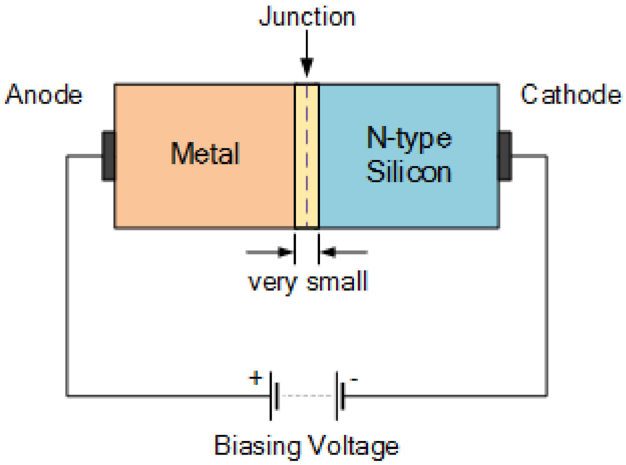
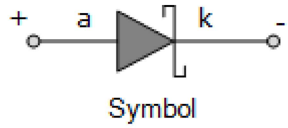




The Schottky Diode

The Schottky Diode is a type of metal-semiconductor diode having a low forward voltage drop and a very fast switching speed

The **Schottky Diode** is another type of semiconductor diode which can be used in a variety of wave shaping, switching and rectification applications the same as any other junction diode. The main adavantage is that the forward voltage drop of a Schottky Diode is substantially less than the 0.7 volts of the conventional silicon pn-junction diode.

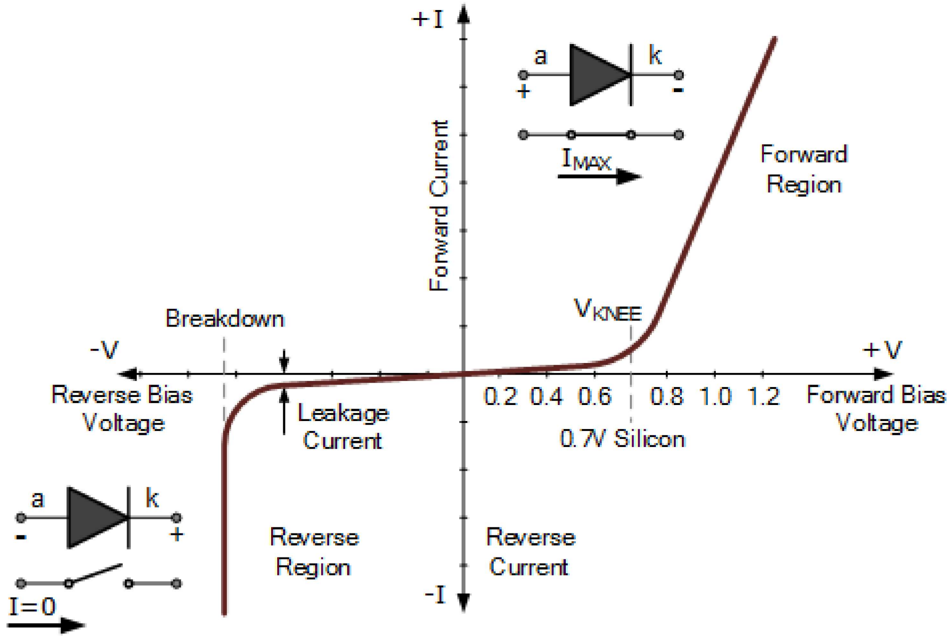
Schottky diodes have many useful applications from rectification, signal conditioning and switching, through to TTL and CMOS logic gates due mainly to their low power and fast switching speeds. TTL Schottky logic gates are identified by the letters LS appearing somewhere in their logic gate circuit code, e.g. 74LS00.

PN-junction diodes are formed by joining together a p-type and an n-type semiconductor material allowing it to be used as a rectifying device, and we have seen that when *Forward Biased* the depletion region is greatly reduced allowing current to flow through it in the forward direction, and when *Reverse Biased* the depletion region is increased blocking current flow.

