SCHURTER Fuses for Space

European Components Initiative
Rome, Italy

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V1

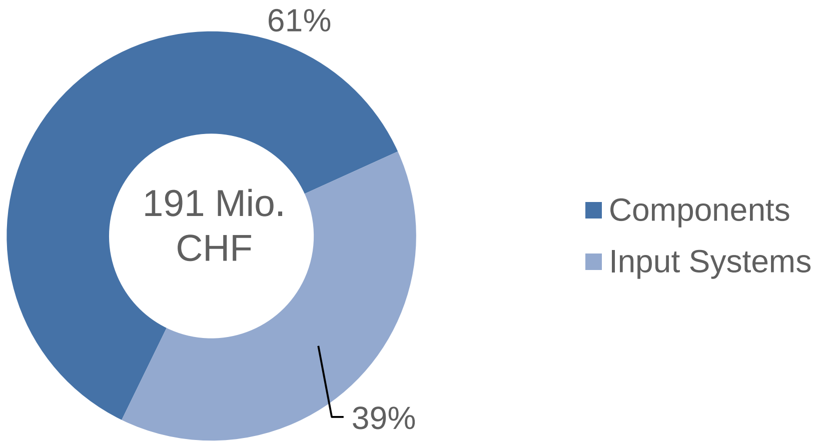
Overview

SCHURTER Electronic Components

«SCHURTER Electronic Components operates successfully as a Swiss technology company worldwide. We offer solutions to our business partners, also for the most demanding requirements. In a dynamic market, we are growing thanks to high technical expertise, financial independence and extraordinary innovation.»

Components

SCHURTER is a leading innovator, manufacturer and distributor of fuses, connectors, circuit breakers, input systems and EMC products – and an important service provider for the PCB assembly and electronics industries.



Input Systems

SCHURTER develops, manufactures and markets input systems, touch screens and touch panels, capacitive sensor keypads, membrane keypads and housing systems in close cooperation with the customers.

Key figures industry segments

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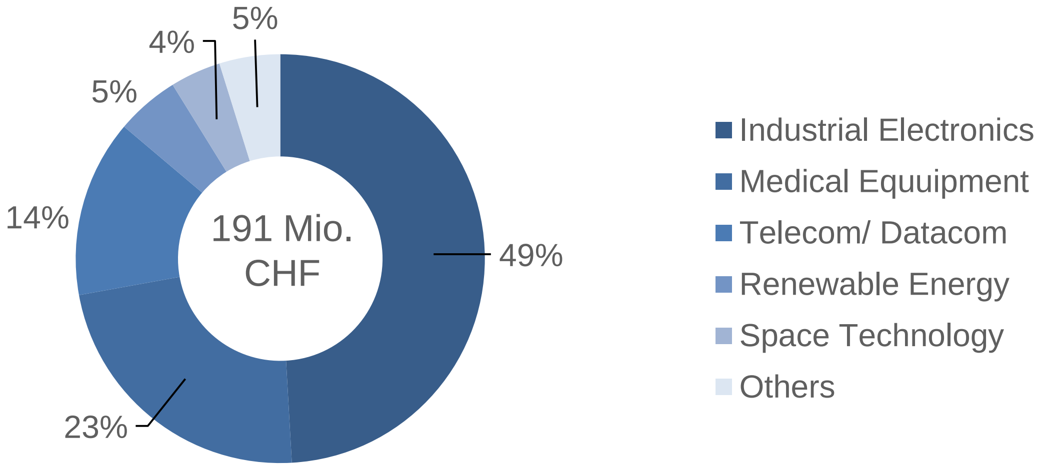
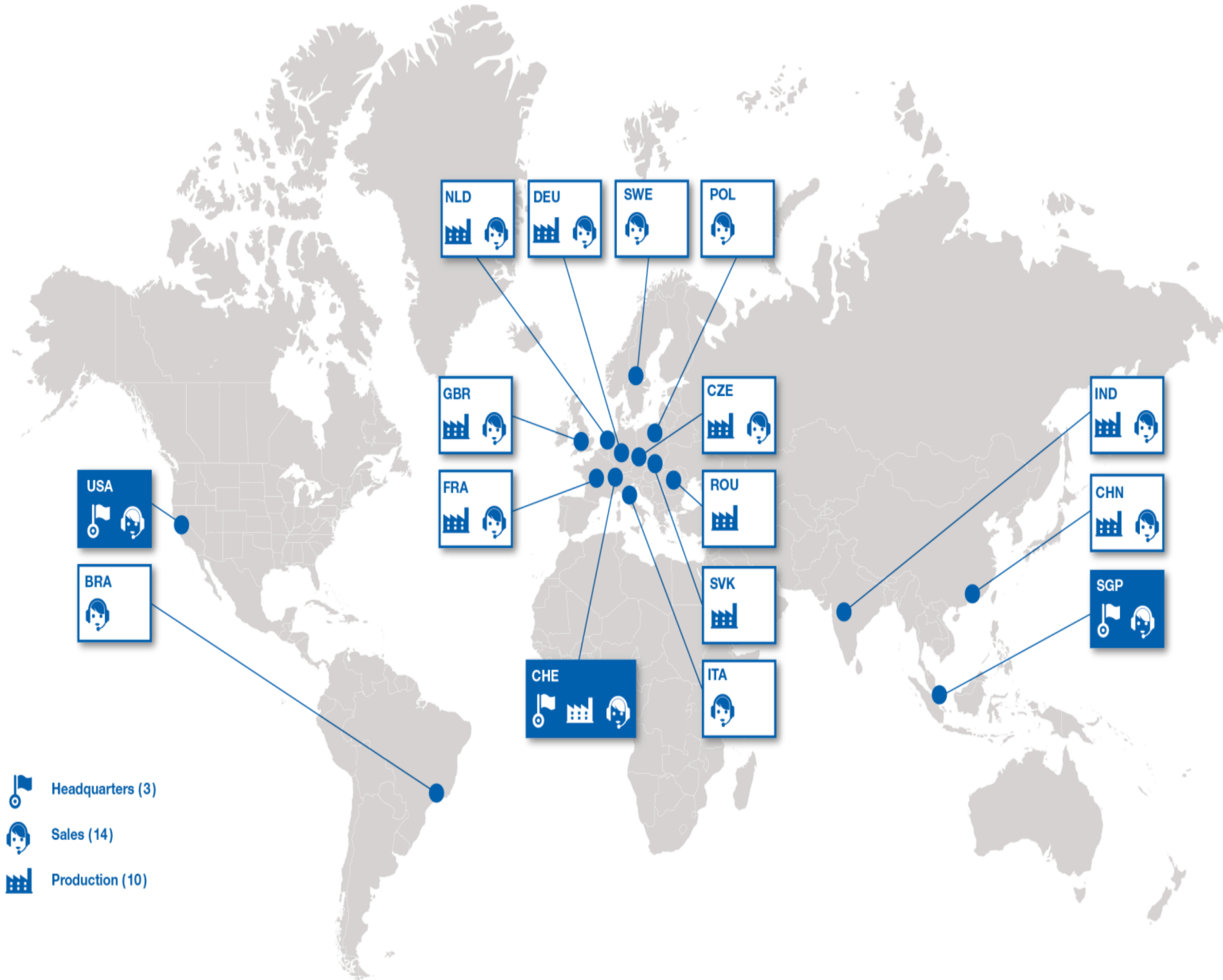


Space Fuse

SCHURTER group companies



Cooperation with ESA / ECI since 2004

ECI, Phase 1: Evaluation & Qualification of an European Thin Film Fuse

SCHURTER Fuse MGA-S:

2004	First contact with ESA/ESTEC/ESCC
2005	Contract with ESA signed
2006	Evaluation process finished
2007	Qualification process finished
2008	MGA-S listed on QPL of ESCC

ECI, Phase 2: Fuse up to 15 A Evaluation & Qualification, Contract No. 19273/05/NL/PA

SCHURTER Fuse HCSF:

2010	Contract with ESA signed
2014	Evaluation process finished
2015	Qualification process finished
2016	HCSF listed on QPL of ESCC

HCSF

Application example

Why fuses are used in space applications?

