8. Rectifier Diodes

Features

Small plastic packaged diodes

- Reverse voltages up to 1700 V
- Axial lead diodes taped for automatic insertion

Threaded stud diodes

- Reverse voltages up to 3000 V
- Hermetic metal cases with glass insulators
- Glass to metal seal
- Threaded studs ISO M4 ... M 24 x1.5, UNF 10 – 32 ... ¾″
- SKN: anode to stud; SKR: cathode to stud

Capsule type diodes

- Reverse voltages up to 3600 V
- Capsule type metal-ceramic packages
- Precious metal pressure contacts

Typical Applications

- All-purpose rectifier diodes
- For p.c.b. mounting
- Snubber diodes

- All-purpose power rectifier diodes
- Cooling via metal plates or heatsinks
- Non-controllable and half-controllable rectifiers
- Free-wheeling diodes
- Snubber diodes

- All-purpose high power rectifier diodes
- High voltage grades available for industrial high power drives and medium traction applications
- Cooling via heatsinks (double or single sided)
- Non-controllable and half-controllable rectifiers
- Free-wheeling diodes
- Special types for high power resistance welding equipment

Type Designation System

SK N a 20 / 13 .... UNF

- SEMIKRON component — SK
- Functional element — N
  - N: Rectifier diode, anode to stud (normal polarity) or capsule type
  - R: Rectifier diode, cathode to stud
  - WD: Rectifier diode for water cooling
  - No letter: Rectifier diode, axial leads
- Avalanche diode (omitted with standard types) — a
- Type number (approx. I_{FAV} [A]) — 20
- Separation mark — /
- Voltage grade (V_{RRM} [V] / 100) — 13
- With the types SKN 4000 and SKN 6000 the forward voltage value is indicated here (for parallel connections) — ....
- UNF thread (on special demand; omitted for normal metric outline) — UNF

8. Rectifier Diodes

Captions of the Figures

Fig. 1 **Left:** Mean power dissipation P_{FAV} agains mean forward current I_{FAV} for pure d.c. (cont.), half sinewaves (sin. 180) and rectangular pulses 120° (rec. 120) and 60° (rec. 60)*.

Right: Case temperature T_{case} against ambient temperature T_{amb}. Parameter: Thermal resistance case to air R_{thca} of heatsink including contact thermal resistance.

For the power dissipation given on the l.h.s. vertical the case temperature given on the r.h.s. vertical is allowable. Recommended mean forward current $I_{FN} = 0.8 \cdot I_{FAV}$.

Fig. 2 **Left**: Mean power dissipation P_{FAV} against mean forward current I_{FAV} for d.c. (cont.), half sinewaves (sin. 180) and rectangular pulses (rec. 30 to 180).

Right: Mean power dissipation P_{FAV} against ambient temperature T_{amb} for various total thermal resistances (junction to ambient) R_{thja}.

Using the total thermal resistance $R_{thja} = R_{thjc} + R_{thca}$ for the heatsink type to be considered, the maximum permissible mean forward current for a given ambient temperature may be taken from fig. 2 (or vice versa).

Fig. 3 Mean forward current I_{FAV} against case temperature T_{case} for d.c. (cont.), half sinewaves (sin. 180) and rectangular pulses 120° (rec. 120) and 60° (rec. 60)*.
Fig. 4 Mean forward current I_{FAV} against ambient tem-perature T_{amb} for d.c. (cont.), half sinewaves (sin. 180) and rectangular pulses 120° (rec. 120) and 60° (rec. 60)*.

Fig. 5 Transient thermal impedance junction to case Z_{thjc} and junction to heatsink Z_{thjH} as functions of the time t elapsed after a step change in power dissipation.

Fig. 6 Forward characteristics. Typical and maximum values. The arrow indicates the recommended value for acceptance tests.

Fig. 7 Ratio of permissible overload forward current values $I_{F(OV)}$ (peak values, half sinewaves), divided by the surge forward current I_{FSM} for 10 ms, against duration of overload. Parameter: value of reverse voltage reapplied between conduction periods.