The action of biasing the pn-junction using an external voltage to either forward or reverse bias it, decreases or increases respectively the resistance of the junction barrier. Thus the voltage-current relationship (characteristic curve) of a typical pn-junction diode is influenced by the resistance value of the junction. Remember that the pn-junction diode is a nonlinear device so its DC resistance will vary with both the biasing voltage and the current through it.

When forward biased, conduction through the junction does not start until the external biasing voltage reaches the “knee voltage” at which point current increases rapidly and for silicon diodes the voltage required for forward conduction to occur is around 0.65 to 0.7 volts as shown.

PN-junction Diode IV-Characteristics



For practical silicon junction diodes, this knee voltage can be anywhere between 0.6 and 0.9 volts depending upon how it was doped during manufacture, and whether the device is a small signal diode or a much larger rectifying diode. The knee voltage for a standard *germanium diode* is, however much lower at approximately 0.3 volts, making it more suited to small signal applications.

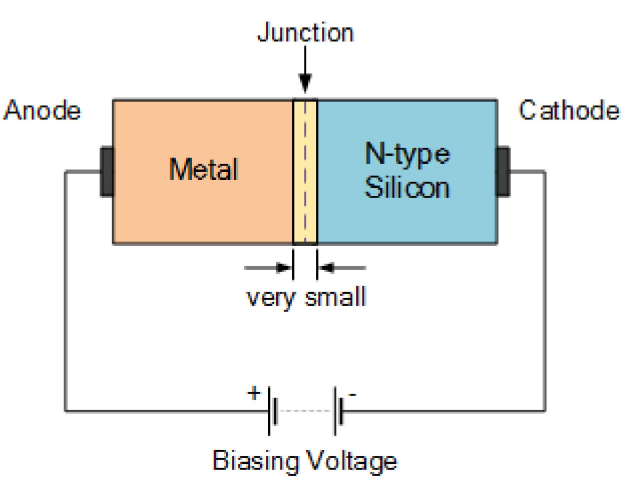
But there is another type of rectifying diode which has a small knee voltage as well as a fast switching speed called a **Schottky Barrier Diode**, or just simply "Schottky Diode". Schottky diodes can be used in many of the same applications as conventional pn-junction diodes and have many different uses, especially in digital logic, renewable energy and solar panel applications.

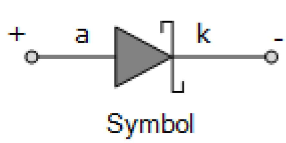
The Schottky Diode

Unlike a conventional pn-junction diode which is formed from a piece of P-type material and a piece of N-type material, Schottky Diodes are constructed using a metal electrode bonded to an N-type semiconductor. Since they are constructed using a metal compound on one side of their junction and doped silicon on the other side, the Schottky diode therefore has no depletion layer and are classed as unipolar devices unlike typical pn-junction diodes which are bipolar devices.

The most common contact metal used for Schottky diode construction is "Silicide" which is a highly conductive silicon and metal compound. This silicide metal-silicon contact has a reasonably low ohmic resistance value allowing more current to flow producing a smaller forward voltage drop of around $Vf<0.4V$ when conducting. Different metal compounds will produce different forward voltage drops, typically between 0.3 to 0.5 volts.

