Technical Information

Characteristics and Maximum Ratings

The electrical performance of a semiconductor device is usually expressed in terms of its characteristics and maximum ratings.

Characteristics are those which can be measured by use of suitable measuring instruments and circuits, and provide information on the performance of the device under specified operating conditions (at a given bias, for example). Depending on requirements, they are quoted either as typical values or guaranteed values.

Typical values are expressed as figures or as one or more curves, and are subject to spreads.

Guaranteed values are preceded either by the symbol > (greater than) or < (less than); sometimes the guaranteed spread limited are indicated by the numbers with three dots between them. Occasionally a typical curve is accompanied by another curve, this being a 95%, or in a few cases, a maximum spread limit curve.

Maximum Ratings give the values which cannot be exceeded without risk of damage to the device. Changes in supply voltage and in the tolerances of other components in the circuit must also be taken into consideration. No single maximum rating should ever be exceeded, even when the device is operated well within the other maximum ratings. The inclusion of the word "admissible" in a title means that the associated curve defines the maximum ratings.

Silicon Diodes

Silicon is a particularly suitable material for the manufacture of diodes because of the small leakage currents, high breakdown voltages, and steep forward characteristics that may be attained. Admissible junction temperatures of up to T_j - +200°C allow a relatively high level of power to be dissipated in a package of small dimensions. Silicon diodes are manufactured as junction diodes by a diffusion process, preferably using the epitaxial planar technique.

The admissible power dissipation P_{tot}, junction temperature T_j, and ambient temperature T_{amb} are related as follows:

$$P_{tot} = \frac{T_j - T_{amb}}{R_{thA}}$$

Since a certain amount of the generated heat must be conducted away from the junction via the connecting leads, the following proviso is often quoted in data sheets: Valid provided that leads are kept at ambient temperature at a distance of 4 mm (p. ex.) from case.

Silicon Capacitance Diodes

Silicon capacitance diodes are used for electronic tuning purposes, automatic frequency control (AFC), frequency modulation, mixing, frequency multiplication, and for controlling the bandwidth of capacitively coupled bandpass filters; they also have applications in dielectric and parametric amplifiers. In all these applications, advantage is taken of the fact that the depletion layer capacitance is dependent on the applied reverse voltage.

Basically, a silicon capacitance diode has the same construction as any normal alloyed or diffused semiconductor diode: the depletion layer of the PN junction contains only very few free charge carriers and can be considered as the dielectric of a capacitor whose plates are formed by the high-conductivity regions. Silicon capacitance diodes are normally operated under reverse bias conditions. If the applied reverse voltage is increased, then the thickness of the depletion layer increases and the depletion layer capacitance consequently decreases.

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Another important parameter of a capacitance diode is the Q factor, whihc should be high. At high frequencies, the Q factor of a capacitance diode is

$$Q \approx \frac{1}{2 \pi f \, C_{tot} \, r_s}$$

where C_{tot} is the diode capacitance, r_s the series resistance of the diode. The series resistance r_s is virtually the same as the bulk resistance of the diode.

As can be deduced from the Q formula, the Q factor of a capacitance diode varies with reverse bias; this is because the diode capacitance decreases as the reverse voltage is increased; the Q factor is also depentdent on frequency.

The "cut-off" frequency, f_{Q1}, of a capacitance diode is that frequency at which the Q factor is reduced to 1, i.e.
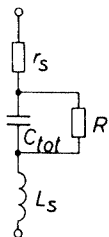
$$Q = \frac{f_{Qi}}{f}$$

Another important factor, which cannot be alogether ignored, is the series inductance L_s. this comprises the inductance of the connecting leads and the internal inductance of the diode. The inductance Ls together with the diode capacitance C_{tot} forms a series-tuned circuit which resonates at a frequency of
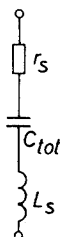
$$f_0 = \frac{1}{2 \pi \sqrt{L_s \cdot C_{tot}}}$$

Depending on the application, a capacitance diode can be represented by the following equivalent circuits:
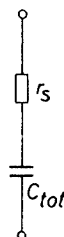
The complete equivalent circuit a) comprises, apart from the diode capacitance C_{tot}, a series resistance rs, a series inductance L_s, and a reverse resistance $R = V_R/I_R$. since the reverse resistance of a silicon diode is extremely high, it is usually ignored, and the circuit then reduces to circuit b). at low and medium frequencies the series inductance L_s can also be ignored; this results in the circuit shown in c).

Junction capacitance, series resistance and reverse resistance are temperature dependent. The temperature coefficient of the junction capacitance is due to the effect of temperature on the diffusion voltage V_D, which is -2 mV/ °C. This means that a reverse voltage reduction of approximately 2 mV has the same effect onthe junction capacitance as a junction temperature increase of 1°C. the temperature coefficient of the junction capacitance is therefore positive, and decreases asa the reverse bias is increased. The reverse resistance decreases by about 6 % and the series resistance by about 1 % if the junction temperature is increased by 1°C.

To ensure that the reverse bias does not vary appreciably with temperature, it is good practice to make the value of the diode series resistor through which the reverse bias is applied as lowas practicable (approx. 30 to 100 kΩ).

In all tuning applications it is important that the AC signal amplitude is small in comparison with the lowest reverse bias voltage applied, as otherwise the non-linearity of the capacitance characteristic will cause signal distortion and an apparent change of capacitance. By the use of two diodes in a push-pull arrangement it is possible to obtain a considerable reduction in distortion, even at large signal amplitudes, because the diodes are then driven in antiphase and thus tend to cancel any distortion.

a)   b)   c)

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