Fig. 8 Mean power dissipation P_{FAV} against mean forward current I_{FAV} for d.c. (cont.), half sine-waves (sin. 180) and rectangular pulses 120° (rec. 120) and 60° (rec. 60)*.

Fig. 9 Ratio of the highest permissible mean overload forward current for intermittent duty $I_{F(OV)}$, to maximum rated steady state mean forward current I_{FAV} against duty cycle ED. Parameter: Overload duration t_e in seconds. For single overloads (ED $\rightarrow$ 0) use the left end points of the curves.

Fig. 10 Overload forward current $I_{F(OV)}$ (crest values of half sinewaves 50 Hz) permissible under fault conditions against duration t of overload after operating the diode at the recommended mean forward current $I_{FN} = 0.8 \cdot I_{FAV}$.

Fig. 11 Allowable peak reverse power dissipation P_{RSM} for avalanche diodes against duration of surge t.

Short duration surges (< 0.8 s): Isolated surges allowable during operation at $0{,}8 \cdot I_{FAV}$.

Long duration surges (> 1 s): Repetitive surges with no allowance made for any dissipation due to forward current.

Fig. 12 Maximum permissible peak current I_{FM} for a single diode shown as a function of the duty cycle ED. Parameter: Number of half sinewaves during conduction time t_e.

Fig. 13 Maximum permissible direct current Id for two diodes in centre tap connection (or four diodes in two-pulse bridge connection) shown as a function of the duty cycle ED. Parameter: number n of cycles during conduction time t_e.

With large resistance welding equipment the rectifier diodes are often arranged in a six-pulse star connection using three single phase transformers with water cooled centre tapped secondary windings. The equipment runs practically in short circuit. In this case the overlap interval is extremely long due to the low commutation volt-age and the high inductance so that the con-duction angle reaches about 180° or more instead of the normal 60°. Therefore under these circumstances the intermittent duty characteristics valid for the centre tap connection as given in fig. 13 may be applied to the six-pulse star connection as well with the current values multiplied by three.

* The curves rec. 60 are also valid for single phase circuits with a capacitive load.

8. Rectifier Diodes

Captions of the Figures (continued)

Fig. 14 Rated forward current I_{FAV} (half sinewaves 180°) as a function of the reference temperature $T_{ref.}$ Parameter: Lead lenght L from the case to the reference points.

Fig. 15 Reverse current I_R (upper end of production spread), measured at direct voltage V_R equal to the rated V_{RRM} value, as a function of the virtual junction temperature T_{vj}.

Fig. 16 Thermal resistance R_{thjr} junction to reference point as a function of the lead length L from the case to the reference points.

Technical Explanations

Non-repetitive peak reverse voltage V_{RSM}

Maximum allowable peak value of isolated transient reverse voltages.

Repetitive peak reverse voltage V_{RRM}

Maximum allowable peak value of repetitive transient reverse voltages.

Continuous direct reverse voltage V_R

For d.c., the reverse voltage should not exceed 0.7 V_{RRM}.

Avalanche breakdown voltage $V_{(BR)}$

This value is given for avalanche types (indicated in the type number by the letter a). At this value of reverse voltage the reverse current starts to increase rapidly.
Reverse voltage peaks of short duration may exceed the avalanche voltage without causing damage, but if these peaks are of long duration or are repetitive, care must be taken that over-dissipation does not occur.

Mean forward current I_{FAV}

Absolute maximum value of continuous forward current for the current waveforms, temperatures and cooling conditions stated, with no margins allowed for overload.

In practical applications, to allow for current or voltage overloads, for degradation of cooling conditions, and for increases in the ambient temperature by, for example, local heating due to adjacent components, **it is recommended that only 80 % of the maximum rated mean forward current is utilized**.

