Diode and its characteristics
Experiment 9

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Abstract

Here we are going to study the characteristics of diode.

1 Introduction

The 1N4148 is a standard silicon switching signal diode. It is one of the most popular and long-lived switching diodes because of its dependable specifications and low cost. Its name follows the JEDEC nomenclature. The 1N4148 is useful in switching applications up to about 100 MHz with a reverse-recovery time of no more than 4 ns.

2 Theoretical Background

2 Diode:
A diode is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

A semiconductor diode, the most commonly used type today, is a crystalline piece of semiconductor material with a pn junction connected to two electrical terminals.

2.1 Breakdown voltage
The breakdown voltage of an insulator is the minimum voltage that causes a portion of an insulator to become electrically conductive.

For diodes, the breakdown voltage is the minimum reverse voltage that makes the diode conduct appreciably in reverse. Some devices (such as TRIACs) also have a forward breakdown voltage.

2.2 Static Resistance:

When forward biased voltage is applied to a diode that is connected to a DC circuit, a DC or direct current flows through the diode. Direct current or electric current is nothing but the flow of charge carriers (free electrons or holes) through a conductor. In DC circuit, the charge carriers flow steadily in single direction or forward direction.

The resistance offered by a p-n junction diode when it is connected to a DC circuit is called static resistance.

Static resistance is also defined as the ratio of DC voltage applied across diode to the DC current or direct current flowing through the diode.

The resistance offered by the p-n junction diode under forward biased condition is denoted as R_f.

$$R_f = \frac{DC\ Voltage}{DC\ Current} \tag{1}$$

2.3 Dynamic Resistance:

The dynamic resistance is the resistance offered by the p-n junction diode when AC voltage is applied.

When forward biased voltage is applied to a diode that is connected to AC circuit, an AC or alternating current flows though the diode.
In AC circuit, charge carriers or electric current does not flow in single direction. It flows in both forward and reverse direction.

Dynamic resistance is also defined as the ratio of change in voltage to the change in current. It is denoted as r_f.

$$r_f = \frac{Change\ in\ voltage}{Change\ in\ current} \tag{2}$$

2.4 Effect of temperature on reverse characteristics:

- PN junction diode parameters like reverse saturation current, bias current, reverse breakdown voltage and barrier voltage are dependent on temperature.

- Mathematically diode current is given by

$$I = I_s e^{\frac{Vq}{nkT} - 1} \tag{3}$$

Hence from equation we conclude that the current should decrease with increase in temperature but exactly opposite occurs there are two reasons:

• Rise in temperature generates more electron-hole pair thus conductivity increases and thus increase in current

• Increase in reverse saturation current with temperature offsets the effect of rise in temperature

• Reverse saturation current (I_S) of diode increases with increase in the temperature the rise is 7 %/C for both germanium and silicon and approximately doubles for every 10C rise in temperature.

• Thus if we kept the voltage constant, as we increase temperature the current increases.

• Barrier voltage is also dependent on temperature it decreases by 2mV/C for germanium and silicon.

• Reverse breakdown voltage (V_R) also increases as we increase the temperature.