Schottky Diode Construction and Symbol





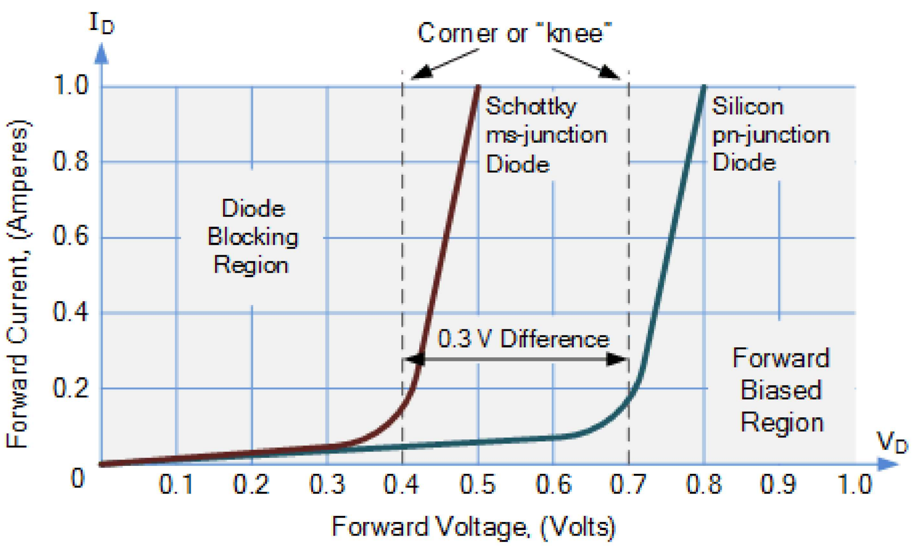
Above shows the simplified construction and symbol of a Schottky diode in which a lightly doped n-type silicon semiconductor is joined with a metal electrode to produce what is called a "metal-semiconductor junction".

The width, and therefore the electrical characteristics, of this *metal-semiconductor junction* will depend greatly on the type of metal compound and semiconductor material used in its constructiom, but when forward-biased, electrons move from the n-type material to the metal electrode allowing current to flow. Thus current through the Schottky diode is the result of the drift of majority carriers.

Since there is no p-type semiconductor material and therefore no minority carriers (holes), when reverse biased, the diodes conduction stops very quickly and changes to blocking current flow, as for a conventional pn-junction diode. Thus for a Schottky diode there is a very rapid response to changes in bias and demonstrating the characteristics of a rectifying diode.

As discussed previously, the knee voltage at which a Schottky diode turns "ON" and starts conducting is at a much lower voltage level than its pn-junction equivalent as shown in the following I-V characteristics.

Schottky Diode IV-Characteristics



As we can see, the general shape of the metal-semiconductor Schottky diode I-V characteristics is very similar to that of a standard pn-junction diode, except the corner or knee voltage at which the ms-junction diode starts to conduct is much lower at around 0.4 volts.

Due to this lower value, the forward current of a silicon Schottky diode can be many times larger than that of a typical pn-junction diode, depending on the metal electrode used. Remember that Ohms law tells us that power equals volts times amps, (P = V*I) so a smaller forward voltage drop for a given diode current, I_D will produce lower forward power dissipation in the form of heat across the junction.

This lower power loss makes the Schottky diode a good choice in low-voltage and high-current applications such as solar photovoltaic panels where the forward-voltage, (V_F) drop across a standard pn-junction diode would produce an excessive heating effect.

However, it must be noted that the reverse leakage current, (I_R) for a Schottky diode is generally much larger than for a pn-junction diode.

Note however that if the I-V characteristics curve shows a more linear non-rectifying characteristic, then it is an *Ohmic contact*. Ohmic contacts are commonly used to connect semiconductor wafers and chips with external connecting pins or circuitry of a system. For example, connecting the semiconductor wafer of a typical logic gate to the pins of its plastic dual-in-line (DIL) package.

Also due to the Schottky diode being fabricated with a metal-to-semiconductor junction, it tends to be slightly more expensive than standard pn-junction silicon diodes which have similar voltage and current specifications. For example, the 1.0 Ampere 1N58xx Schottky series compared to the general purpose 1N400x series.

Schottky Diodes in Logic Gates

The Schottky diode also has many uses in digital circuits and are extensively used in Schottky transistor–transistor logic (TTL) digital logic gates and circuits due to their higher frequency response, decreased switching times and lower power consumption. Where high speed switching is required, Schottky based TTL is the obvious choice.