RMS forward current I_{FRMS}

Limiting value for continuous operation which is permissible considering the electrical and thermal properties of the internal connections of the diode. It is valid for any conduction angle and current waveform and may not be exceeded even under best cooling conditions.

Allowable overload currents

For the power diodes, the overload currents which are permissible for short-time overloads or for intermittent duty may be calculated by means of the transient thermal impedance or the thermal impedance under pulse conditions (fig. 5) so that the virtual junction temperature at no instant exceeds the maximum value. The dissipation values necessary for this calculation may be taken from fig. 1 or calculated from the threshold voltage and forward slope resistance (see below). For low power diodes the allowable overload currents are given by fig. 9.

Please note that the overload currents $I_{F(OV)}$ given by fig. 9 may not be fully utilized in excess of the current permissible under extremely good cooling conditions.

Single cycle surge current I_{FSM}

Maximum peak value of a single half sinewave current surge of 10 ms duration. After occasional current surges up to this limiting value the diode will withstand the peak reverse voltages stated in fig. 7.

i^2t value

The i^2t value for the diode is given to assist in the selection of suitable fuses to protect against damage due to short circuits. The i^2t value of the fuse over the specified time interval and for the input voltage used must be less than the value for the diode.

Threshold voltage $V_{(TO)}$ and forward slope resistance r_T.

These values define the forward characteristics of the diode and may be used to calculate the peak (P_F) and average (P_{FAV}) forward power dissipation:

$$P_F = V_{(TO)} \times i_F + r_T \times i^2_F$$

$$P_{FAV} = V_{(TO)} \times I_{FAV} + r_T \times i^2_{FRMS}$$

$$\frac{I^2_{FRMS}}{I^2_{FAV}} = \frac{360°}{\Theta} \quad \text{for rectangular pulses,}$$

$$\frac{I^2_{FRMS}}{I^2_{FAV}} = 2{,}5 \quad \text{for half sinewaves.}$$

In the above equations:

Θ	– conduction angle,
i_F	– instantaneous forward current,
I_{FAV}	– mean forward current,
I_{FRMS}	– rms forward current.

Recovered charge Q_{rr}

This is the charge that flows through the external circuit during the reverse recovery time (i.e. the area under the current vs. time graph).

Thermal Resistance R_{th}

For diodes normally mounted on heatsinks the internal thermal resistance from junction to case R_{thjc} and the contact thermal resistance between the case and the heatsink R_{thch} are given, the latter being valid only if the assembly instructions stipulated below are followed.

For diodes not mounted on heatsinks the thermal resistance R_{thja} (junction to ambient) is given. In this case much of the heat transfer takes place via the connecting leads so the length of these leads is an important factor.

With diodes for p.c.b. mounting the quoted thermal resistances R_{thja} are valid for the diode seated tightly on to a p. c. b. having tinned tracks 2 to 3 mm wide.

Diodes with long connecting wires can be spaced 5 to 10 mm away from the p.c.b. This method of mounting will reduce the thermal resistance by 10 % or 15 % respectively due to the air cooling of the wires.

Large area, tin plated p.c.b. tracks can reduce the thermal resistance by 25 % to 30 %. In this case the diode must be seated directly on to the p.c.b. If the diode is freely suspended by its leads from solder or screw terminals, a reduction of up to 20 % in thermal resistance can be expected.

Recommended snubber (RC) network

Where only low-energy transients may occur, e.g. those caused by hole storage, the recommended snubber network is sufficient. For avalanche diodes, under these conditions no transient suppressing network is necessary at all.

Where high-energetic transients are to be expected, a more efficient suppressing network than is recommended in the table should be used. This applies especially where the rectifier diodes are connected directly to the mains or to a large transformer.

Protection against overvoltages (SKWD types)

Even with low operating voltage considerable transient overvoltages may occur across inductances caused by switching or may be transmitted from the line via the transformer winding capacitance. For protecting the diodes against these transients it is recommended to use capacitors of 20 to 100 µF (depending on the operating voltage) connected parallel to each diode by short, sturdy leads.

