Newcomers' Notebook

Diodes – the electronic non-return valves

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Although simple semiconductor devices, diodes are found in a massive range of applications. In your journey through radio and electronics, you'll mostly encounter 'everyday' diodes widely used in two application areas – signal circuits on one hand, and power circuits on the other. Beyond that, specialised diodes have been developed for particular applications. Diodes – simple explanations without complex mathematics.

When electricity was discovered, the initial belief was that current flowed from the positive terminal to the negative terminal. This description of electricity flow is called 'Conventional Current'. In 1897, a British physicist, J J Thomson (1856 – 1940) discovered that current flow is actually electrons moving from the negative to the positive. This is what really happens and is termed 'Electron Flow'. Both terms are in use today in various engineering spheres.

In describing semiconductors, I will use 'Electron Flow'.

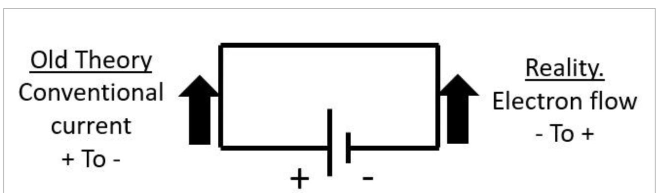


Figure 1. Diagram of old theory and reality.

About semiconductors

A semiconductor is a device somewhere between a conductor and an insulator. So, depending on its use, a semiconductor can behave as either a conductor or an insulator.

The base material of semiconductors is usually silicon (Si) or germanium (Ge). Neither of these is a great conductor; so, the manufacturer dopes (injects an impurity) into the material. Doping with aluminium creates a base material lacking an electron and these are called holes. The resulting material is called P-type.

Doping the base material with phosphorus creates a base material with an extra electron. The resulting material is called N-type.

When N-type and P-type base materials are joined, the N-type has electrons looking to fill the P-type holes. A small number of electrons will flow to fill the holes at the junction. This small junction area is called the *depletion layer*, also known as the depletion zone and depletion region.

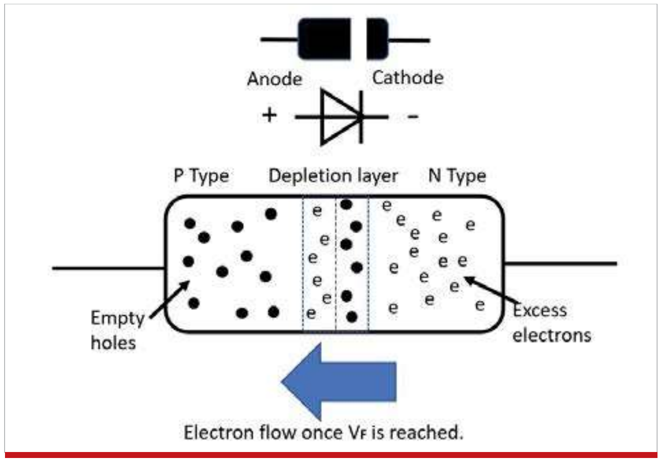


Figure 2. A P-N junction.

Semiconductor devices have a standard numbering system, depending on who makes them and where. Many manufacturers stick with the Joint Electron Device Engineering Council (JEDEC) standard semiconductor numbering system. In this system, the leading number of the semiconductor type indicates the number of junctions in the device.

- 1N4001 is a semiconductor with one junction (a diode).
- 2N3904 is a semiconductor with two junctions (a transistor).

About forward and reverse bias

Looking at the two layers of Figure 2, the electrons want to move from the N-type, with excess electrons, to the P-type, with the holes. This is the natural path and called *forward bias*. The electrons will not go the other way unless a high voltage is applied, which is called *reverse bias*.

The forward voltage in the circuit across the N- and P-types must exceed a defined level – called Forward Voltage (V_F) which is around 0.7 V for silicon devices, but varies with devices. This is the voltage level required to cause electrons to flow through the depletion layer.

Diodes

A diode is a device that lets electrons flow in one direction only. Diodes come in many shapes, sizes, colours, and applications. There are speciality diodes that are operated in the reverse bias region.

