

## Physical Explanation

### GENERAL TERMINOLOGY

Semiconductor diodes are used as rectifiers, switches, varactors and voltage stabilizers (see Zener databook).

Semiconductor diodes are two-terminal solid-state devices having asymmetrical voltage-current characteristics. Unless otherwise stated, this means a device has single pn-junction corresponding to the characteristics shown in figure 1.

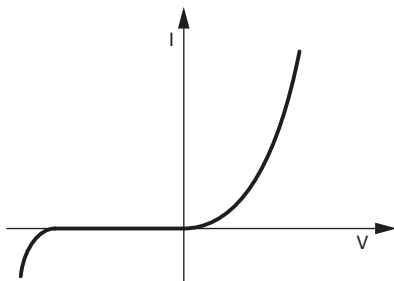


Fig. 1

An application of the voltage current curve is given by

$$I = I_S \left( \exp \frac{V}{V_T} - 1 \right)$$

where

$I_S$  = saturation current

$$V_T = \frac{k \times T}{q} = \text{temperature potential}$$

If the diode is forward-biased (anode positive with respect to cathode), its forward current ( $I = I_F$ ) increases rapidly with increasing voltage. That is, its resistance becomes very low.

If the diode is reverse-biased (anode negative with respect to cathode), its reverse current ( $-I = I_R$ ) is extremely low. This is only valid until the breakdown voltage  $V_{BR}$  has been reached. When the reverse voltage is slightly higher than the breakdown voltage, a sharp rise in reverse current results.

#### Bulk resistance

Resistance of the bulk material between junction and the diode terminals.

#### Parallel resistance, $r_P$

Diode resistance resulting from HF rectification which acts as a damping resistance to the pre-tuned demodulation circuit.

#### Differential resistance

See forward resistance, differential

#### Diode capacitance, $C_D$

Total capacitance between the diode terminals due to case, junction and parasitic capacitances.

#### Breakdown voltage, $V_{BR}$

Reverse voltage at which a small increase in voltage results in a sharp rise of reverse current. It is given in the technical data sheet for a specified current.

#### Forward voltage, $V_F$

The voltage across the diode terminals which results from the flow of current in the forward direction.

#### Forward current, $I_F$

The current flowing through the diode in the direction of lower resistance.

#### Forward resistance, $r_F$

The quotient of DC forward voltage across the diode and the corresponding DC forward current.

#### Forward resistance, differential $r_f$

The differential resistance measured between the terminals of a diode under specified conditions of measurement, i.e., for small-signal AC voltages or currents at a point of forward direction V-I characteristic.

#### Case capacitance, $C_{case}$

Capacitance of a case without a semiconductor crystal.

#### Integration time, $t_{av}$

With certain limitations, absolute maximum ratings given in technical data sheets may be exceeded for a short time. The mean value of current or voltage is decisive over a specified time interval termed integration time. These mean values over time interval,  $t_{av}$ , should not exceed the absolute maximum ratings.

#### Average rectified output current, $I_{FAV}$

The average value of the forward current when using the diode as a rectifier. The maximum allowable average rectified output current depends on the peak value of the applied reverse voltage during the time interval at which no current is flowing. In the absolute maximum ratings, one or both of the following are given:

- The maximum permissible average rectified output current for zero diode voltage (reverse).
- The maximum permissible average rectified output current for the maximum value of URRM during the time interval at which no current is flowing.

#### Note

- $I_{FAV}$  decreases with an increasing value of the reverse voltage during the interval of no current flow.

### Rectification efficiency, $\eta_r$

The ratio of the DC load voltage to the peak input voltage of an RF rectifier.

### Series resistance, $r_s$

The total value of resistance representing the bulk, contact and lead resistance of a diode given in the equivalent circuit diagram of variable capacitance diodes.

### Junction capacitance, $C_j$

Capacitance due to a pn junction of a diode which decreases with increasing reverse voltage.

### Reverse voltage, $V_R$

The voltage drop which results from the flow of reverse current (through the semiconductor diode).

