Diodes – The electronic non-return valves.

Simple explanation without complex mathematics

by Jules Perrin VK3JFP

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 called J J Thomson (1856 – 1940) discovered that current flow is 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, “Electron Flow” will be used.

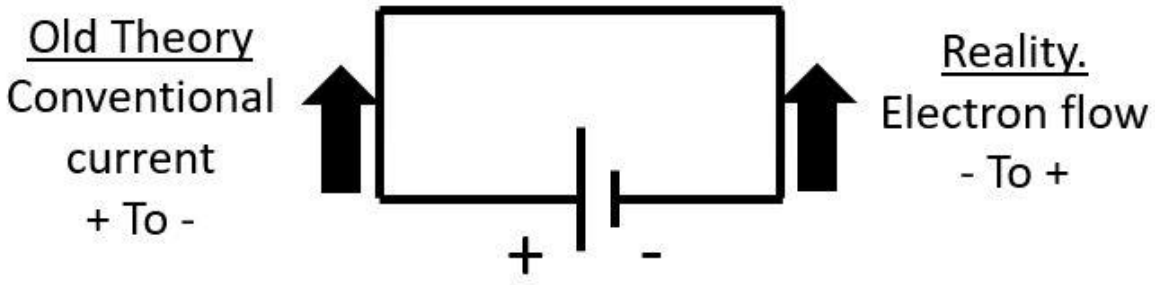


Figure 1: Diagram of old theory and reality.

Semiconductor

A semiconductor is a device somewhere between a conductor and an insulator. So, depending on the application, a semiconductor can be either a conductor or an insulator.

The base material of semiconductors is usually Silicon (Si) or Germanium (Ge). Neither of these are great conductors so the manufacturer will dope (inject an impurity) into the material. Doping with aluminium creates a base material lacking an electron and these are called holes. The resulting material in called a P type.

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

When a N type and P type base material are joined, the P type with the holes and the N type has electrons looking to fill the holes. A small number of electrons will flow to fill the holes at the junction. This small junction area is called the depletion layer.

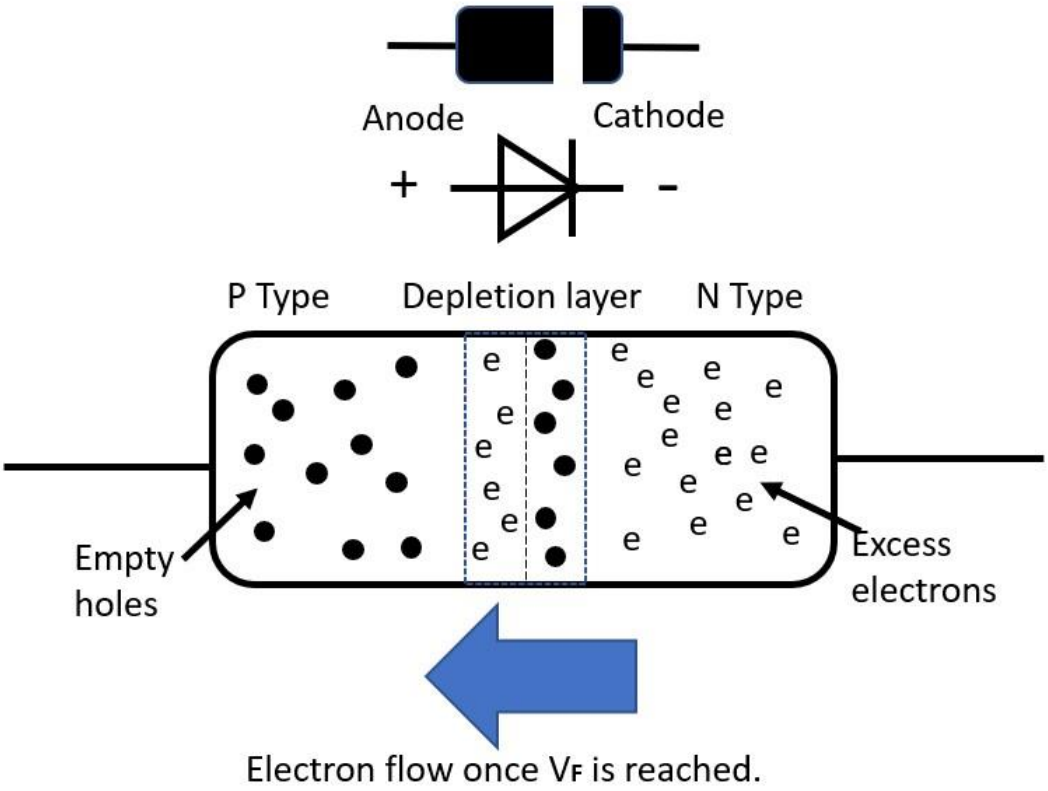


Figure 2: N and P type junction.

In the common semiconductor numbering system, the leading number of the semiconductor indicates the number of junctions in the device.

- 1N4001 is a semiconductor with one junction.
- 2N3904 is a semiconductor with two junctions.

Forward Bias

Looking at the two layers, 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 the forward bias. The electrons don't want to go the other way unless a high voltage point is reached and that is called reverse bias.

The forward voltage in the circuit across the N and P types must exceed a defined point called Voltage Forward (V_F), around 0.7 V 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 can operate in the reverse bias region. A good suggestion is to download and read the data sheet for the diode you plan to use.