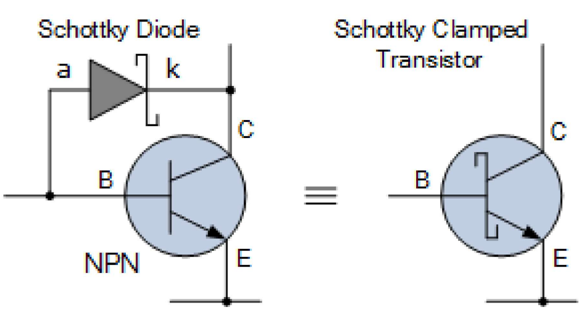
There are different versions of Schottky TTL all with differing speeds and power consumption. The three main TTL logic series which use the Schottky diode in its construction are given as:

Schottky Diode Clamped TTL (S series) – Schottky "S" series TTL (74SXX) is an improved version of the original diode-transistor DTL, and transistor-transistor 74 series TTL logic gates and circuits. Schottky diodes are placed across the base-collector junction of the switching transistors to prevent them from saturating and creating propagation delays allowing for faster operation.

Low-Power Schottky (LS series) – The transistor switching speed, stability and power dissipation of the 74LSXX series TTL is better than the previous 74SXX series. As well as a higher switching speed, the low-power Schottky TTL family consumes less power making the 74LSXX TTL series a good choice for many applications.

Advanced Low-Power Schottky (ALS series) – Additional improvements in the materials used to fabricate the ms-junctions of the diodes means that the 74LSXX series has reduced propagation delay time and much lower power dissipation compared to the 74ALSXX and the 74LS series. However, being a newer technology and inherently more complex design internally than standard TTL, the ALS series is slightly more expensive.

Schottky Clamped Transistor



All the previous Schottky TTL gates and circuits use a Schottky clamped transistor to prevent them from being driven hard into saturation.

As shown, a Schottky clamped transistor is basically a standard bipolar junction transistor with a Schottky diode connected in parallel across its base-collector junction.

When the transistor conducts normally in the active region of its characteristics curves, the base–collector junction is reverse biased and so the diode is reverse biased allowing the transistor to operate as a normal npn transistor. However, when the transistor starts to saturate, the Schottky diode becomes forward biased and clamps the collector-base junction to its 0.4 volt knee value, keeping the transistor out of hard saturation as any excess base current is shunted through the diode.

Preventing the logic circuits switching transistors from saturating decreases greatly their propagation delay time making Schottky TTL circuits ideal for use in flip-flops, oscillators and memory chips.

Schottky Diode Summary

We have seen here that the **Schottky Diode** also known as a **Schottky Barrier Diode** is a solid-state semiconductor diode in which a metal electrode and an n-type semiconductor form the diodes ms-junction giving it two major advantages over traditional pn-junction diodes, a faster switching speed, and a low forward bias voltage.

The metal–to-semiconductor or ms-junction provides a much lower knee voltage of typically 0.3 to 0.4 volts compared against a value of 0.6 to 0.9 volts seen in a standard silicon base pn-junction diode for the same value of forward current.

Variations in the metal and semiconductor materials used for their construction means that silicon carbide (SiC) Schottky diodes are able to turn "ON" with with a forward voltage drop as little as 0.2 volts with the Schottky diode replacing the less used germanium diode in many applications requiring a low knee voltage.

Schottky diodes are quickly becoming the preferred rectification device in low voltage, high current applications for use in renewable energy and solar panel applications.

However, compared to pn-junction equivalents Schottky diode reverse leakage currents are greater and their reverse breakdown voltage lower at around 50 volts.

A lower turn-on voltage, faster switching time and reduced power consumption makes the Schottky diode extremely useful in many integrated-circuit applications with the 74LSXX TTL series of logic gates being the most common.

Metal–semiconductor junctions can also be made to operate as "Ohmic contacts" as well as rectifying diodes by depositing the metal electrode onto heavily doped (and thus low-resistivity) semiconductor regions. Ohmic contacts conduct current equally in both directions allowing semiconductor wafers and circuits to connect an to external terminals.

Read more Tutorials inDiodes

20 Comments

Join the conversation

- *Barry*

  Thank you very helpful. Prefect layout. Thanks

  Posted on [January 07th 2022 | 1:54 pm]
  [Reply]
- *pranita*

  provide me all the upcoming updates on my mail.