Diode specifications and applications are set out in manufacturers' data sheets, which are generally available on the internet. To learn about a particular diode type, a good suggestion is to download and read the data sheet.

A widely used diode is the 1N4001 rectifier diode. It would be one of the most commonly used for many electronic projects. This diode is made by many manufacturers so there may be slight specification variations between manufacturers of the 1N4001.

Looking at the diode, it has these basic characteristics:

- Cylindrical and black;
- Axial leads extend from each end;
- Its type number is screen-printed on the black surface;
- A white band denotes the cathode end of the diode;

Other diodes types can look different.

Characteristics data

I_F (AV) – 1.0 A — The average forward current this diode can operate at is 1 A.

V_{RRM} – 50 V — The maximum repetitive voltage applied in the reverse direction. So, this diode is not good at rectifying voltages over 50 VAC. Other diodes can work at higher voltages, e.g, the 1N4007 can handle 1000 VAC.

I_{FSM} – 30 A — This is the maximum non-repeated forward surge current it can withstand over 8.3 milliseconds (sine wave). So, 1 A average forward current to 30 A surge is a tolerant device.

I_{FSM} – 45 A — These two look the same, but this is only for a 1 ms square wave.

V_F = 1.1 V — This diode requires 1.1 V applied before the electrons will move through the depletion layer and start conducting.

I_R = 5 uA — This is the reverse leakage current when the V_{RRM} is reached. This is temperature dependent, increasing with temperature rise.

T_J max = 150^0 C — Maximum operating temperature.

Plotting these numbers shows a diagram of the diode's current flow. See **Figure 3.**

This is just a short look at the 1N4001's datasheet.

Explore a datasheet such as the KBP005G bridge rectifier for yourself. This device has four diodes in the package connected as a bridge rectifier; the numbers are worth reading.

Diode types and symbols

There are many diode types available. The table here is a short list of diode types with symbols drawn in accordance with the International Standard, IEC 60617. The Australian Standard, AS/NZS 1102, was withdrawn from publication in 2017.

The anode end is annotated with a + symbol and the cathode end is annotated with a - symbol.

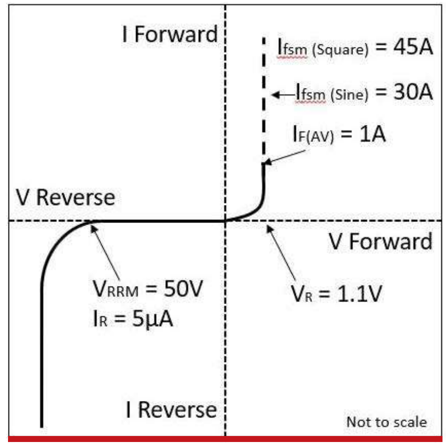
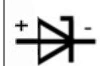
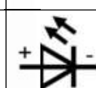
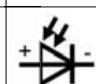
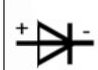
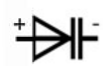
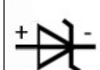


Figure 3: IN4001 voltage vs current (V-I) plot.

Table of diode types and their applications

Avalanche diodes		A diode that works in the reverse bias region as a 'relief valve' in a circuit. Example is if DC power is connected the wrong way the current will flow through the diode and not damage the circuit.
Light-emitting diodes (LED)		Special diodes that emit light when activated.
Photodiodes		Light sensing diode.
Power diode, signal diode		Power diodes are used to rectify AC in power supplies, while signal diodes have much lower ratings for use in signal circuits.
Schottky		Low V_F and fast switching times. Used in high-speed circuitry and RF devices such as mixers, and detectors. Also found in switched-mode power supplies.
Varicap or varactor		Diode acting as a voltage-controlled capacitor.
Zener diodes		More correctly termed reverse breakdown diodes. This effect, called Zener breakdown, occurs at a defined voltage, enabling the diode to be used as a voltage reference.

An old tech once said to me that semiconductors operate by smoke and mirrors. But, once the smoke gets out, they are stuffed. Over my years, I have succeeded in letting smoke out of many semiconductors. Bear this thought in mind when passing on your knowledge to a budding tech.

If you have a topic you would like to be covered in a future instalment of Newcomers' Notebook, email Jules at: jp.bqt@bigpond.net.au

Have fun and stay safe.