XMUT204 Electronic Design

Demo 1 – Diode Characteristics

This particular demo shows and discusses characteristics of a typical rectifier diode based on a given manufacturer datasheet. The example diode used in this exercise is 1N4000 series diode family (1N4001-1N4007), typically implemented for general-purpose applications in electronics e.g. small-power low-voltage circuit applications, signal rectifications, etc.

Figure 1: 1N4000 series family diode

The information gather in this demo are from three different datasheets of 1N4000 series diode:

- Fairchild 1N4001-81693
- ONSEMI 1N4001-D
- Vishay 1N4001

The presentation of information on datasheets may vary from one manufacturer to another, but they basically all convey the same information. The mechanical information, such as package dimensions, are not shown on this particular datasheet but are generally available from the manufacturer. Notice on the datasheet used in this exercise that there are three categories of data given in table form and four types of characteristics shown in graphical form.

- Data categories – descriptive information about the characteristics and behaviour of the device.
- Graphical categories – visual (in form of graphs) information about the characteristics and behaviour of the device.

A. Data Categories

Among the three data categories of device characteristics, absolute maximum ratings is needed for setting the upper limit of the operational conditions of the device. Thermal characteristics will give designer information about the temperature condition of the operation of the device whereas the electrical characteristics will provide the operational values required in the circuit design.

A.1. Absolute Maximum Ratings

The absolute maximum ratings indicate the maximum values of the several parameters under which the diode can be operated without damage or degradation. For greatest reliability and longer life, the diode should be operated well under these maximums. Generally, the maximum ratings are specified for an operating ambient temperature (T_A) of 25° C unless otherwise stated. Ambient temperature is the temperature of the air surrounding the device.

Absolute Maximum Ratings* T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75° C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Figure 2: Absolute maximum ratings

The parameters given in the Figure 1 given above are as follows:

V_{RRM} - The peak reverse voltage that can be applied repetitively across the diode. Notice that it is 50 V for the 1N4001 and 1000 V for the 1N4007. This rating is the same as the PIV.

$I_{F(AV)}$ - The maximum average value of a 60 Hz half-wave rectified forward current. This current parameter is 1.0 A for all of the diode types and is specified for an ambient temperature of 75°C.

I_{FSM} - The maximum peak value of non-repetitive single half-sine-wave forward surge current with a duration of 8.3 ms. This current parameter is 30 A for all of the diode types.

T_{stg} - The allowable range of temperatures at which the device can be kept when not operating or connected to a circuit.

T_J - The allowable range of temperatures for the pn junction when the diode is operated in a circuit.

A.2. Thermal Characteristics

All devices have a limit on the amount of heat that they can tolerate without failing in some way. Notice that the parameters described in this section referring to the power dissipated in the device and thermal resistance of the device. There is no information provided for thermal management of the device using cooling devices such as heat sink, fans, etc.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

Figure 3: Thermal characteristics

P_D - Average power dissipation is the amount of power that the diode can dissipate under any condition. A diode should never be operated at maximum power, except for brief periods, to assure reliability and longer life.

$R_{\theta JA}$ - Thermal resistance from the diode junction to the surrounding air. This indicates the ability of the device material to resist the flow of heat and specifies the number of degrees difference between the junction and the surrounding air for each watt transferred from the junction to the air.

A.3. Electrical Characteristics

The electrical characteristics are specified under certain conditions and are the same for each type of diode. These values are typical and can be more or less for a given diode. Some datasheets provide a minimum and a maximum value in addition to a typical value for a parameter.

Electrical Characteristics T_A = 25°C unless otherwise noted

Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{ir}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

Figure 4: Electrical characteristics

V_F - The forward voltage drop across the diode when there is 1 A of forward current. To determine the forward voltage for other values of forward current, you must examine the forward characteristics graph.

I_{rr} - Maximum full load reverse current averaged over a full ac cycle at 75° C.

I_R - The reverse current at the rated reverse voltage (V_{RRM}). Values are specified at two different ambient temperatures.

C_T - This is the total diode capacitance including the junction capacitance in reverse bias at a frequency of 1 MHz. Most of the time this parameter is not important in low frequency applications, such as power supply rectifiers.

B. Graphical Characteristics

Among the four device characteristics shown as graphs are: the forward current derating curve, forward characteristics curve, non-repetitive surge current, and reverse characteristics. These characteristics are typically non-linear and are commonly determined from the graphs.

B.1. Forward Current Derating Curve

This curve on the datasheet in Figure 4 shows maximum forward diode current $I_{F(AV)}$ in amps versus the ambient temperature. Up to about 75° C the diode can handle a maximum of 1 A. Above 75° C the diode cannot handle 1 A, so the maximum current must be derated as shown by the curve.

For example, if a diode is operating in an ambient temperature of 120° C, it can handle only a maximum of 0.4 A, as shown in Figure 4.