In telecom satellites the electrical energy from solar arrays and batteries are joined together via Power Supply Regulator and Power Distribution Unit. On the other hand the energy is distributed to different sub-systems (modules).

«Important» Modules like SM (Service) or CM (Communication) have to be protected.

Therefore:

⇒ A fuse protect sub-systems from component damage if an critical overcurrent occurs

⇒ Due to of sub-system redundancy a fuse have to break up the energy flux of the failed module or sub-system in a fast, reliable and safe manner.

How many fuses have SCHURTER served to space customers since 2008?

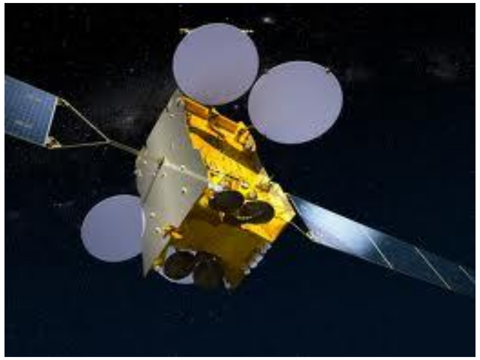
Indeed more than 180’000 fuses!!!

MGA-S

HCSF

The space fuses from SCHURTER are used in:

> Telecommunication Satellites
> Observation, Navigation GPS, etc.
> Laboratory equipment in space stations or ground applications



Source: ESA

Sporadic used in:

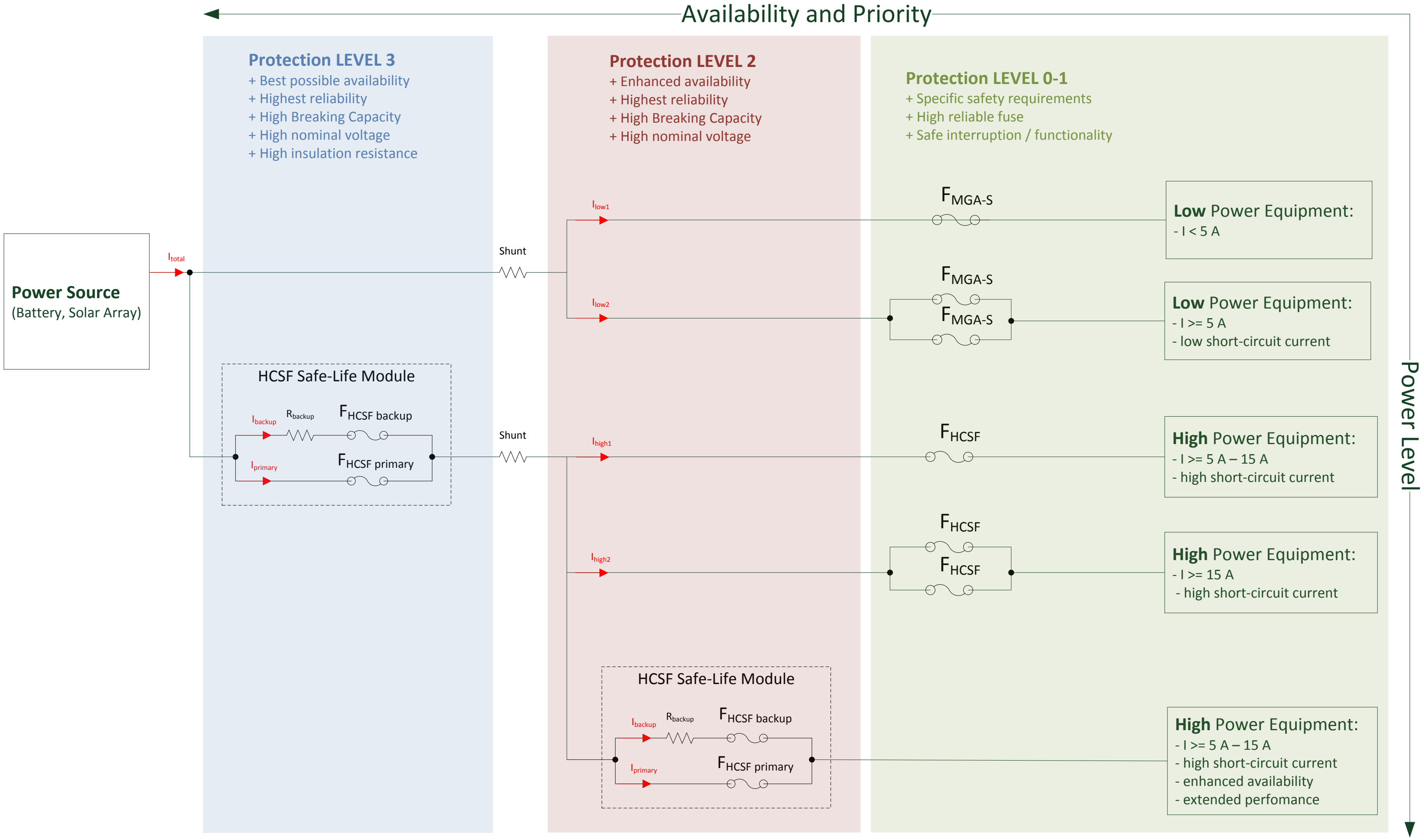
> Mapping satellites (glaciology, geotectonic, etc.)
> Meteorological satellites

Potential future applications:

> Exploration, Research in Space
> «Next Generation» Observation satellites (EnMAP)
> «Next Generation» Communication satellites (Laser communication -> LCT)

Application: Power - Protection Level

Fuses are broadly used in telecom spacecraft and other application where safety requirements are needed.
Depending on system level (availability, priority, etc.) the best suitable type of protection device has to be chosen.



MGA-S

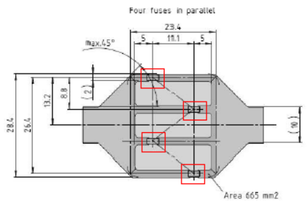


Figure 14: Four fuses in parallel

MGA-S in parallel

HCSF

Protection Level 4: Fully redundant protection device / module

Fuse Selection

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Fuse Selection for Application Specific Circuit Protection

The criteria on fuses for effective circuit protection varies depending on the application requirements like protection functionality level. In particular for space application, the remarkable environment conditions, the high reliability and availability of safety requirements of the system need additional dimensioning actions to get the best fitting fuse.

The most important design parameters for fuses and their related performance data are listed below:

Application Requirements / Parameter	Relation	Fuse performance data	SCHURTER Fuses for Space	
			MGA-S	HCSF
Safety requirements (electrical protection reaction sensitivity – fail safe)	←→	Fuse tripping characteristic - quick acting F, very fast acting FF	FF	F
Safety requirements (reliability, availability)	←→	Design / technology – e.g solid state, qualification and reliability data, safe-life concept	Solid state ESCC QPL Rel. data available	Solid state ESCC QPL Rel. data available
Environment requirements (space, ground, etc.)	←→	Qualification and approval as in [1], ESCC-Q-ST-30-11C as in [4]	ESCC 4008001	ESCC 4008002
Supplied voltage	←→	Rated voltage	125 VDC	125 VDC
Average load current	←→	Rated current	0.14 – 3.5 A	5 – 15 A
Short inrush current	←→	Breaking capacity (e.g. HCSF safe-operating area)	Max 300 A	Min 1000 A See Safe-Operating Area data in E-HB, as in [7]
Current pulse profile (duty cycle, peak current, amount of pulses during mission time)	←→	I^2t, current pulse derating factor	See MGA-S Data Sheet as in [5] and SCHURTER guide to fuse selection	See HCSF Data Sheet, as in [6]and E-HB, as in [7]
Ambient temperature	←→	Temperature derating	See MGA-S Data Sheet	See HCSF Data Sheet or E-HB
Size and mounting	←→	E.g. SMD	SMD 1206	SMD 3220

