Power Dissipation in Power Entry Modules

If different electrical components are combined in an appliance inlet to form a power entry module, the individual power losses and temperature deratings of all components involved must be carefully taken into account in order to ensure long-term safe operation.

SCHURTER DG11 and DG12: power entry modules with V-Lock cord retention and IP54 protection rating

Power entry modules (PEMs) consist of a combination of components for the safe power supply of devices. In addition to the IEC appliance inlet connector, mains switches, fuseholders or circuit breakers and filters can be integrated. All these components are tested according to their respective component standard so that the entire component can be certified by the certification bodies.

Each of these components is designed for a specific minimum and maximum ambient temperature. Important: The maximum rated current may only be used at the rated temperature. At higher ambient temperatures, the current must be reduced accordingly. This is usually specified in the temperature derating on the data sheets.

As power entry modules are installed in a cut-out in the appliance housing, the different ambient temperatures inside and outside must be taken into account. Inside, higher temperatures are almost always to be expected during operation, as the electrical load leads to heating (e.g. switching power supply, power semiconductors and heating elements).

Power dissipation

During operation, the components generate self-heating, which is shown as power dissipation in the data sheets. This power dissipation heats up the entire PEM and can lead to increased temperatures of all installed components. Important here too: All components of a PEM have a nominal power dissipation, so that the sum of all power dissipations is effective in the combined element.

The individual components of a PEM at a glance:

1. Appliance couplers

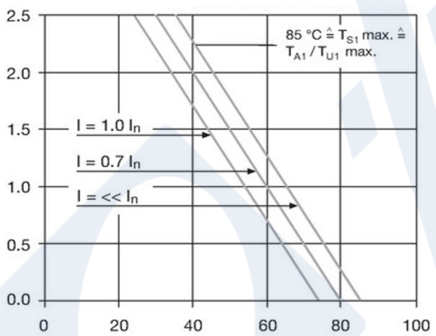
IEC 60320 approved appliance couplers are suitable for use in ambient temperatures up to 40 °C. The average temperature over a period of 24 hours should not exceed 35 °C with a lower limit of -5 °C

1.1. Appliance coupler pins

The requirements for appliance inlets state that the temperature of the connector pins of the corresponding plug must not exceed 70 °C. In this case, the IEC 60320 standard refers to a appliance coupler for cold appliactions. Cold appliance connectors must not be used on appliances with external parts whose temperature rise may exceed 75 °C during normal operation and can be touched by the moving supply cable.

2. Fuseholder

Fuseholders are generally approved for ambient temperatures up to a maximum of 85 °C. This is also the maximum temperature for touchable surfaces according to the fuseholder standard IEC 60127-6. As the fuse in the fuseholder generates relevant heat at rated current, the power dissipation that the fuseholder can absorb is limited. This power dissipation is specified in watts at rated current and rated temperature, e.g. 2.5 W at 10 A and 23 °C. The fuse must therefore be selected so that the maximum power dissipation is not exceeded. If the ambient temperature is higher than the rated temperature, temperature derating is applied. This curve reduces the permissible power dissipation as the ambient temperature increases. For example, a fuseholder with a max. power dissipation of 2.5 W at 23 °C can be operated at an ambient temperature of 40 °C with a fuse that has a maximum power dissipation of 1.7 W.

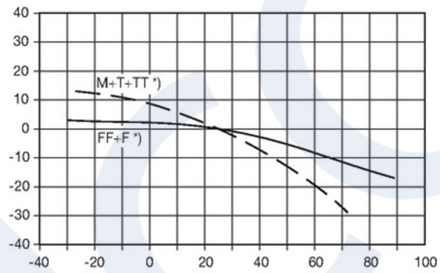


Derating curve for a fuseholder with 2.5 W power dissipation. Diagram: permitted power consumption vs ambient temperature

3. Fuse-link

A fuse generates heat depending on the current load and the electrical resistance of the fuse-link. This power dissipation is measured in a standardized test procedure in the fuse standard IEC 60127. The maximum power dissipation is specified in the data sheet in watts at the corresponding current rating. The fuse power dissipation must not be greater than the maximum power dissipation of the fuseholder. The fuse power dissipation also has a temperature derating. At higher ambient temperatures, the current through the fuse must therefore be reduced, otherwise the fuse will become too hot and reliable operation can no longer be guaranteed.

