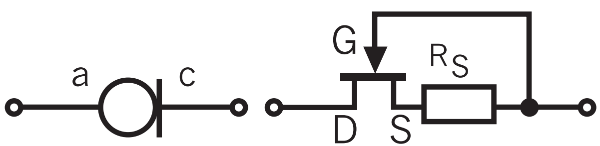
at a different frequency is being passed. This will produce the usual sidebands found in, e.g., a superhet receiver or an FM transmitter.

The SMV1249 varicaps come in an SOT-23 plastic case measuring about 3x2mm, and having surface mount tabs. The varicap is connected according to this figure:

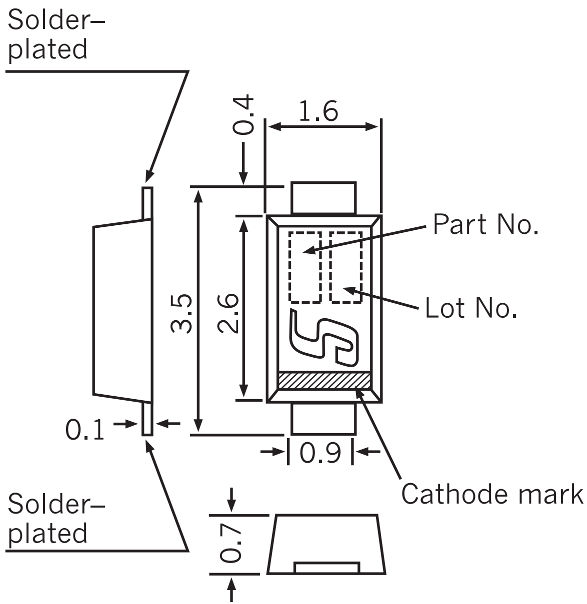


CURRENT REGULATION DIODES

The name of these devices is a bit of a misnomer, as they are actually not diodes, at least not in the usual sense. These devices are actually junction field effect transistors which have their gate and source shorted together. Unlike Zener diodes which keep a constant voltage, these diodes keep a constant current. These devices keep the current flowing through them unchanged when the voltage changes.



The drain current for an FET at zero bias, is the maximum current that can pass through the FET when the gate voltage is held at zero. As the voltage across the two terminals of the shorted FET increases, so too does the current passing through the device. When the voltage is large enough (about 1.5 volts for the S102-T current regulator diodes in your kit), the current through the devices reaches one milliamp, and remains at that value until the voltage exceeds the 100 volt rated voltage capacity of the device. The S102-T devices come in the surface mount package shown on the following page.



Solder–
plated
0.4
1.6
Part No.
Lot No.
3.5
2.6
0.1
0.9
Cathode mark
Solder–
plated
0.7

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