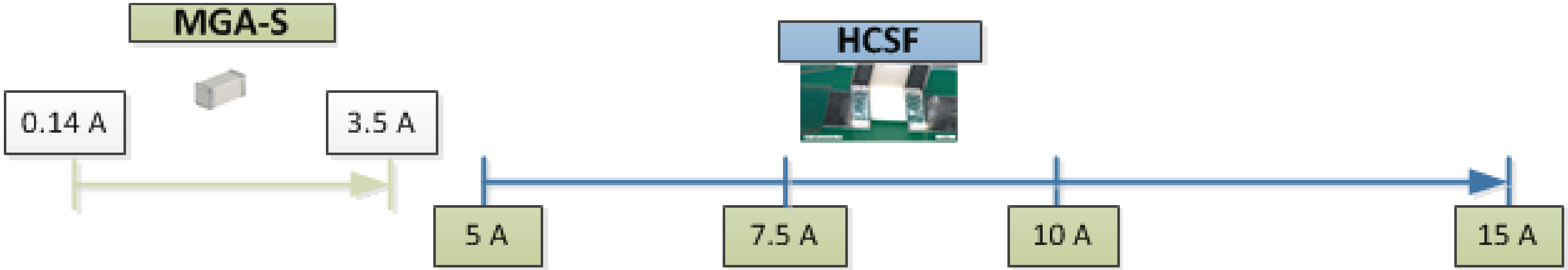
The SCHURTER MGA-S & HCSF fuses are the exclusive ESA ESCC qualified and listed parts.

With the established and ESA ESCC qualified space fuse called MGA-S (MGA Space) and the new qualified space fuse called HCSF (High Current Space Fuse), SCHURTER AG covers nominal current protection requirements for space application from 0.14 A up to 15 A or even more, if they are set in parallel. Both fuse types are sealed, based on solid state thin film technology and comply with the strict requirements of space.

ESA ESCC qualified fuse families:

MGA-S: Small SMD fuse (1206)
Rated current range: 0.14 A up to 3.5 A
Application: Overcurrent protection in “Low Power” module
Qualified since 2008

HCSF: SMD fuse (3220)
Rated current range: 5 A up to 15 A
Application: Overcurrent protection in “Low Power” and “High Power” module
Qualified since 2016



MGA-S Key Figures

- ESA ESCC QPL (ESCC 4008/001) since 2008
- Established fuse for space application
- Hermetically sealed
- Solid state thin film fuse technology – no wire!
- SMD 1206 - very compact size, smallest fuse!
- Very quick acting
- DC and AC rated
- Rated current from 0.14 A up to 3.5 A
- High breaking capacity – up to 300 A at 125 VDC
- SnPb finish – effective whisker growing barrier
- Each fuse undergoes extensive control and screening procedures during production processes according to ESCC 4008

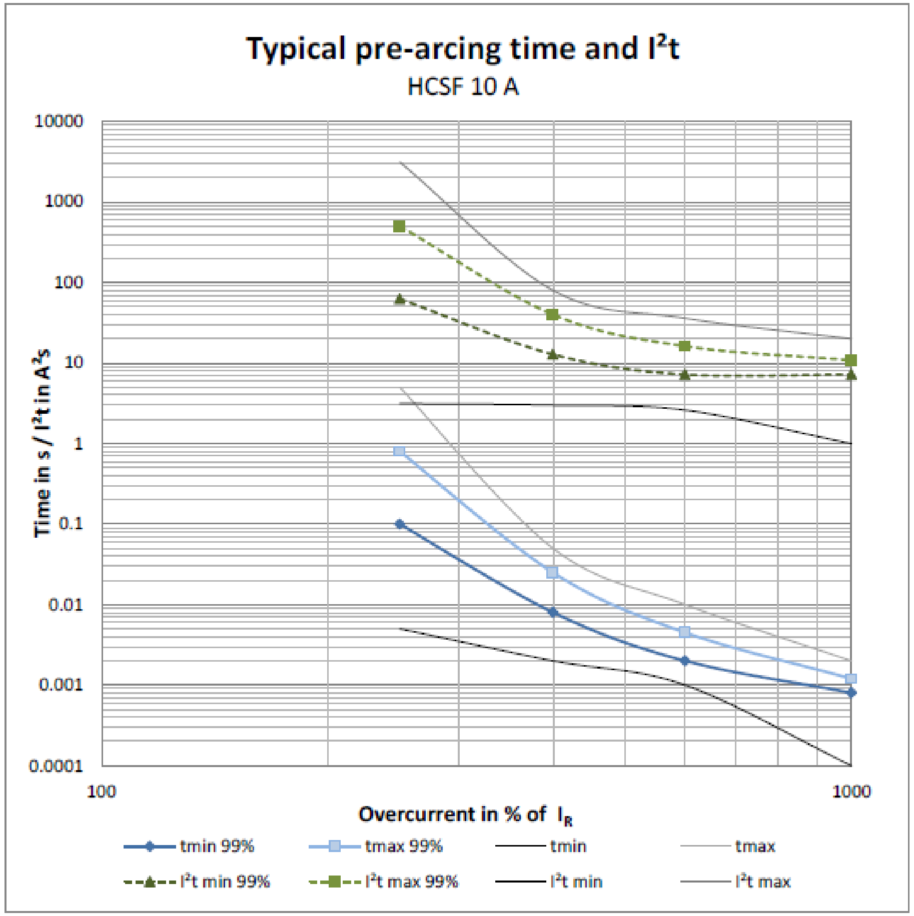
HCSF Key Figures

- ESA ESCC QPL (ESCC 4008/002)
- High reliable fuse – based on MGA-S experiences
- Solid state thin film fuse technology – no wire!
- SMD 3220 - very compact size (8 x 5 x 5 mm)
- Quick acting
- DC and AC rated
- Rated current from 5 A to 15 A
- High breaking capacity
- Current pulse resistive – design guide for current pulse mode (available in 2016)
- SnPb finish – effective whisker growing barrier
- Each fuse undergoes extensive control and screening procedures during production processes according to ESCC 4008

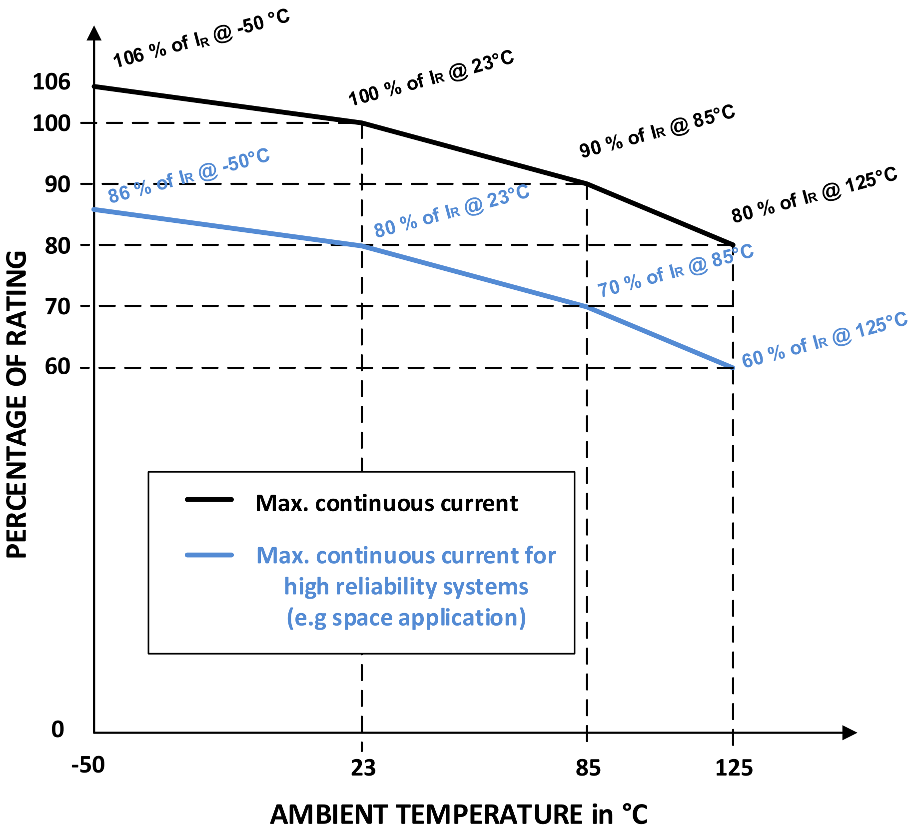
HCSF Key Figures: Overload Operating

Overload Current Characteristic

Rated current I_R	100 % I_R	125 % I_R	250 % I_R		400 % I_R		600 % I_R		1000 % I_R	
	Min	Min	Min	Max	Min	Max	Min	Max	Min	Max
5 A – 15 A	Continually	1 h	5 ms	5 s	2 ms	50 ms	1 ms	10 ms	0.1 ms	2 ms