Protection against over-current and short circuits

Fast operating fuses should be used to protect against short circuits whereas magnetic or thermally actuated circuit breakers may be employed to protect against slowly increasing overloads. In particular thermally operated circuit breakers should be used when forced cooling is employed to prevent damage to the diodes in event of a failure of the fan.

Parallel connection of rectifier diodes

When parallel connection of diodes is necessary to achieve the required forward current, care must be taken in the construction of the assembly to ensure that equal current sharing occurs. In particular the connecting bus-bars must have nearly identical impedances. If the average forward currents of the diodes are limited to 80 % of their maximum value, then no special selection of diodes for equal forward voltage drop is necessary.

With the SKWD types the individual V_F value is printed on each diode for easy matching.

Series connection of rectifier diodes

When diodes are connected in series to provide a higher reverse voltage rating parallel resistances should be connected across each diode to ensure equal division of the reverse voltage.

If steeply increasing reverse voltages are expected then an additional parallel capacitor of the same value as recommended for the RC snubber network should be added.

In any case the reverse voltage per diode must be limited to 90 % of the single diode rating.

Assembly instructions

The mounting surface of the heatsink must be flat and clean and thermal compound must be coated on all mating surfaces between the diode and the heatsink.
Care must be taken neither to exceed nor to fall short of the specified mounting torque – a torque spanner should be used.

The heatsink should be mounted so that their cooling fins are parallel to the flow of cooling air, and they should be mounted near to the air inlet so that the air is not preheated by other components. If forced cooling is used care must be taken in the design of ducting that the whole flow of air passes though the heatsink fins and also that the air flow is equally distributed. With natural cooling equipment cabinets should be constructed so that a “chimney effect” gives a strong air flow from the bottom to the top of the cabinet.

The glass seals should not be subjected to mechanical stresses during assembly and operation. In particular, with the diodes with flag terminals the connections to the terminals should be made by soldered flexible wires – screw connections should not be used. During soldering the temperature of the solder should not exceed 270 °C.

Rectifier diodes supplied with solder leads should be soldered at iron or bath temperatures of

$$250^{+0}_{-10}\,°C$$

The maximum allowable temperature is 255 °C for 5 seconds.

Special mounting instructions for capsule diodes

In order to obtain the maximum possible current from a capsule diode, double-sided cooling (DSC) is normally used. In this case it is clamped between two identical heatsinks. It is also permissible to have single-sided cooling (SSC) only. In the case of double-sided cooling the thermal resistance figures relate to both heatsinks together.

The mounting instructions given for double-sided cooling may also be applied in the case of single-sided cooling with the appropriate modifications.

In order to guarantee good electrical and thermal contact, the contact areas of the heatsinks must be clean and metallic bright. The roughness remaining after grinding these areas must be less than 10 µm, the unevenness less than 10 µm. The contact areas should be coated by a thin layer (ca. 10 µm) of thermal compound (e.g. Electrolube 2 GX (Ident No. 30147770).

The clamp must be shaped so that one of the two heatsinks may move freely during mounting. It is therefore recommended that one of the clamp plates should form a pivoting support together with the heatsink (contact between a spherical and a flat surface). The other plate should be shaped so that the heatsink does not deform when the screws are tightened.

The heatsink which moves freely must not be used for supporting the unit in the mechanical structure of the stack or assembly. The electrical connection must be made by a flexible lead.

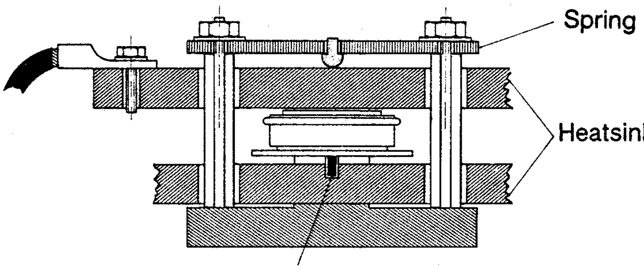


Fig. 1 Mounting capsule diodes

Assembly of capsule diodes using the clamps type MC

The contact faces on the heatsink for the diode and for current take-off points must be bare metal. If they are aluminium, before assembly the oxide layer must be removed with an abrasive sponge (e.g. Scotchbrite).