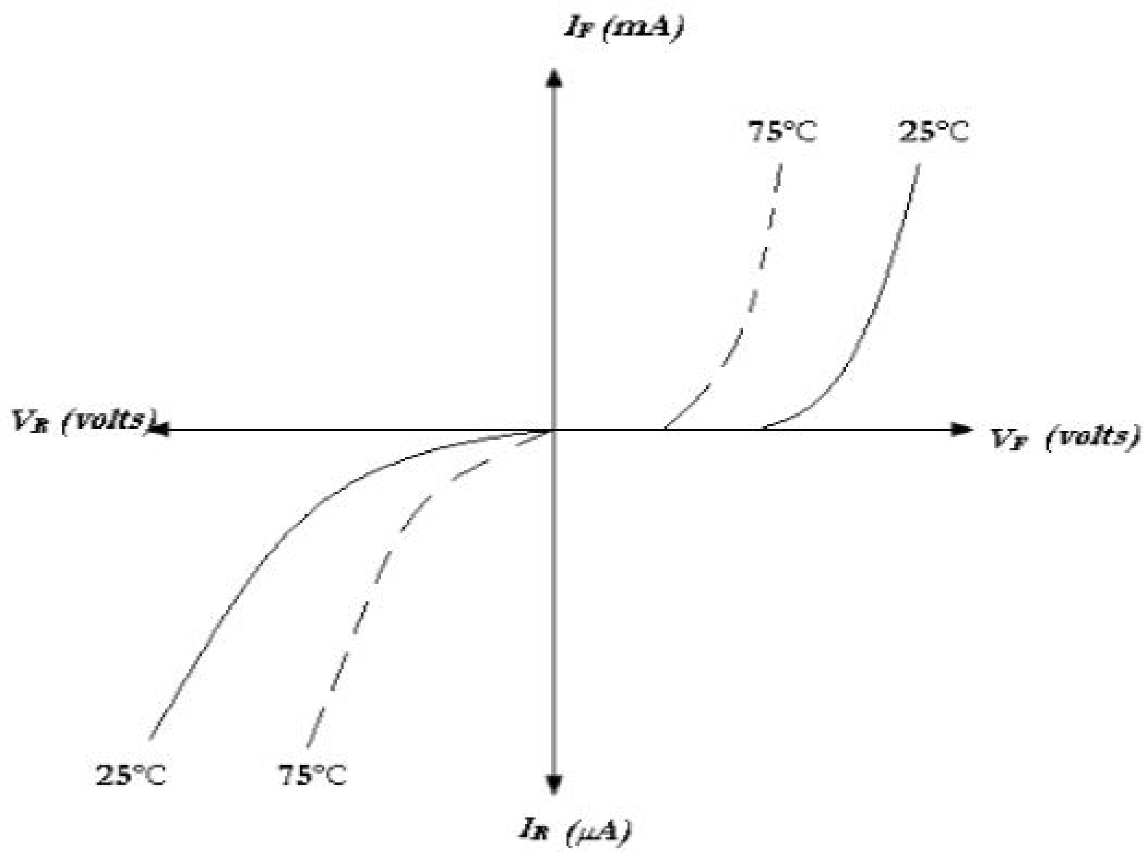


Figure: Characteristics of diode with respect to temperature

2.5 specifications of diodes:

Limit specifications

Maximum forward continuous current

The product of forward voltage drop and current through the diode is the power dissipation of the diode. Power dissipation results in a temperature rise. The maximum temperature that a diode can operate is around 125 C although some parts can operate at over 150 C. It is always good to operate any component below its maximum rated temperature. Be very aware that the specification assumes that the diode is operated with an infinite heat sink attached. No such heat sink exists and you must de-rate the specification based upon the actual heat sink characteristics and ambient temperature. This very important step is often overlooked and the result is diode failure from overheating even if the diode is operated below the specified maximum.

Maximum forward surge current

This specification generally applies to power rectifier diodes and addresses the turn-on transient current when large filter capacitors have to be rapidly charged. This specification is usually several times higher than the continuous current rating but only applies if the duration is brief.

Maximum forward peak current

This specification generally applies to power rectifier diodes and addresses the fact that conduction through the diode is only for a small percentage of the total AC cycle time. As an example, a one ampere DC average current might require brief peak currents of ten amperes or more. The peak currents cause local hot spots which can damage the diode if they exceed the maximum temperature.

Maximum reverse voltage

In the reverse direction the diode is an insulator but only if the reverse voltage is not too high. There is some voltage at which the diode structure breaks down and considerable reverse current can result which will usually destroy the diode instantly. The rating is often given as PIV for Peak Inverse Voltage. It is always a good idea to choose a diode with a significantly higher PIV rating than the maximum reverse voltage it will experience as this provides a safety margin.

Reverse recovery time

Because of some complex physics, a diode that has been conducting in the forward direction will briefly conduct in the reverse direction. This results in extra heat being generated in power rectifiers and limits how high the AC frequency can be.

Maximum junction temperature

This is the maximum temperature that the diode junction should be operated at. It is often in the 125 to 150 C range.

Characteristic specifications

Forward voltage
This is generally given as a maximum at one or more operating currents.