Temperature Derating



HCSF Key Figure: Breaking Capacity

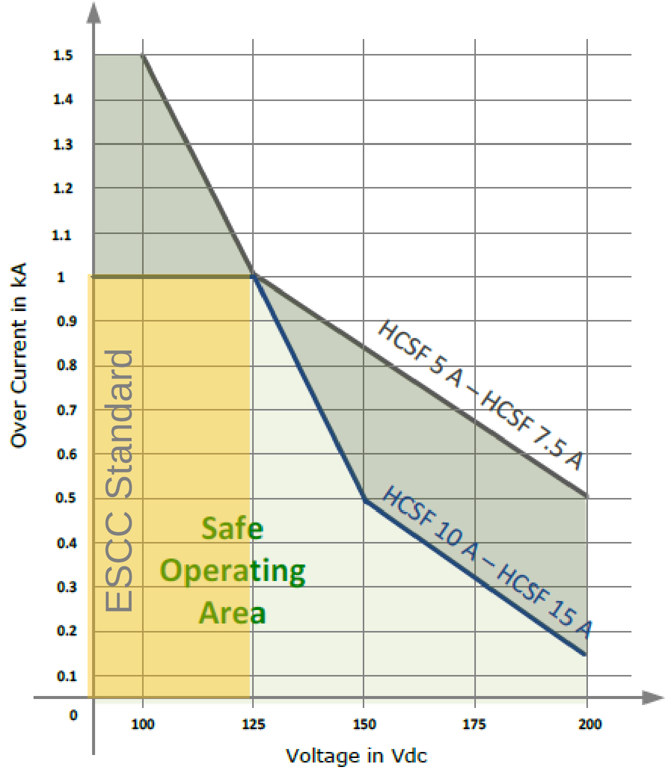
Breaking Capacity: Is the ability of a fuse to interrupt without being destroyed or causing an electric arc with unacceptable duration.

Big safety margin - the true breaking capacity of the HCSF is beyond the qualified rating!!!

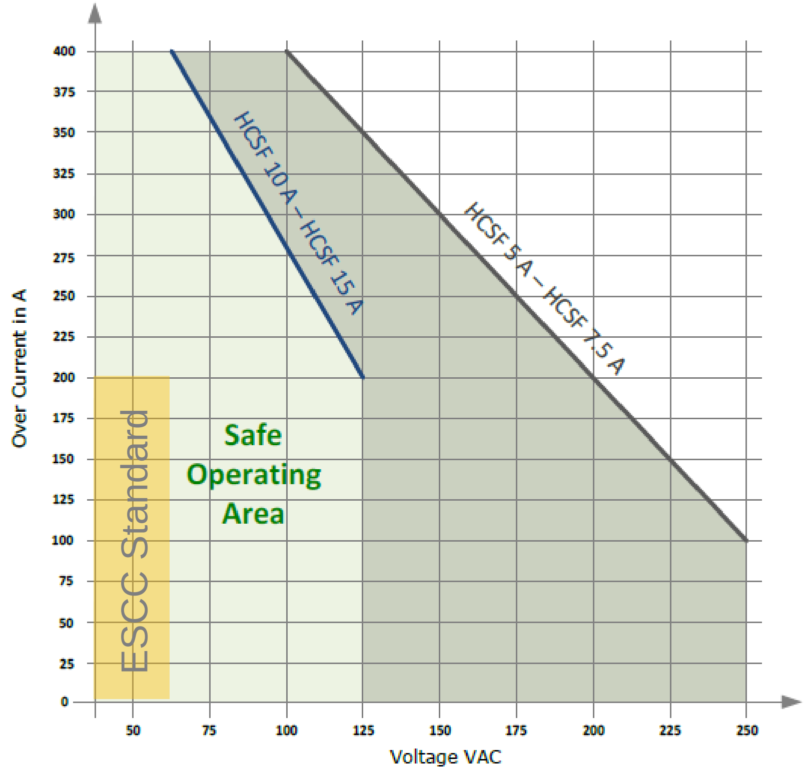
ESCC 4008/002:

- BC at DC according to the data sheet is 1000 A at 125 VAC
- BC at AC according to the data sheet is 200 A at 63 VAC

DC Breaking Capacity Limits $I_{BCmax} = f(U_{DC})$



AC Breaking Capacity Limits $I_{BCmax} = f(U_{AC})$



HCSF Key Figure: Current Pulse

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Fundamental behavior: The current pulse resistivity of fuses mainly depends on the pulse energy (I^2t) and the repetition time – caused by the thermal constant of the fuse.

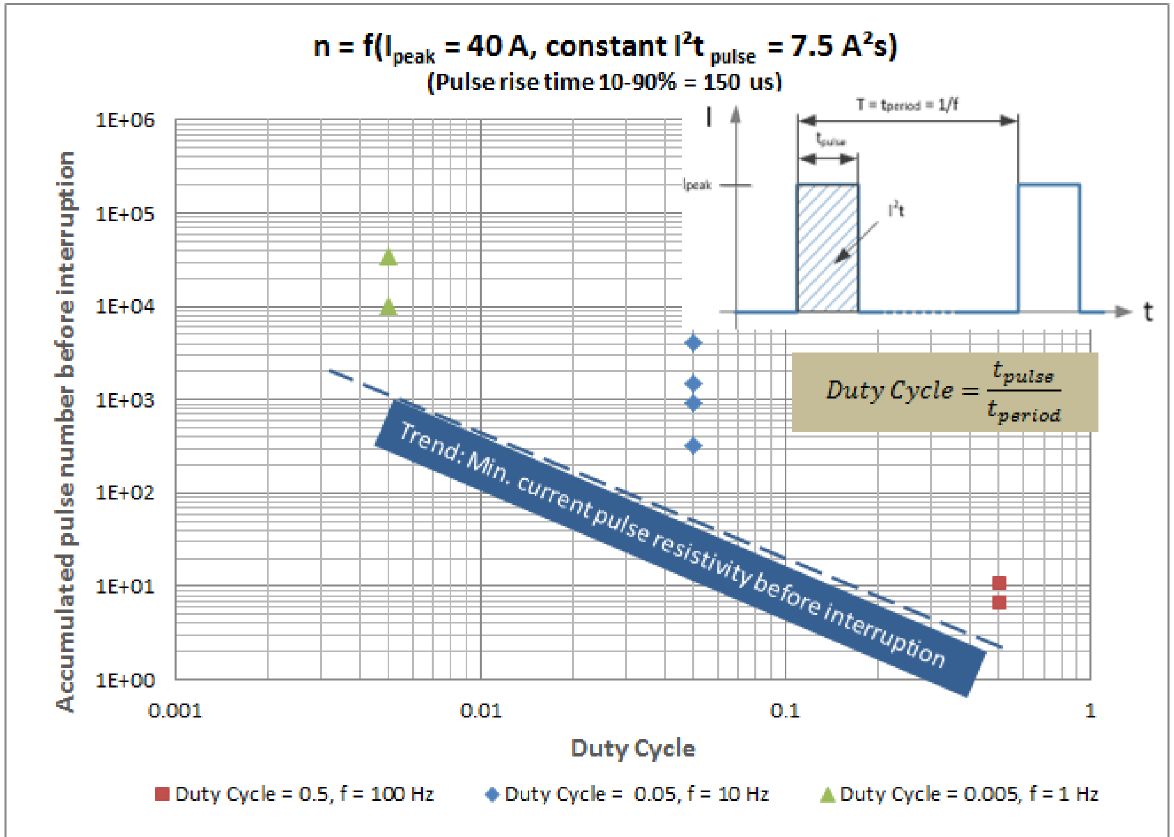


Chart: Current pulse resistivity at 23 °C of HCSF 10 A

SCHURTER is performing extended current pulse tests.