### Reverse current, $I_R$ (leakage current)

The current which flows when reverse bias is applied to a semiconductor junction.

### Reverse resistance, $R_R$

The quotient of the DC reverse voltage across a diode and the corresponding DC reverse current.

### Reverse resistance, differential, $r_r$

The differential resistance measured between the terminals of a diode under specified condition of measurement i.e., for small-signal (AC) voltage or currents at a point of reverse-voltage direction V-I characteristic.

### Peak forward current, $I_{FRM}$

The maximum forward current with sine-wave operation,  $f \geq 25$  Hz, or pulse operation,  $f \geq 25$  Hz, having a duty cycle  $t_p/T \leq 0.5$ .

### Peak reverse voltage, $V_{RRM}$

The maximum reverse voltage having an operating frequency  $f \geq 25$  Hz for sine-wave as well as pulse operation.

### Peak surge forward current, $I_{FSM}$

The maximum permissible surge current in a forward direction having a specified waveform with a short specified time interval (i.e., 10 ms) unless otherwise specified. It is not an operating value. During frequent repetitions, there is a possibility of change in the device's characteristic.

### Peak surge reverse voltage, $V_{RSM}$

The maximum permissible surge voltage applied in a reverse direction. It is not an operating value. During frequent repetitions, there is a possibility of change in the device's characteristic.

### Power dissipation, $P_v$

An electrical power converted into heat. Unless otherwise specified, this value is given in the data sheets under absolute maximum ratings, with  $T_A = 25$  °C at a specified distance from the case (both ends).

### Switching on characteristic

#### Forward recovery time, $t_{fr}$

The time required for the voltage to reach a specified value (normally 110 % of the steady state forward voltage drop), after instantaneous switching from zero or a specified reverse voltage to a specified forward biased condition (forward current).

This recovery time is especially noticeable when higher currents are to be switched within a short time. The reason is that the forward resistance during the turn-on time could be higher than the DC current (inductive behavior). This can result in the destruction of a diode because of high instantaneous power loss if constant current control is used.

#### Turn on transient peak voltage, $V_{fp}$

The voltage peak (overshoot) after instantaneous switching from zero or a specified reverse voltage to a specified forward biased condition (forward current). The forward recovery is very important especially when higher forward currents must be switched on within a very short time (switching on losses).

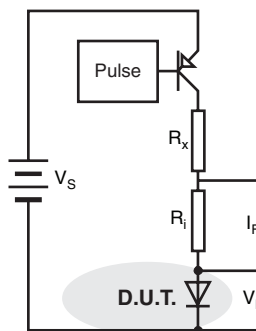


Fig. 2

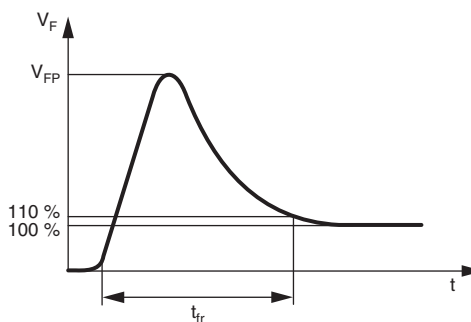


Fig. 3

### Switching off characteristic, inductive load

#### Reverse recovery time, $t_{rr}$

The time required for the current to reach a specified reverse current,  $i_R$  (normally 0.25 % of  $I_{FRM}$ ), after switching from a specified forward current  $I_F$  to a specified reverse biased condition (reverse voltage  $V_{Batt}$ ) with a specified slope  $di_F/dt$ .

## Physical Explanation

### Peak reverse recovery current, $I_{RM}$

The peak reverse current after switching from a specified forward current  $I_F$  to a specified reverse biased condition (reverse voltage  $V_R$ ) with a specified switching slope  $dl_F/dt$ . The reverse recovery is very important especially when switching from higher currents to high reverse voltage within a very short time (switching off losses).