With plated surfaces it is sufficient to clean them with a solvent, and this also applies to the contact faces of the diode.

In addition both mating surfaces should be coated with thermal compound, for instance, Contact Treatment Grease 2 GX from Electrolube, and it is recommended this be done with a squeegee. Each contact face of the diode should be placed on its mating heatsink surface and twisted backwards and forwards by hand at the same time applying a firm pressure. Note that the centre pin (9) must first be placed in position. When the diode is removed from the heatsink the mating surfaces must be uniformly coated with thermal compound, or they can be thinly recoated.

Next the clamp is assembled so that the cross piece (5) with the pressure plate (4) and the tension bolts (10) are at the top. Underneath the cross piece (3) with the pressure plate (4) is put in position and the two bolts (10) are alternately tightened up until a slight resistance is felt. Now a check is made that both cross pieces (3) and (5) are parallel. For this it is sufficient to check that the tie bolts project to equal amounts beyond the cross piece (3). The tension bolts (10) may now be alternately tightened up until the metal gauge (8) can be easily moved.

The tension bolts should not be tightened beyond this point under any circumstances otherwise the mounting force will be exceeded. For this same reason the pre-set nut (6) compressing the Belleville washers should never be adjusted.

The metal gauge (8) is secured so that it cannot fall out.

Assembling and disassembling of capsule diodes

Capsule diodes contain thin layers of precious metal between the silicon chip and the hard metal contacts.
When the capsule is pressed these layers are deformed and provide intimate contacts with the brittle surfaces.

If the diode is too often assembled and diassembled (and eventually shaked when loose) there is the danger that the pieceparts move and the contacts deteriorate. For this reason any tests or measurements should be done with the lower specified value of the mounting force F. For blocking voltage test 80 % of this lower specified value are sufficient.

Two times disassembling and re-assembling are harmless provided the loose diode is not shaked.

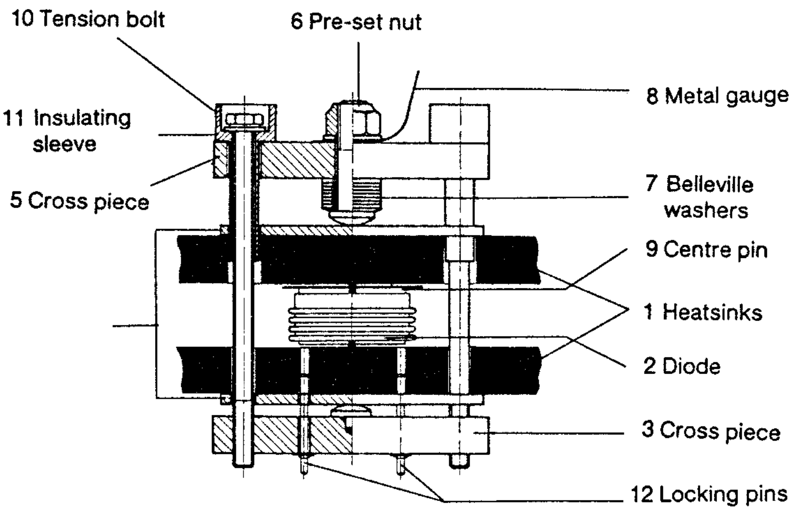


Fig. 2 Mounting clamps MC

UNF threads

The diodes with threaded studs have normally the metric ISO threads as specified in the outline drawings. On special demand diodes with UNF threads are available, the dimensions of which are given in parenthesis.