The aim of this effort is to outline the fundamental behaviour at common current pulse conditions.

The design rules (derating factor for current pulse operating) are going to be a part of the HCSF Engineering Handbook 0105.2216.

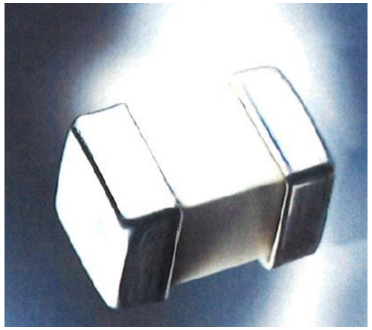
HCSF vs HCF

HCSF => High reliable fuse for Space acc. to ESCC 4008

HCF => High performance fuse for Avionics and similar applications

The HCF is the cost effective (mass production) version of the HCSF without extended production controls (X-Ray & visual inspection), lead free finish, not sealed, no marking on fuse body and without control and screening tests (Chart F2 and F3 according to ESCC 4008).

HCSF 7.5 A



HCF

Parameter	HCSF	HCF
Rated Current (continuous)	5 A to 15 A	5 A to 15 A
Rated voltage DC / AC	125 VDC / 63 VAC	125 VDC / 63 VAC
Design safety margin (limits)	200 VDC / 125 VAC	125 VDC / 63 VAC
Breaking capacity at rated voltage DC / AC	1000 A / 200 A	Max. 1000 A / 200 A

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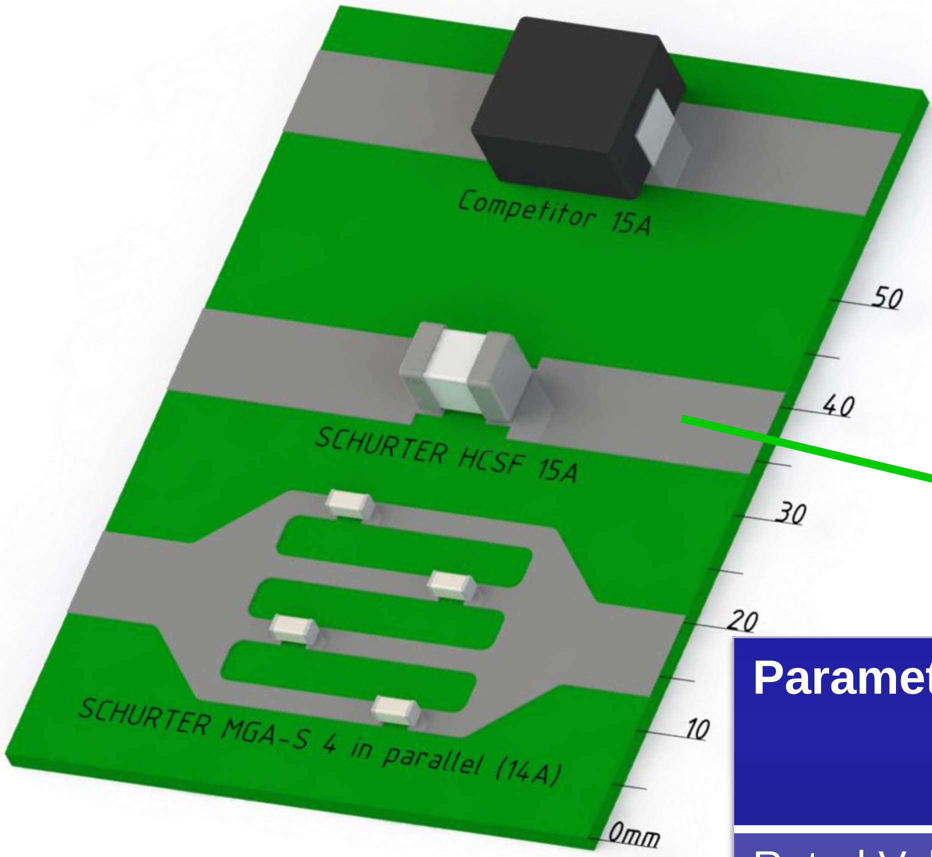
Comparison of 15 A rated current fuse, in space on PCB and breaking capacity



Parameter	MGA-S in ||	HCSF	Typical comparable product
Rated Voltage DC	125 VDC	125 VDC	< 100 VDC
BC at DC	300 A	1000 A	<= 1000 A
Rated Voltage AC	32 VAC	63 VAC	No rating
BC at AC	50 A	200 A	No rating

Proven Long Term Stability - Life Test at 125 °C

- The SCHURTER HCSF was tested up to 90 % of IR during **max. 4168 h** (Evaluation Phase in 2013 to 2014).
- No significant aging observed!
- Since extended data are available a test current of 80 % IR is defined (see ESCC 4008/002) – additional design margin!

Good to know!

According to MIL-PRF-23419/12E a fuse shall be supplied with 64 % of the rated current

> Life (2,000 hours): Fuses shall be mounted by their terminals in sockets and mounted in a chamber at +125°C ±3°C, 0°C ambient. The fuses shall be electrically connected to a dc source supplying each fuse with 64 percent of the +25°C rated value of current. The fuses shall remain in the chamber at specified current for 2,000 ±8 hours. The electrical circuit shall provide a suitable indicator, which shall be monitored daily during the length of the life test, to identify failure (blowing) of any fuse. The time of failure shall be recorded to the nearest ±12 hours and the blown fuse replaced with a short circuit for the remainder of the test. The DC resistance of each fuse shall be measured before and after testing as specified in MIL-PRF-23419 and shall not have changed by more than ±10 percent.

What does this mean?

⇒ In fact the SCHURTER HCSF was tested with > 30 % more electrical power.

⇒ It is a stable fuse design at static loads and high temperature because no significant aging was observed.

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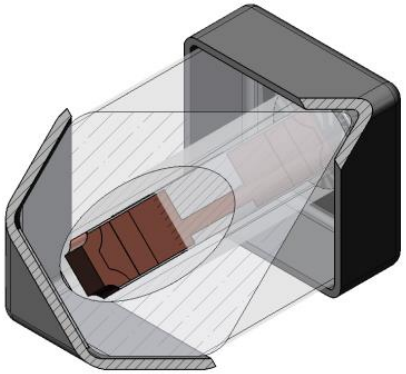
Main Components

Fuse Element:	Solid state thin film technology
Body:	High performance, pure ceramic housing
Filler:	Silicone filler, conditioned and performed



The constructions of the space fuses from SCHURTER are strong inherited.

HCSF 7.5 A

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What does this mean?