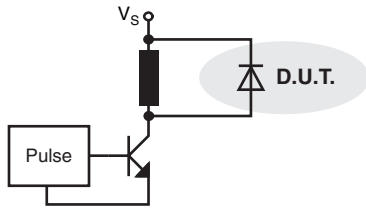


Fig. 4

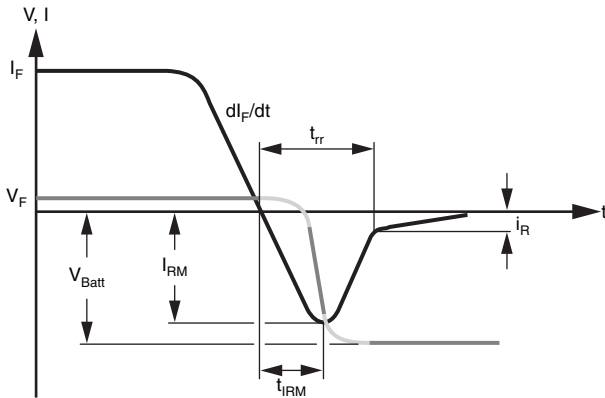


Fig. 5

### Reverse avalanche energy, $E_R$

The reverse avalanche energy when using the rectifier as a freewheeling diode with an inductive load. When the inductance is switched off, the current through the inductance will keep on flowing through the D.U.T. until the stored energy,

$$E_R = \frac{1}{2} \times L \times I^2$$

is dissipated within the rectifier. Under this condition the diode is in a reverse avalanche mode with a reverse current at the beginning which is equal to the current that was flowing through the inductance just before it was switched off.

The reverse energy capability depends on the reverse current and the junction temperature prior to the avalanche mode.

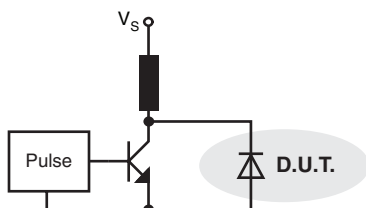


Fig. 6

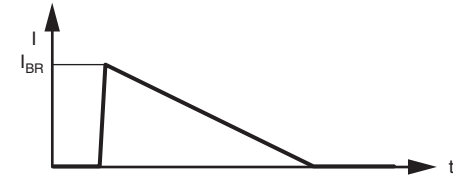
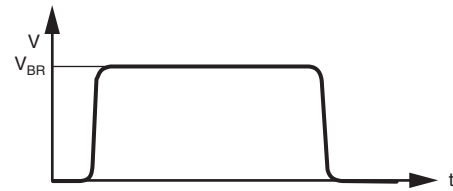


Fig. 7

### Switching off characteristic, instantaneous switching

#### Reverse recovery time, $t_{rr}$

The time required for the current to reach a specified reverse current,  $i_R$  (normally 0.25 A), after instantaneous switching from a specified forward current  $I_F$  (normally 0.5 A) to a specified reverse current  $I_R$  (normally 1.0 A).

#### Reverse recovery charge, $Q_{rr}$

The charged stored within the diode when instantaneous switched from a specified forward current  $I_F$  (normally 0.5 A) to a specified reverse current  $I_R$  (normally 1.0 A).

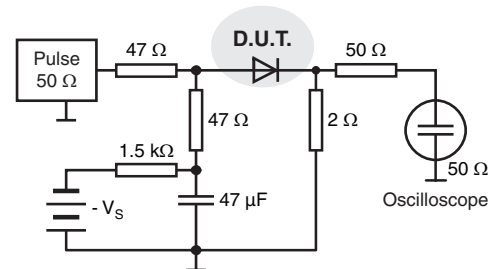


Fig. 8

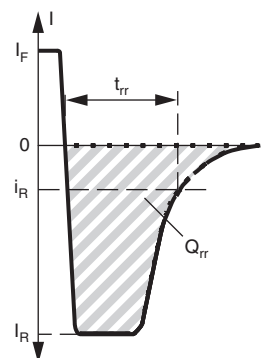


Fig. 9