Demo 1 – Diode Characteristics

XMUT204 Electronic Design

Overview

- Example 1N4000 series diode
- Data categories:
  - Absolute maximum ratings
  - Thermal characteristics
  - Electrical characteristics
- Graphical characteristics:
  - Forward current derating curve
  - Forward characteristics curve
  - Non-repetitive surge current
  - Reverse characteristics

Example Diode

This demo is about analysing the detailed characteristics of an example of real-life diode as outlined in its manufacturer datasheet. The chosen diode is:

- 1N4000 series diode family (1N4001-1N4007).

- General-purpose applications in electronics e.g. small power low voltage circuit application, signal rectification, etc.

Please refer to the datasheet files of the chosen diode provided, these are from three different manufacturer. But, the characteristics being discussed in this demo are common among these datasheets.

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

Based on the nomenclature commonly found in the diode datasheet, we usually could find two groups of device characteristics and behaviours:

- 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.

Note: other devices such as transistor, ICs, etc. should have their own categorisation schemes that could potentially be different from our example here.

In the following slides, we will delve into the details of these categories.

A. Data Categories

From the datasheet, there are typically three data categories of device characteristics:

- Absolute maximum ratings - setting the upper limits of the operational conditions of the device.
- Thermal characteristics - the temperature condition requirement of the operation of the device.
- Electrical characteristics - operational values required for the circuit design.

A.1. Absolute Maximum Ratings

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.

- The absolute maximum ratings - 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 - an operating ambient temperature (T_A) of 25° C, unless otherwise stated.
- Ambient temperature - temperature of the air surrounding the device.

A.1. Absolute Maximum Ratings (cont.)

V_{RRM} - The peak reverse voltage that can be applied repetitively across the diode e.g. 50 V (1N4001) and 1000 V (1N4007). This rating is also the PIV.

$I_{F(AV)}$ - The maximum average value of a 60 Hz half-wave rectified forward current. It is 1.0 A for all of the diode types and 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. It 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

Thermal Characteristics

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

All devices have a limit on the amount of heat that they can tolerate without failing in some way.

P_D - Average power dissipation – 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. It is 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

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_{rr}	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

- 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.

A.3. Electrical Characteristics (cont.)

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 - 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.

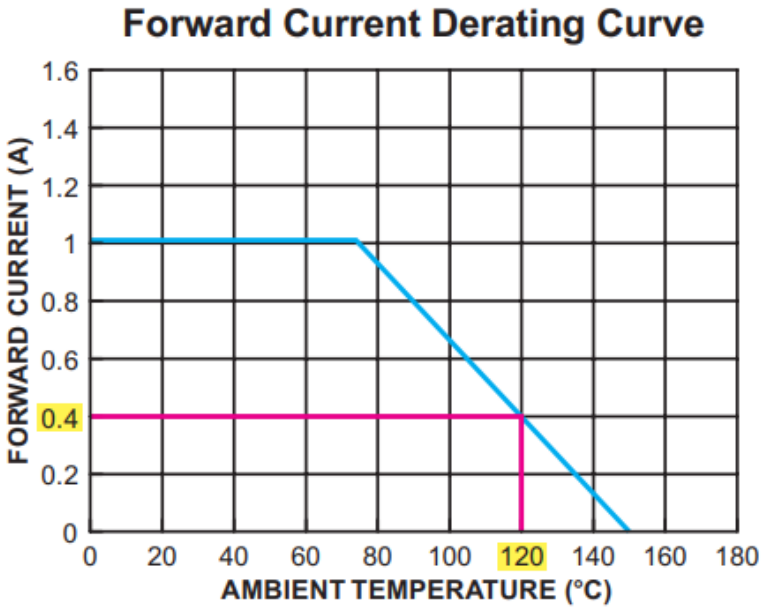
C_T - Total diode capacitance including the junction capacitance in reverse bias at a frequency of 1 MHz. It is not important in low frequency applications, such as power supply rectifiers.

B. Graphical Characteristics

- We look into four device characteristics shown as graphs which are:
  - the forward current derating curve,
  - forward characteristics curve,
  - non-repetitive surge current, and
  - reverse characteristics.

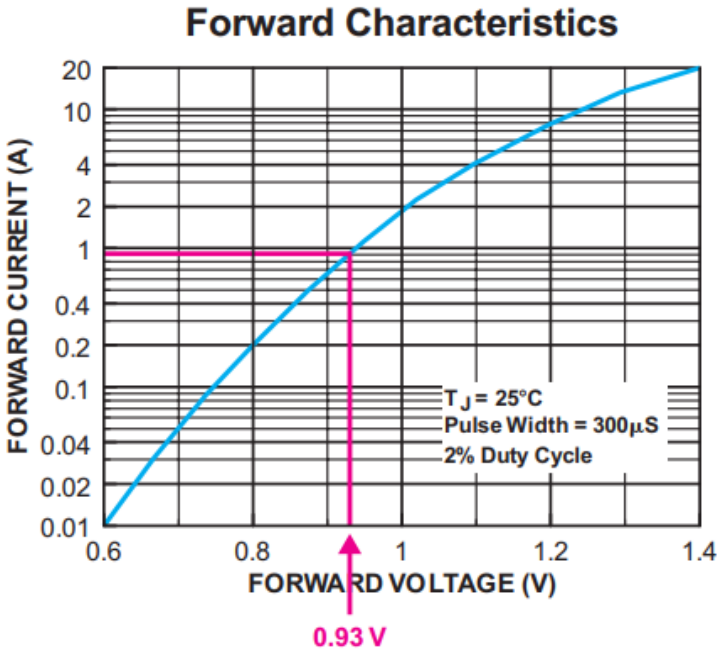
- These characteristics are typically non-linear and are commonly determined from the graphs.