- Main production processes taken over from MGA-S for HCSF
- The fuse element technology of HCSF is based on the MGA-S
- All materials are similar (housing, plating finish, filler, solder, substrate)

ESCC (European Space Component Coordination)

ESCC 4008:	Generic Specification for Fuses
ESCC 4008/001:	Detail Specification based on SCHURTER MGA-S
ESCC 4008/002:	Detail Specification based on SCHURTER HCSF

ESCC 4008

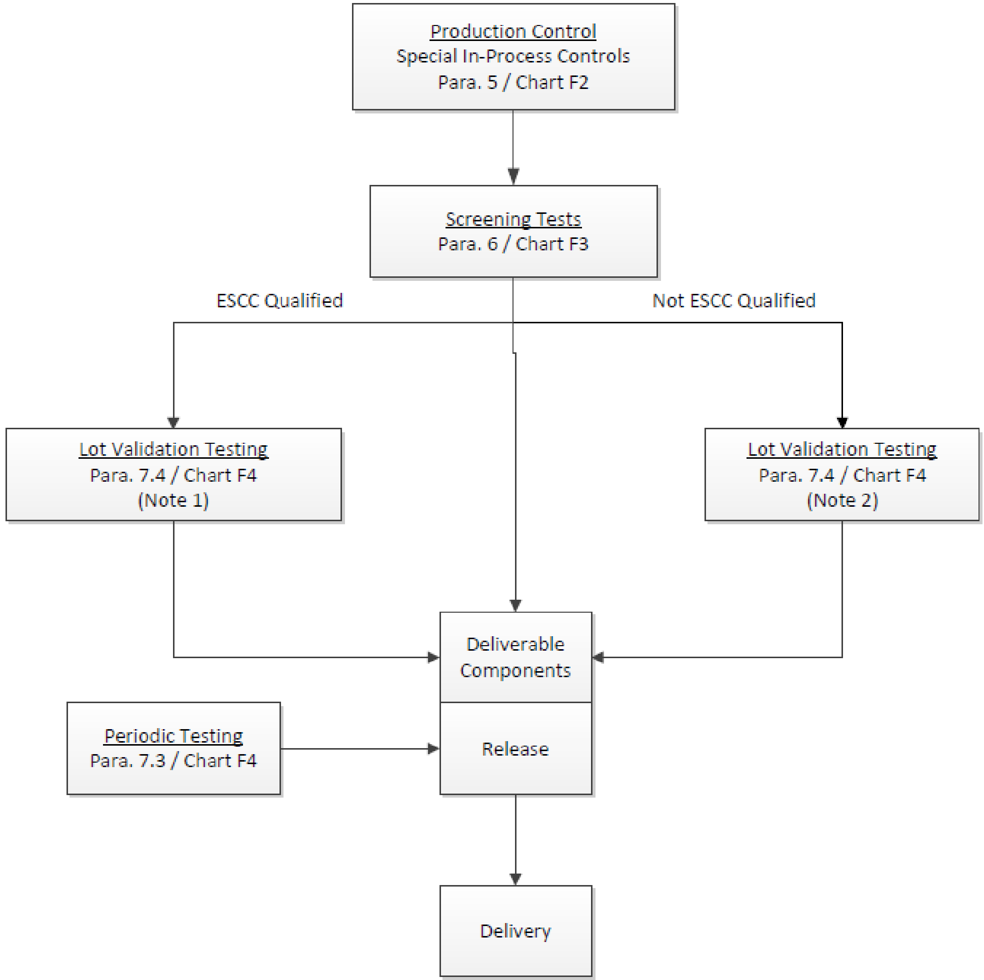
ESCC 4008/**001**
based on MGA-S

ESCC 4008/**002**
based on HCSF

ESCC 4008 Generic Specification for FUSES

Defines:

- General Requirements for the Qualification
- Procurement / Prod. Control – Chart F2 and F3
- Qualification of Maintenance – Chart F4
- Delivery of fuses for space applications



Source: ESCC 4008, Issue 4, www.escies.com

ESCC Detail Specification No. 4008/001 & 002 based on SCHURTER FUSES (MGA-S & HCSF)

Definition:

This specification details the ratings, physical and electrical characteristics and test and inspection data for the component type variants and/or the range of components specified below. It supplements the requirements of, and shall be read in conjunction with, the ESCC Generic Specification listed under Applicable Documents.

Source: ESCC 4008/001, Issue 5, www.escies.com

ESCC Component Number:

Example: 400800101

- Detail Specification Reference: 4008001
- Component Type Variant Number: 01 (as required)

Source: ESCC 4008/001, Issue 5, www.escies.com

Numbering	MGA-S	HCSF
Range	4008001**01-19**	4008002**21-39**
Definition	Numbers <= 20 represent MGA-S variants	Numbers >= 21 represent HCSF variants

MGA-S 3.5 A

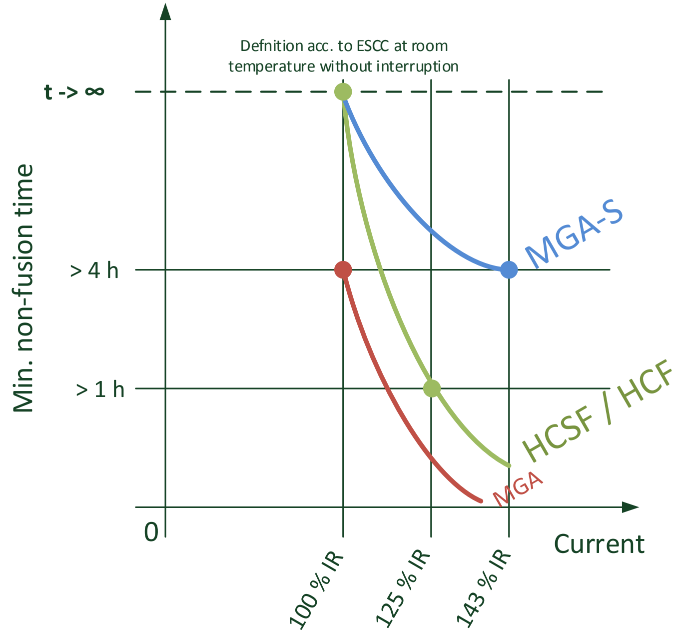
HCSF 7.5 A

Deviations between MGA-S and HCSF

Rated current and nominal current

Parameter	MGA-S	HCSF
Rated Current **IR**	Continuous current at 23 °C	Continuous current at 23 °C
Nominal Current	*143 % IR_{MGA-S}* *(MGA UL Rating : 100 % IR_{MGA})*	*100 % IR*
Remark	MGA is based on **UL-Standard**	HCF/HCSF is based on **IEC-Standard**

The HCSF is a IEC 60127-4/7 based SMD fuse. This type of fuse carries 125 % IR during 1 h without blowing or significant aging effects after test campaign.

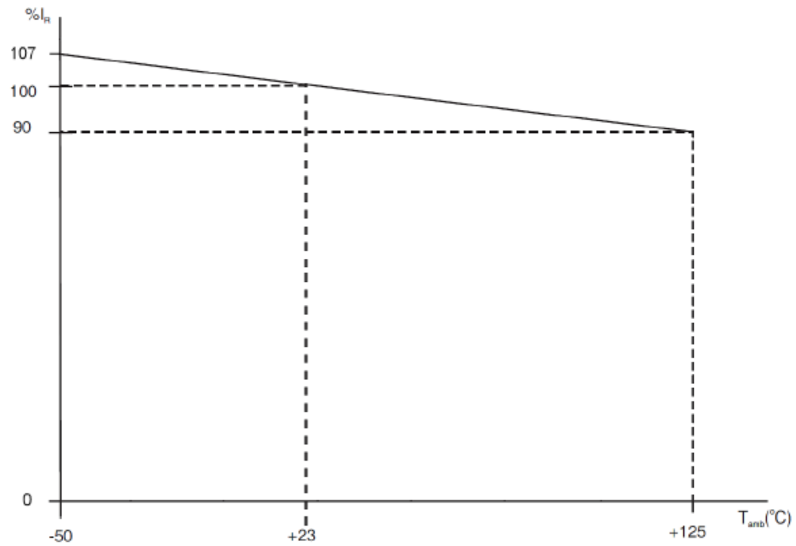


Deviations between MGA-S and HCSF

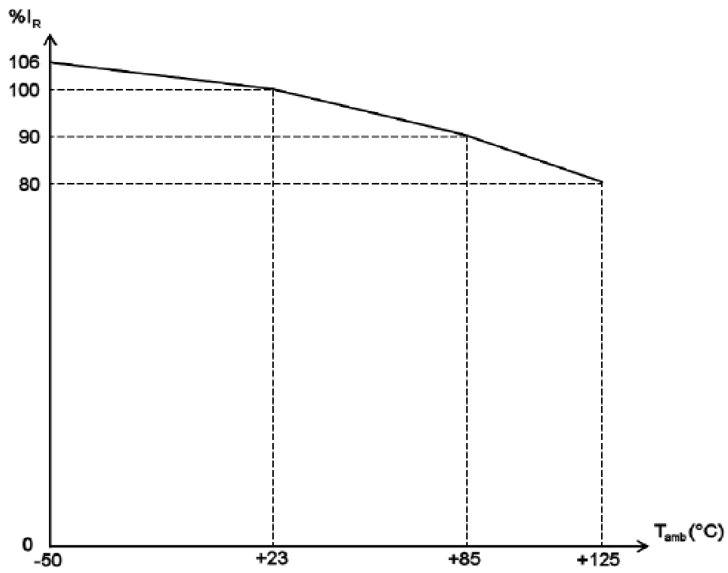
Operating Temperature / Temperature Derating Factor