Assembling recommendations for SKN 4000 and SKN 6000

The figure shows an example for mounting SKN 4000 between two water cooled capsules. The surfaces of the cooling capsules should be even with not more than 10 µm deviation, and the roughness should not exceed 10 µm. Galvanic plating with nickel and silver is recommended. Nickel alone is to be refused because of its high-resistive oxide layer.

The surfaces may be coated with a thin layer of contact grease Electrolube 2 GX (Ident No. 30147770). So-called thermal compound should not be used because it spoils the electrical contact.

The screws are first turned in by hand and then tightened by a spanner in small steps in the sequence A-A-B-B until the specified force of (27±3) kN is reached. The distance h must be the same all over the periphery.

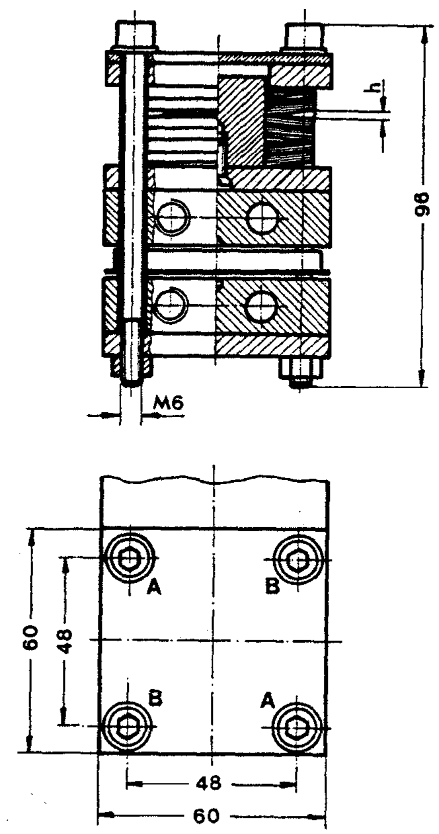
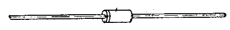
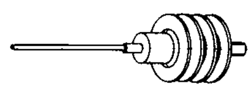
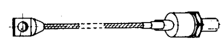


Fig. 3 Example for mounting a diode SKN 4000 between two water-cooled capsules.

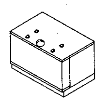
back zurück

Summary of Types (continued)