The standardized tests for fuse-links (IEC and UL) are carried out at 23 °C and 25 °C respectively. In practice, however, the ambient temperatures are considerably higher, especially where the fuse-link is used in a closed fuseholder or in the vicinity of other heat-generating components. For such applications, the shift of the operating current according to the diagram below must therefore be taken into account.



Temperature derating of a fuse (super slow to super fast tripping characteristic). Diagram: percentage shift in operating current vs ambient temperature

4. Mains switch

Mains switches are tested in accordance with the IEC 61058-1 switch standard with regard to the permissible ambient temperature. The mains switches used in most power entry modules have a maximum permissible ambient temperature of 85 °C. The marking T85/55, for example, indicates that the connection side of the switch is suitable for an ambient temperature of 85 °C, while the actuating part (e.g. rocker) may be exposed to the ambient temperature of 55 °C specified in the standard.

5. Circuit breaker

Circuit breakers (CBE) with thermal releases react to a change in the ambient temperature. With thermal circuit breakers, the bimetal is heated by the losses caused by the load current in the bimetal. SCHURTER circuit-breakers are designed for an ambient temperature of 23 °C. If the ambient temperature is different, the following correction factors apply to the rated current:

Ambient temperature [°C]	Correction factor
-30	0.76
-20	0.81
0	0.90
+23	1.00
+40	1.03
+50	1.04
+60	1.06

Example: Rated current = 5 A; Ambient temperature = 50 °C; --> Correction factor = 1.04; Resulting rated current = 5.2 A --> Choose a new CBE with next higher rated current: 6 A

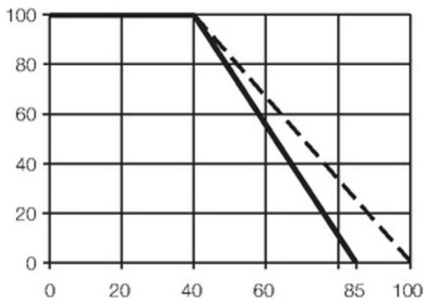
6. Mains filter

Mains filters are designed for a rated current at a specific ambient temperature, e.g. 40 °C. A filter consists of various components with different maximum temperatures. Components in the current path (e.g. chokes) cause heating according to the current flow and the electrical resistance of the coil.

$$I = I_n \sqrt{\frac{T_{max} - T_a}{T_{max} - T_n}}$$

Formula for calculating the derating of filters: In = nominal current; Tmax = max. permissible temperature; Ta = ambient temperature; Tn = nominal temperature

However, the most temperature-critical components of a filter are the capacitors, which have a maximum permissible temperature of 125 °C, for example. To prevent the capacitors from being exposed to excessively high temperatures, the load current must be reduced at higher ambient temperatures in accordance with the temperature derating formula.



Derating curve of a filter (simplified). Diagram: permitted operating current in % I_n vs ambient temperature

Temperature deratings

The individual components of a power entry module have different temperature

Ambient temp. inside [°C]	Fuseholder [A]	Fuse-link [A]	Mains switch [A]	Inlet plug [A]	Filter [A]	Circuit breaker [A]
23	10	10	10	10	10	10
30	9.3	9.8	10	10	10	9.8
40	8.1	9.2	10	10	10	9.7
50	6.6	8.6	10	9	7.8	9.6
60	5.0	8.0	10	7	7.4	9.4
70	2.5	7.2	10	5	3.3	0
80	0	0	10	0	1.1	0

