Small Signal Diodes

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. For example, referred to a reverse voltage of 3V, depletion layer capacitance and reverse voltage are related by the following equation:

$$C = C_{3V} \cdot \left(\frac{3V + V_D}{V_R + V_D}\right)^n$$

where V D is the diffusion potential (0.7 V for silicon). The value of the exponent "n" depends on the manufacturing process, and is 0.33 for diffused diodes with a linear PN junction, 0.5 for alloyed diodes, or diodes with a steep diffusion profile and can be 0.75 and more if a special diffusion technique involving several superimposed diffusion processes is used.

These so-called "large capacitance ratio" or **tuner diodes** have a hyperabrupt (retrograded) PN junction giving a steep capacitance characteristic. This makes it possible for the first time to cover the entire frequency range of a VHF or UHF television tuner, or that of an MW receiver, without any band switching. Because the exponent "n" in the capacitance formula is not a constant, but varies with reverse voltage, the capacitance variation of these tuner diodes does not follow a mathematically definable law. To ensure accurate tracking, therefore, diodes intended for incorporation into tuners are supplied in matched groups.

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

$$Q = \frac{1}{2\pi f C_{tot} r_S}$$

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 dependent on frequency.

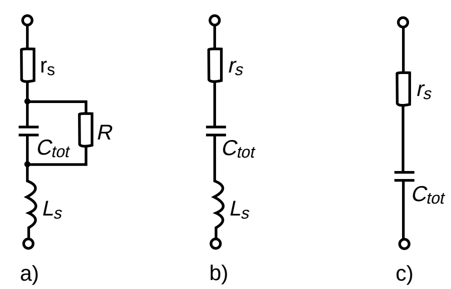
The “cut-off” frequency, f_{Q1}, of a capacitance diode is that frequency at which the Q factor is reduced to 1, i.e.

$$Q = \frac{f_{Q1}}{f}$$

Another important factor, which cannot be altogether ignored, is the series inductance L_S. This comprises the inductance of the connecting leads and the internal inductance of the diode. The inductance L_S 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 r_S, 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 reduc-tion of approximately 2 mV has the same effect on the junction capacitance as a junction temperature increase of 1°C. The temperature coefficient of the junction capacitance is therefore positive, and decreases as 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 low as practicable (approx. 30 to 100 kW).

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 capaci-tance 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.

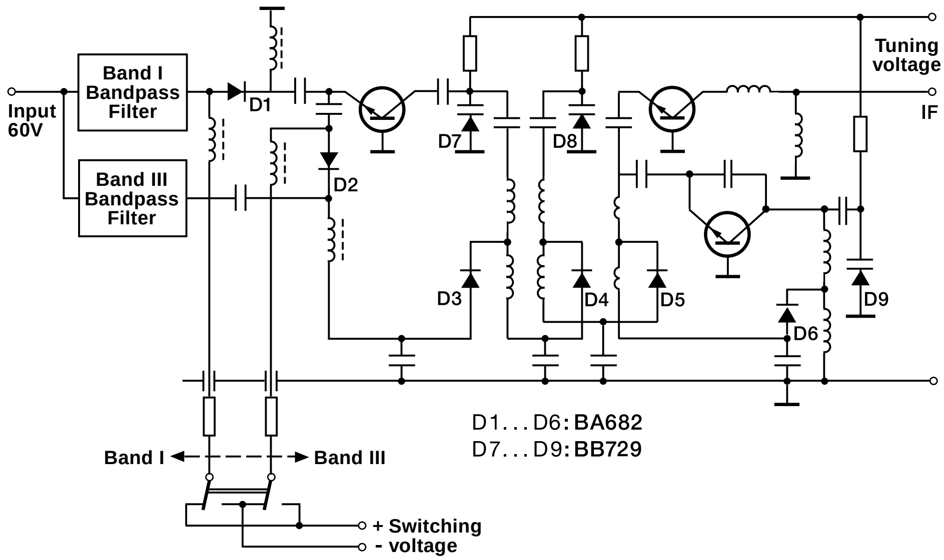
Silicon Diode Band-Switches

These diodes were developed for electronic band switching in television and radio tuners operating at MW to UHF. Diode switches, unlike the switching diodes normally used for logic applications (for example, 1N4148 or similar), are intended as an electronic equiv-alent to the contacts of mechanical range switches.

Diode switches exhibit either a very high reverse impedance (approx. 1 MW in parallel with approx. 1.3 pF) when they are non-conducting (switch open), or a very low dynamic forward impedance (approx. 0.5 W in series with approx. 2.5 nH) when they are conducting (switch closed).

The construction of the diode switches ensures that full advantage can be taken of their inherently small series inductance, since connecting leads or electrodes may be soldered directly to the case.

The following circuit diagram illustrates the use of type BA782 diode switches in an electronically tuned VHF television tuner.



Silicon Schottky Barrier Diodes

Schottky diode current flow is due to majority carrier conduction. It is not affected by reverse recovery transients as are conventional PN diodes due to stored charge and minority carrier injection.

The low forward voltage drop and fast switching make the diodes ideal for protection of MOS devices, steering, biasing and coupling for fast switching and low logic level applications.