Reverse leakage current
t This is how much reverse current may exist under reverse bias conditions. It is a measure of imperfections in the manufacturing process and has no relation to the reverse saturation current which is many orders of magnitude smaller.

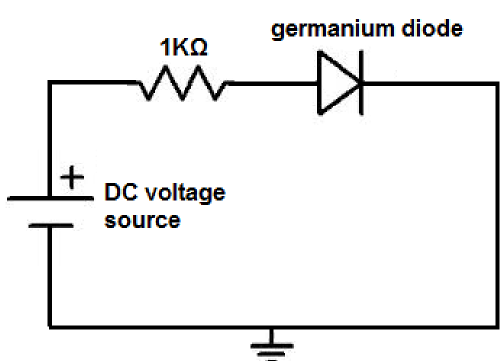
Turn-on or turn-off time
This is generally given as the maximum number of nanoseconds (sometimes picoseconds) for the diode to switch between forward and reverse operating conditions

Junction capacitance
This parameter is generally given in picofarrads at some operating point. The capacitance is inversely related to the depletion region width and decreases with reverse voltage and increases significantly with forward current.

Thermal resistance
This is an important specification for removing heat from the diode. Thermal resistance has units of degrees C per watt and the value from the junction to the case is provided and the value from case to ambient is provided. For small diodes that are rarely mounted in a heat sink the value from junction to ambient is often provided. An external heat sink can significantly lower the thermal resistance from the case to ambient. As an example, if a small diode has a thermal resistance from junction to ambient of 180 C/W then if the diode is dissipating 0.5 watts then the junction temperature will be (0.5 * 180) or 90 C above ambient.

3 Procedures

we need to make a circuit containing voltage ,Resistance and diode and find out breakdown voltage and characteristics of the circuit which is shown below.and compare theoretical measurements with actual outputs.

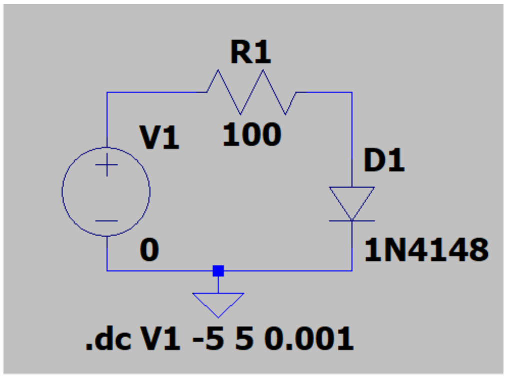


4 Analysis

case 1

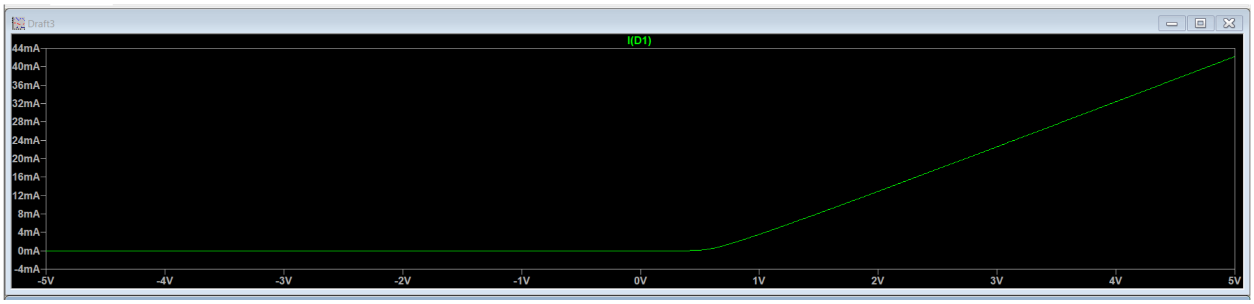
v1=-5 to 5,R1=100

the output and circuit are shown below.



Circuit diagram

Output voltage



Output current

case 2:

V1 =-100 to 100

and R1=100K

breakdown voltage is between 75 and 80V from the below graph.

5 Conclusions

- there are some limitations of diodes which must be kept in mind while using them.
- we should use higher values of resistors for diodes for breakdown voltages.
- we should also keep in mind the effect of temperatures on diodes.

Thank you