Resulting currents at ambient temperature for selected SCHURTER power entry modules

deratings and different maximum operating temperatures. However, the individual deratings do not have to be summed up. It is important to weigh up which components are the most critical. Particularly critical are those components where the ambient temperature has a major influence on the function. This is the case, for example, with the fuse and fuseholder as well as the appliance circuit breaker. An increased ambient temperature can significantly affect the tripping time. These components should therefore be given priority. For the other components, the maximum operating temperature is particularly important. The power dissipation of the fuse at load current must be less than the power dissipation of the fuseholder. The temperature derating of the fuseholder must be applied according to the ambient temperature inside the enclosure. The same applies to circuit breakers and filters. Assuming that the outside temperature corresponds to a normal operating temperature of 23 °C (from 0 °C to max. 35 °C), this should be sufficient for reliable operation so that the maximum component temperature is not exceeded.

Measurements

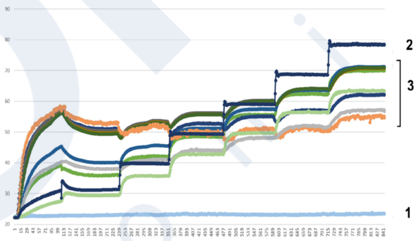
In order to determine the influence of the various components of a PEM on the overall temperature increase, the temperatures of all components were measured individually. None of them were allowed to exceed the maximum permissible material temperature (e.g. capacitor max. 125 °C). In addition, the maximum temperatures of the various standards for the individual components had to be observed (e.g. fuse holder touchable temperature max. 85 °C). The plug pin was allowed to reach a maximum temperature of 70 °C.. The PEMs were mounted on a mounting plate in the climate chamber to ensure the most practical measurement possible. This allowed measurements to be taken at a higher internal temperature and a constant external temperature. The load current was reduced according to the temperature derating of 100 % with increasing ambient temperature. With correct derating, the maximum material temperature was not allowed to be exceeded at any ambient temperature.

Results

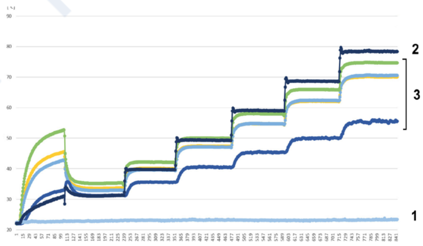
The outside temperature (1) remained constant at 23 °C throughout the test. The indoor temperature (2) was increased from 23 °C in 10 °C increments up to 80 °C. The rated current was reduced from 10 A to 0 A in accordance with the derating. It was seen that the individual components (3) reached ever higher temperatures despite the reduced current reached ever higher temperatures without exceeding the maximum permissible material temperatures. This proved that the temperature deratings were correct and critical excess temperatures were prevented.

Conclusions

With PEMs, the ambient temperature both outside and inside the appliance must be taken into account. At higher ambient temperatures above the nominal value, the temperature derating should therefore be applied wherever possible. As PEMs consist of different components, each of these components must be tested separately. The fuse with the fuseholder and the circuit breaker are the most temperature-critical components. It therefore makes sense to prioritize the temperature derating of these components. If these components are not present, the ambient temperature of the filter needs to be taken into account in particular. In the case of appliance plugs and switches, it is usually sufficient if the maximum temperatures are not exceeded.
Compliance with the ambient temperatures and the careful application of temperature derating ensure the long-lasting and safe operation of a power entry module.



SCHURTER DD12: 1 = external temperature, 2 = internal temperature, 3 = filter components, fuseholder, switch



SCHURTER DG11: 1 = external temperature; 2 = internal temperature, 3 = circuit breaker

Ambient temperature	23 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C
DD11	10 A	9.3 A	8.1 A	6.6 A	5.0 A	2.5 A	0 A
DD12	10 A	9.3 A	8.1 A	6.6 A	5.0 A	2.5 A	0 A
DG11 (CBE max. 60 °C)	10 A	9.8 A	9.7 A	9.6 A	9.4 A	0 A	0 A
DG12 (CBE max. 60 °C)	10 A	9.8 A	9.7 A	7.8 A	7.4 A	0 A	0 A

Resulting currents at ambient temperature for selected SCHURTER PEMs

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