B.1. Forward Current Derating Curve



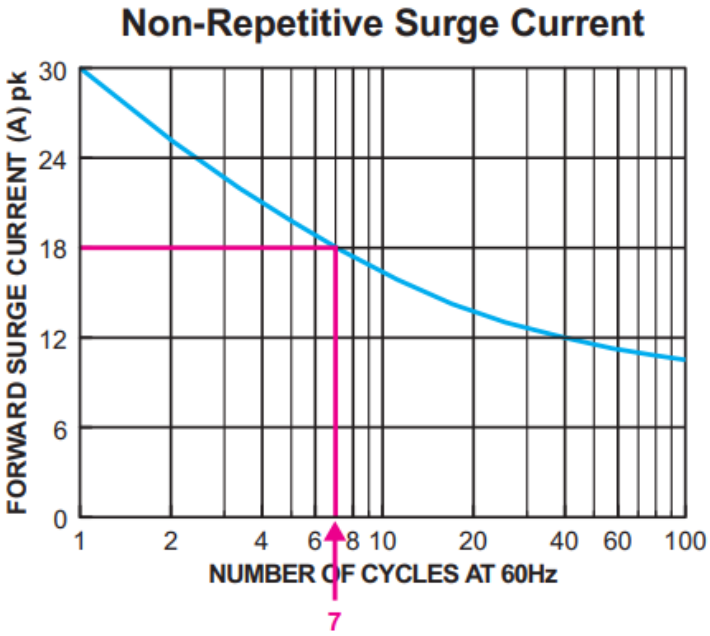
- Maximum forward diode current $I_{F(AV)}$ in amps versus the ambient temperature.
- Up to about 75° C, the diode can handle a maximum of 1 A.
- Above 75° C, the diode cannot handle 1 A, so the maximum current must be derated as shown by the curve.
- For example, if a diode is operating in an ambient temperature of 120° C, it can handle only a maximum of 0.4 A, as shown above.

B.2. Forward Characteristics Curve



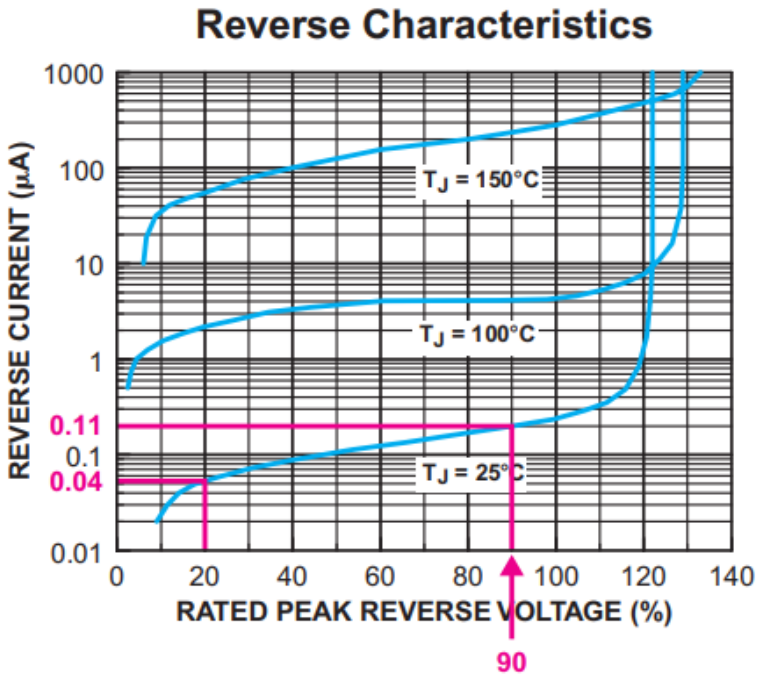
- Instantaneous forward current as a function of instantaneous forward voltage.
- Data for this curve is derived by applying 300 µs pulses with a duty cycle of 2%.
- The graph above is for T_J = 25° C.
- For example, a forward current of 1 A corresponds to a forward voltage of about 0.93 V, as shown above.

B.3. Non-repetitive Surge Current



- Forward max. surge current, I_{FSM} as a function of the number of cycles at 60 Hz.
- For a one-time surge, the diode can withstand 30 A.
- 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 above.

B.4. Reverse Characteristics



- 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 above.