Parameter	MGA-S	HCSF
Power on operating temperature	-50 to +125 °C	-50 to +125 °C
Power off max. temperature (storage temperature range)	-55 to + 150 °C	-55 to + 150 °C

The HCSF have the same operating temperature range that the MGA-S represent. But the maximum continuous current depending on operating temperature is different => Temperature derating curves MGA-S (left chart) and HCSF (right chart):



Maximum Continuous Current vs. Operating Temperature



Maximum Continuous Current vs. Operating Temperature

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Deviations between MGA-S and HCSF

Insulation Resistance after interruption

Parameter	MGA-S	HCSF
Resistance at 250 V	20 kOhm minimum	100 kOhm minimum

The insulation resistance is measured at twice the rated voltage of the DUT (2 x 125 V = 250 V).

Breaking Capacity at DC

Max. BC	MGA-S	HCSF
125 VDC (time constant <= 1ms)	Variant 01-10: 300 A Variant 11-12 : 50 A	Full range: >= 1000 A

Screening Test “Burn-In” Chart F3 – electrical test current

Parameter	MGA-S	HCSF
Burn-In Conditions (80 +0 / -3) °C, 168 h	95.7 % IR	90.8 % IR

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ESCC Detail Specification No. 4008/001 & 002 based on SCHURTER FUSES (MGA-S & HCSF)

Deviation from Chart F2 to F4 – Conditions at Overload Operating

MGA-S	HCSF
Overload Current:	Overload Current:
357 % IR	400 % IR
571 % IR	600 % IR
857 % IR	1000 % IR

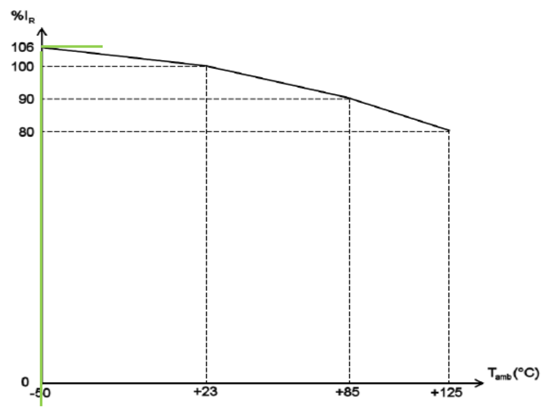
The Overload Current conditions are different because the HCSF is a real IEC based fuse compared to the MGA-S that is derived from UL.

The fuse characteristic is typically defined at 1000 % IR (time-lag, quick acting, etc.)

ESCC Detail Specification No. 4008/001 & 002 based on SCHURTER FUSES (MGA-S & HCSF)

Deviation from Chart F4 only – Verification of Overload Operating at DC Rated Voltage

	MGA-S	HCSF
(22 +/-3) °C	357 % IR 571 % IR 50 A (BC) 300 A (BC)	250 % IR 400 % IR 600 % IR 1000 A (BC)
(-50 -0/+5) °C	382 % IR 611 % IR 50 A (BC) 300 A (BC)	265 % IR 424 % IR 636 % IR 1000 A (BC)



Maximum Continuous Current vs. Operating Temperature

A selection of the Stress Tests during Evaluation Phase

Environmental Tests (of each rated current)

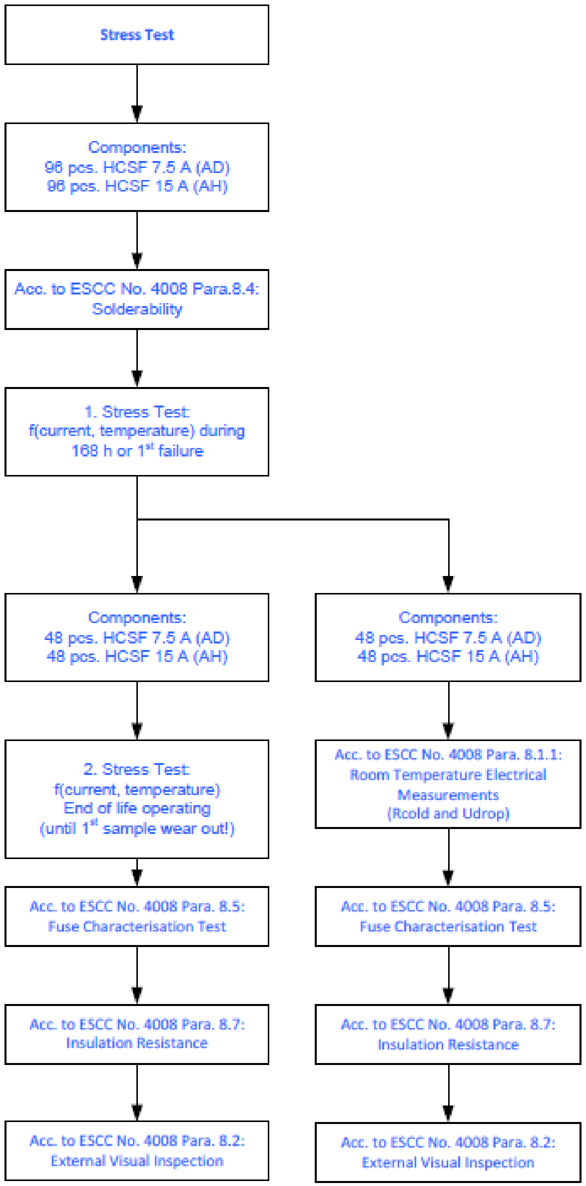
Environmental Test			
Test	**Quantity Tested**	**Quantity Pass**	**Comment**
Para 8.8 Operating Life Test	40	40	ok
Para. 8.9 Rapid Change of Temperature (200 Cycle, according to ESCC 4008/002 Detail Spec.)	10	10	ok
Para. 8.10 Vibration	10	10	ok
Para. 8.11 Shock	10	10	ok

etc…

Extended Life Test – 4168 h Test

Environmental Test					
Stress Test "End of Life"		**Quantity Tested**	**Quantity Pass after 2168 h**	**Quantity Pass after 4168 h**	**Comment**
Operating Life Test 4168 h at 85 °C	110 % IR	48	45	44	
	100 % IR	48	48	46	
	90 % IR	48	48	48	ok
Operating Life Test 4168 h at 125 °C	90 % IR	48	46	45	
	80 % IR	48	48	47	
	70 % IR	48	48	48	ok