Avalanche Rectifier Diodes

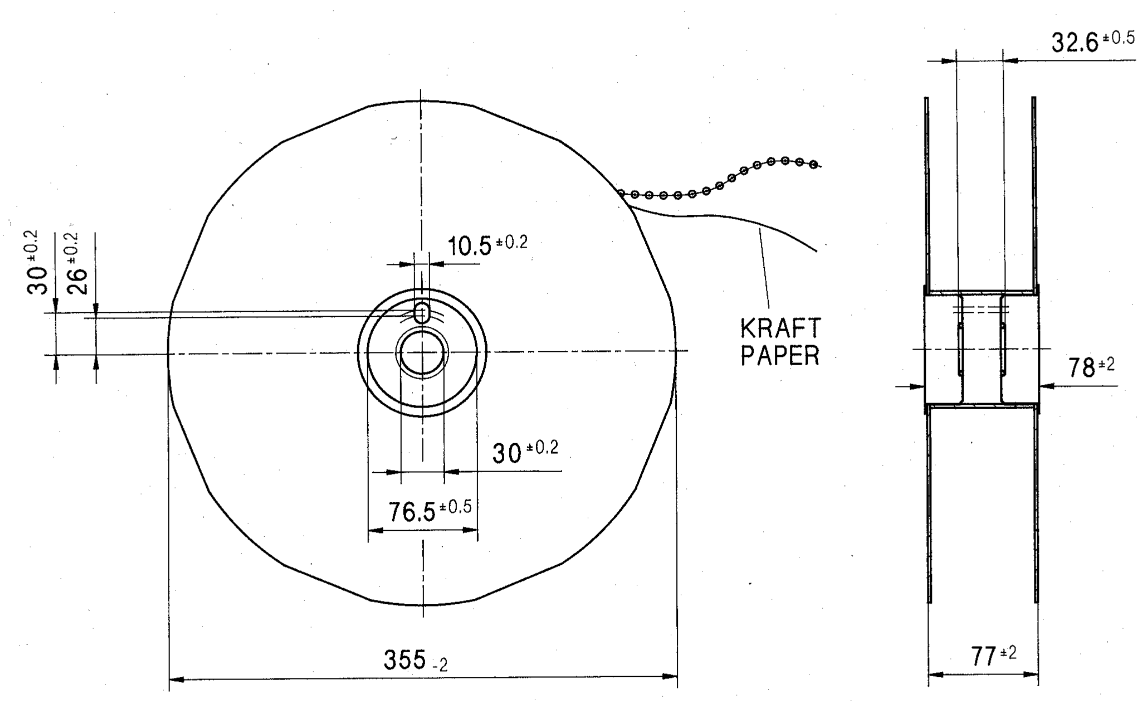
Type	V_{RRM} V_{RSM} V	$V_{(BR)}$ min.	I_{FRMS} A	I_{FAV} sin. 180 A	@ T_{case} °C	I_{FSM} 10 ms 25 °C A	i^2t 10 ms 25 °C A^2s	Case		Page
SKa 1		1 300 1 700	3	1,15	45[1)]	60	18	E 33		B 8-5
SKa 3		1 300 1 700	6,7	1,8	45[1)]	180	162	E 34		
SKNa 2/13 **SKNa 2/17**		1 300 1 700	5	2,0	45[1)]	180	160	E 5		B 8-9
SKNa 4/13 **SKNa 4/17**		1 300 1 700	10	3,7	45[1)]	190	180	E 6		
SKNa 20/13 **SKNa 20/17**		1 300 1 700	40	20	93	375	700	E 9		B 8-13

High Current Rectifier Diode Blocks for Water Cooling

SKWD 7000	200 ... 600			7 000	H_2O 8 l/min T_W=40°C	120 000	$72 \cdot 10^6$	C 4		B 8-49

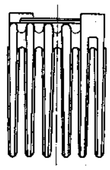
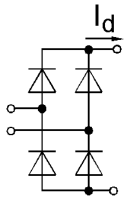
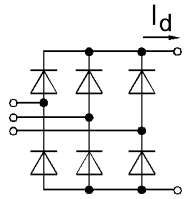
1) T_{amb}

Reel for Axial Leaded Diodes



Dimensions in mm

Current Ratings (Limiting Values)

Rectifier Diode		 Type	R_{thca} °C/W	 I_d A		 I_d A	
SKN 20 SKR 20	SKNa 20	K 9 K 5 K 3	11 5,5 3,5	20 28 35	17 23 30	29 40 50	24 33 42
SKN 26 SKR 26		K 9 K 5 K 3	11 5,5 3,5	20 28 35		29 40 50	
SKN 45 SKR 45		K 5 K 3 K 1,1	5,2 3,2 1,3	40 56 86		57 81 120	
SKN 70 SKR 70		K 3 K 1,1 P 1/120 K 1,1 F	3,2 1,3 0,85 0,60	66 112 156 174		96 159 225 246	
SKN 71 SKR 71		K 3 K 1,1 P 1/120 K 1,1 F	3,2 1,3 0,85 0,60	66 112 156 174		96 159 225 246	
SKN 100 SKR 100		K 3 K 1,1 K 0,55 K 1,1 F P 1/75	3,1 1,2 0,65 0,40 0,8	80 140 190 240 190		117 204 270 336 270	
SKN 130 SKR 130		K 1,1 K 0,55 K 1,1 F P 1/75	1,2 0,65 0,40 0,8	160 230 290 220		225 315 405 300	
SKN 240 SKR 240		K 1,1 K 0,55 K 1,1 F K 0,55 F P 1/200 P 4/200	1,1 0,55 0,35 0,17 0,40 0,29	210 340 460 620 420 480		300 480 630 840 570 660	
SKN 320 SKR 320		K 0,55 K 0,55 F P 1/200 P 4/200	0,55 0,17 0,40 0,25	390 760 480 600		570 1080 690 840	
SKN 400		K 0,55 K 0,55 F	0,55 0,17	310 700		450 1000	
SKN 450		2 x P 8/180 2 x P 17/130 F	0,32 0,145	430 710		620 1000	
SKN 501		2 x P 8/180 2 x P 8/180 F 2 x P17/130 F	0,32 0,105 0,145	550 1000 900		800 1400 1250	
SKN 870		2 x P 8/180 2 x P 8/180 F 2 x P 9/210 F	0,29 0,078 0,065	600 1400 1500		870 2000 2200	
SKN 1500		2 x P 8/180 2 x P 8/180 F 2 x P 9/210 F	0,29 0,071 0,055	350 1850 2100		500 2650 3000	
SKN 2000		2 x P 8/180 2 x P 8/180 F 2 x P 9/210 F	0,29 0,071 0,055	600 2200 2500		800 3500 3700	