A typical datasheet can easily be downloaded from the internet.

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

Looking at the diode, it has the following characteristics. Other types of diodes will look different.

- Round and black.
- Axial leads extending from either end.
- The number is stamped in the black surface.
- A white band denotes the cathode end of the diode.

Characteristics data

I_F (AV) – 1.0 A	The average forward current this diode can operate with is 1 A.
V_{RRM} – 50 V	The maximum non repeated voltage applied in the reverse direction. So, this diode is not good at rectifying voltages over 50 V AC. Other diodes are available e.g. the 1N4007 can handle 1000V AC.
I_{FSM} – 30 A	The maximum unrepeated forward surge current over a short period of 8.3 ms 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 µA	This is the reverse current leakage when the V_{RRM} is reached. This is temperature dependant and increases to at 125 degrees C.
T_J max = 150^O C	Maximum operating temperature.

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

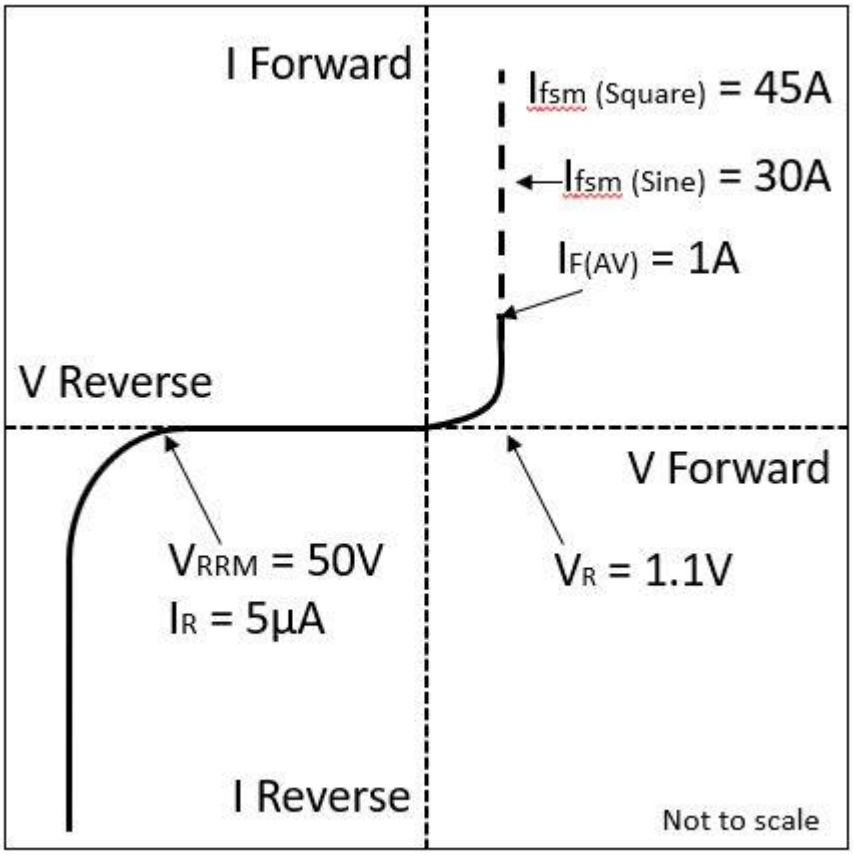


Figure3: IN4001 plot.

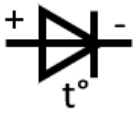
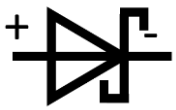
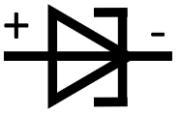
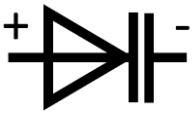
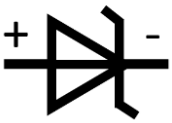
This is a short look at the datasheet, so explore a datasheet such as the KBP005G for yourselves. This device has four diodes in the package as a rectifier, but the numbers are worth reading.

Diode Types and Symbols

There are many diode types available. Below is a short list of diodes with symbols drawn in accordance with the International Standard IEC60617. The Australian Standard, AS/NZ 1102, was withdrawn from publication in 2017.

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

Avalanche diodes		A diode that works in the reverse bias region as a relief valve on the circuit. Example is if the power is connected the wrong way the current will flow through the diode and no damage the circuit.
Gunn diodes		Used is in electronic oscillators to generate microwaves in applications such as radar speed guns and microwave ovens.

Light-emitting diodes (LED)		Special diodes that emit light when activated.
Thermal diodes		An electrical diode used as a heat pump or thermoelectric cooler.
Photodiodes		Light sensing diode.
Rectifier diode		Smoothing ac signals.
Schottky diodes		Lower V_F and used in high-speed circuitry and RF devices such as switched-mode power supply, mixers, and detectors.
Tunnel diodes		A very fast diode and may be used at low temperatures, high magnetic fields and in high radiation environments. Ideal for space applications. Also called Esaki diodes.
Varicap or varactor		Diodes acting as voltage-controlled capacitors.
Zener diodes		More correctly termed reverse breakdown diodes. This effect called Zener breakdown, occurs at a precisely defined voltage, allowing the diode to be used as a precision 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. Bare 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.