  Posted on [September 02nd 2021 | 12:06 pm]
  [Reply]
- *EDIGA VENKATESH GOUD*

  Good Afternoon Sir/Mam, Content you posted is very useful and easy to Understand. Thank You for providing this Content to us. Is there any App related to Electronic Tutorials ? Sir / Mam

  Posted on [July 10th 2021 | 8:31 am]
  [Reply]
- *pornsak*

  good article

  Posted on [May 18th 2021 | 12:42 am]
  [Reply]
- *Aakash verma*

  great website….. you are only missing p-i-n diodes to be perfect

  Posted on [May 12th 2021 | 7:58 am]
  [Reply]
- *Louis Beaumont*

  I need a diagram for connecting a shottky diode to two parallel batteries.

  Posted on [March 01st 2021 | 9:37 pm]
  [Reply]
- *Antonio Lima*

  Muito bom Trabalho. Parabéns.

  Posted on [December 29th 2020 | 10:05 am]
  [Reply]
- *carla*

  great website….. you are only missing p-i-n diodes to be perfect

  Posted on [November 16th 2020 | 3:48 am]
  [Reply]
- *Will*

  My first visit to this site. Wonderful diagrams provide a very helpful pathway to processing and understanding key concepts.

  Excellent for Radio Amateurs hoping to increase their knowledge in order to upgrade their ham license, e.g., Tech to General or General to Extra.

  Thank you!

Will
Chicago

Posted on November 14th 2020 | 8:21 pm
Reply

- *Ron dumont*

  Great review I got a hold a ham license radio amateur Technician class and at my age I'm working on my general class and in my past time I've worked for a lot of major corporations I do know the component levels and circuit designs and it's a great pleasure the review at all thank you as a radio ham guy would say qsts to the best of you

  Posted on November 11th 2020 | 11:55 pm
  Reply
- *logu*

  well explained. more on rf filters and ripple filters desirable

  Posted on October 11th 2020 | 12:32 pm
  Reply
- *elme*

  tencs for di explanaishon

  Posted on October 09th 2020 | 10:27 pm
  Reply
- *aditi singh parihar*

  thanks. for explanation

  Posted on October 06th 2020 | 3:48 pm
  Reply
- *Jyoti verma*

  ◦•●◉✿I wana develop my skill✿◉●•◦

  Posted on September 26th 2020 | 7:48 am
  Reply
- *Adeoti abraham*

  what a wonderful explanation

  Posted on March 11th 2020 | 2:43 pm
  Reply
- *Elias*

  nice exolanation

  Posted on February 12th 2020 | 6:06 pm
  Reply
- *GEL*

  Thanks i'm 1st year college it's second sem

  Posted on January 29th 2020 | 10:36 am
  Reply
- *Alpar Cseley*

  Thank you for these excellent, informative pages, most useful for not-electronic engineers!
  Schottky diode I-V characteristic diagram: on the vertical axis the unit is Ampere. Is it correct? Should not be mA?

Missing from the Schottky diode section is the definition of the knee voltage: forward voltage at what current?
Also, I cannot find the description, explanation of "zero bias" Schottky diodes. It would be nice to incorporate those in the text.

Posted on July 09th 2019 | 3:48 am
Reply

- *Wayne Storr*

  1. The vertical y-axis is the current axis as shown with the units of micro-amps (uA), milli-amps (mA) or amperes (A), depending on the device.
  2. Again depends on the Schottky device obtained from its datasheet.
  3. Zero bias means no external voltage potential is applied to the diode.

  Posted on July 09th 2019 | 7:46 am
  Reply

- *jiang ann*

Good article, thank you so much. I learned a lot about the Schottky Diode. Your article details it， at the same time, the article layout is also beautiful. There are all kinds of electronic components online shops for us to buy the Schottky Diode, do you know how to judge whether its quality is good or bad?

Posted on June 26th 2019 | 9:42 am
Reply