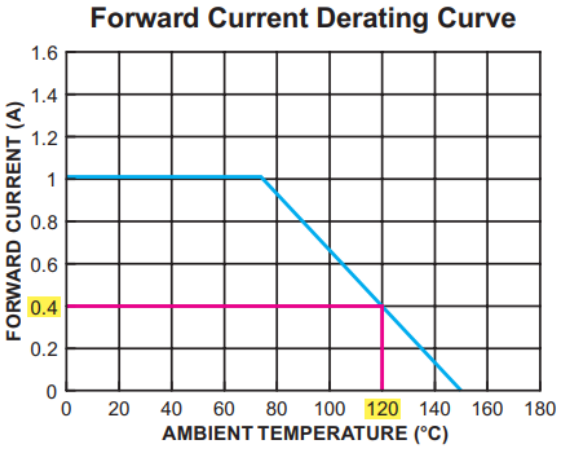

Figure 5: Forward current derating curve

B.2. Forward Characteristics Curve

Another graph from the datasheet shows instantaneous forward current as a function of instantaneous forward voltage. As indicated, data for this curve is derived by applying 300 μs pulses with a duty cycle of 2%. Notice that this graph is for T_J = 25° C.

For example, a forward current of 1 A corresponds to a forward voltage of about 0.93 V, as shown in Figure 5.

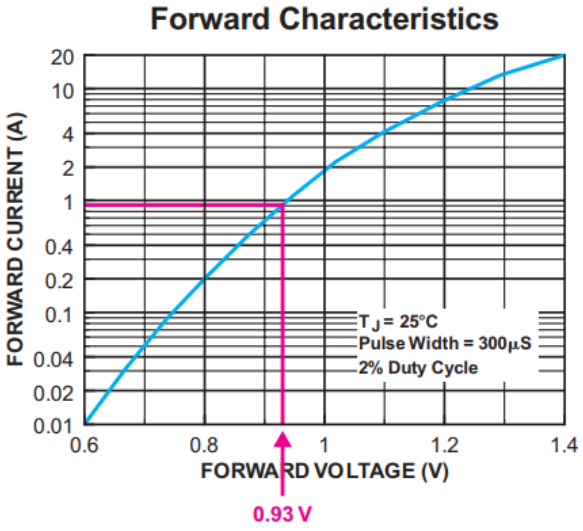

Figure 6: Forward characteristics

B.3. Non-repetitive Surge Current

This graph from the datasheet shows I_{FSM} as a function of the number of cycles at 60 Hz. For a one-time surge, the diode can withstand 30 A. However, if the surges are repeated at a frequency of 60 Hz, the maximum surge current decreases.

For example, if the surge is repeated 7 times, the maximum current is 18 A, as shown in Figure 6.

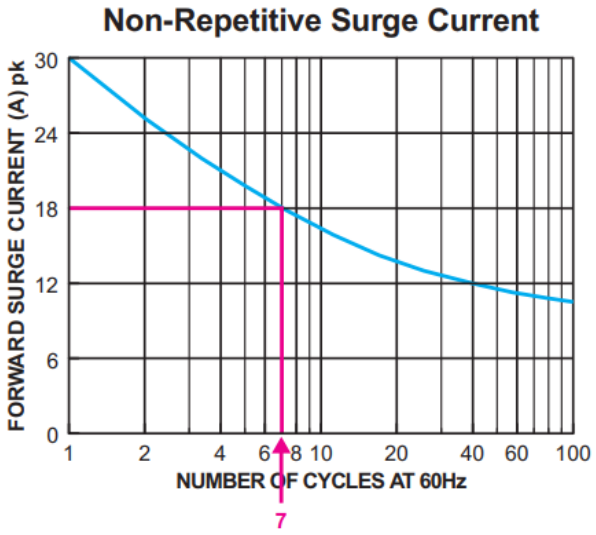

Figure 7: Non-repetitive surge current

B.4. Reverse Characteristics

This graph from the datasheet shows how the reverse current varies with the reverse voltage for three different junction temperatures. The horizontal axis is the percentage of maximum reverse voltage, V_{RRM}.

For example, at 25°C, a 1N4001 has a reverse current of approximately 0.04 μA at 20% of its maximum V_{RRM} or 10 V. If the V_{RRM} is increased to 90%, the reverse current increases to approximately 0.11 μA, as shown in Figure 7.

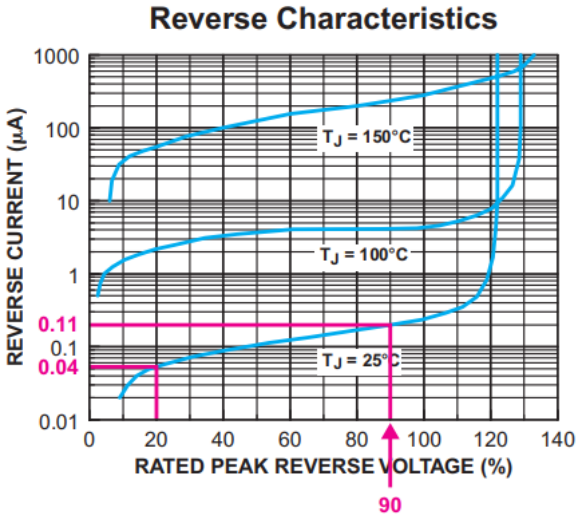

Figure 8: Reverse characteristics