Natural cooling: T_{amb} = 45 °C; forced air cooling: T_{amb} = 35 °C

Heatsinks

Rectifier Diodes	Heatsinks	Approximate weight g	Thermal resistance R_{thca} (including contact thermal resistance) Natural cooling °C/W	 Forced air cooling v_{air} = 6 m/s °C/W
SKN 20, SKR 20 **SKN 26, SKR 26** **SKNa 20**	K 5 – M 6 K 3 – M 6	100 200	5,5 3,5	– –
SKN 45, SKR 45 **SKN 70, SKR 70** **SKN 71, SKR 71**	K 5 – M 8 K 3 – M 8 K 1,1 – M 8 P 1/120 – M 8	100 200 700 1300	5,2 3,2 1,3 0,85	– – 0,60 0,40
SKN 100, SKR 100 **SKN 130, SKR 130**	K 3 – M 12 K 1,1 – M 12 P 1/75 – M 12	200 700 820	3,1 1,2 0,8	– 0,40 0,27
SKN 240 **SKR 240**	K 1,1 – M 16 x 1,5 K 0,55 – M 16 x 1,5 P 1/200 – M 16 x 1,5 P 4/200– M 16 x 1,5	700 2 000 2 200 4 000	1,1 0,55 0,40 0,29	0,35 0,17 0,17 –
SKN 320 **SKR 320** **SKN 400**	K 0,55 – M 24 x 1,5 P 1/200 – M 24 x 1,5 P 4/200– M 24 x 1,5	2 000 2 200 4 100	0,55 0,40 0,25	0,17 0,15 –
SKN 450 **SKN 501**	2 x P 17/130 P 17/130 + 2 x P 17/60 2 x P 8/180 P 8/375 + 2 x P 8/180	3 000 3 000 3 450 7 000	0,49 – 0,32 –	0,122[1] 0,155[1] 0,090[2] 0,109[2]
SKN 870 **SKN 1500**	2 x P 8/180 P 8/375 + 2 x P 8/180 2 x P 9/210	3 450 7 000 8 200	0,30 – 0,22	0,067[2] 0,094[2] 0,065[2]
SKN 2000	2 x P 8/180 P 8/357 + 2 x P 8/180 2 x P 9/210 P 9/430 + 2 x P 9/210	3 450 7 000 8 200 16 700	0,30 – 0,205 –	0,055[2] 0,066[2] 0,053[2] 0,063[2]
SKN 3000 **SKN 3400**	2 x N 4/250 2 x N 4/400	12 550 20 080	– –	0,405[3] 0,033[3]

[1] $V_{air}/t = 300\ m^3/h$

[2] $V_{air}/t = 600\ m^3/h$

[3] $v_{air} = 8$ m/s

The thermal resistances with natural cooling are valid for heatsinks with black surfaces. They increase by 20 % with metallic surfaces.