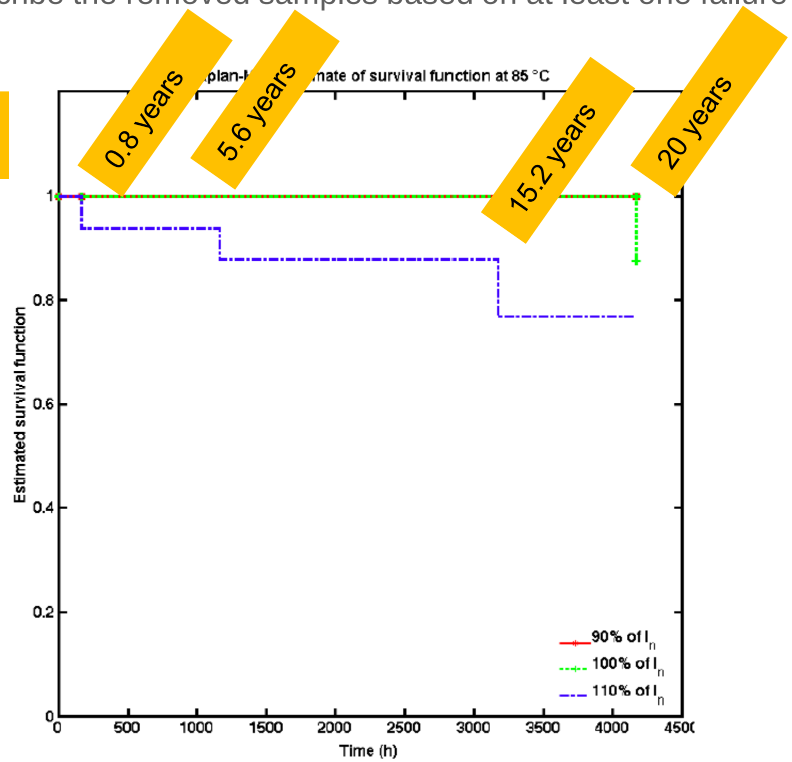
Evaluation Test: Stress Test at 85 °C



I_n	Test Current	168 h	1168 h	2168 h	3168 h	4168 h
7.5 A	110 % of I_n	14/16 (-2)	7/8 (-1)	7/7	7/7	7/7
	100 % of I_n	16/16	8/8	8/8	8/8	7/8 (-1)
	90 % of I_n	16/16	8/8	8/8	8/8	8/8
15 A	110 % of I_n	16/16	8/8	8/8	7/8 (-1)	7/7
	100 % of I_n	16/16	8/8	8/8	8/8	7/8 (-1)
	90 % of I_n	16/16	8/8	8/8	8/8	8/8

The blue coloured figures describe the removed samples based on at least one failure criteria.

Corresponding calculated life time
(Arrhenius life-stress model)



Overview extended Stress Tests

ESCC 4008 Para. 8.15 Thermal Vacuum Test (125 °C, p <= 6.7 E-2 mbar, min. 48 h)

But SCHURTER tested the double of the sample size and at significant lower pressure (< 10 E-5 mbar)

4.1 Electrical measurement: Deviation of the R_{cold} and U_{drop}

	R_{cold} deviation			U_{drop} deviation			Result
	Min	Max	AVG	Min	Max	AVG	
HCSF 7.5 A	0.86 %	1.37 %	1.15 %	-3.22 %	1.79 %	-0.13 %	Pass
HCSF 15 A	0.72 %	1.44 %	1.09 %	-0.34 %	2.17 %	0.56 %	Pass

Table 2: Deviation of the electrical values

All samples passed! No aging effects or indication of this have been observed!

ESCC 4008 Para 8.9, Rapid Change of Temperature

Both, the MGA-S and HCSF, exceed **200 cycles** in contrast to the 25 cycles - defined in the ESCC 4008 Generic Specification.

This test have been totally three times repeated! All samples passed!

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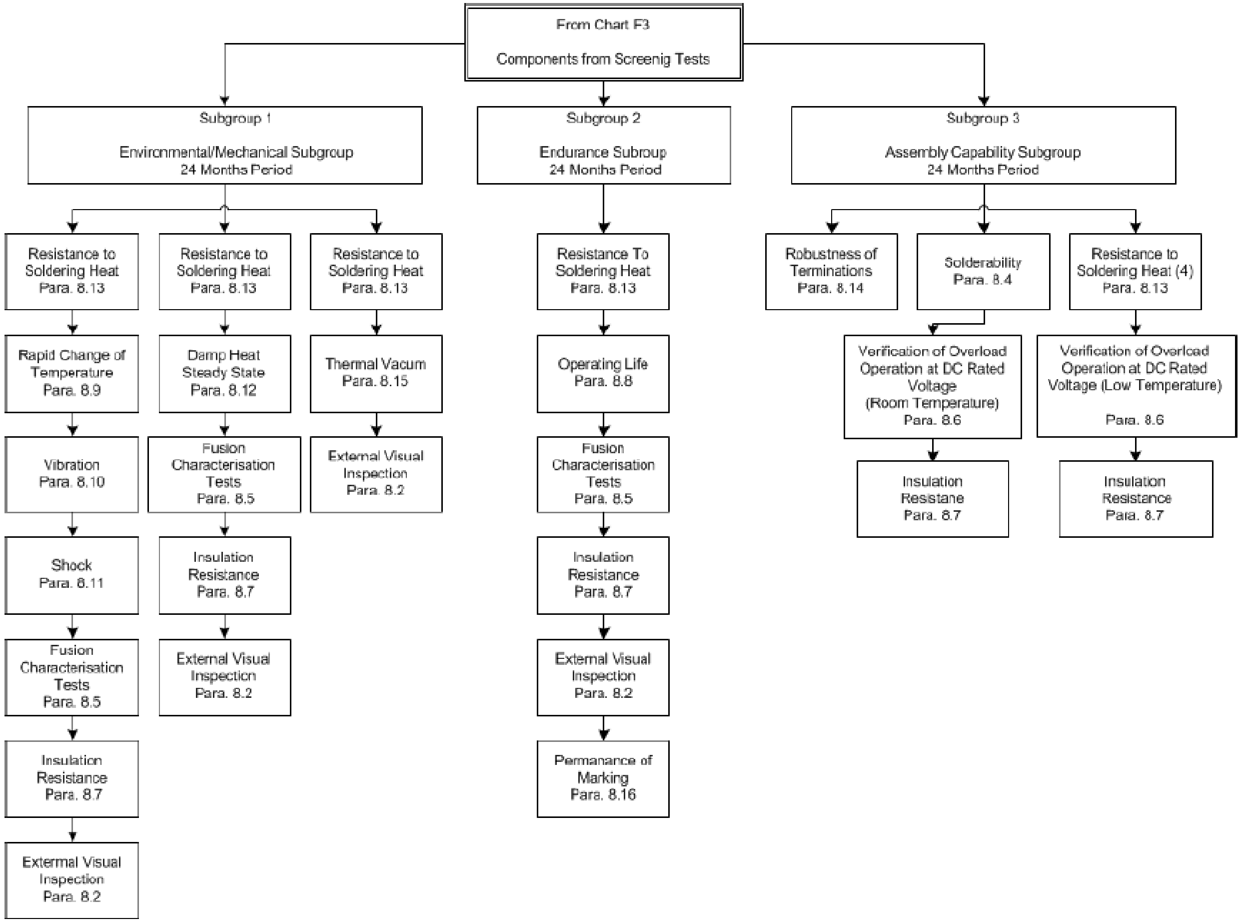
Based on the good results in the Evaluation Tests the Qualification Test procedure was started in 2015.

Overview Results of each fuse rated current type

ESCC 4008 Chart F4

Chart F4

Subgroup	Test	Quantity Tested	Quantity Pass	Comment
1	Para. 8.13 Resistance to Soldering Heat	46	46	ok
	Para. 8.9 Rapid Change of Temperature	20	20	ok
	Para. 8.10 Vibration	20	20	ok
	Para. 8.11 Shock	20	20	ok
	Para. 8.12 Damp Heat Steady State	20	20	ok
	Para. 8.15 Thermal Vacuum	6	6	ok
	Para. 8.5 Fusion Characterisation Tests	40	40	ok
	Para. 8.7 Insulation Resistance	30	30	ok
	Para. 8.2 External Visual Inspection	46	46	ok
2	Para. 8.13 Resistance to Soldering Heat	20	20	ok
	Para. 8.8 Operating Life	20	20	ok
	Para. 8.5 Fusion Characterisation Tests	20	20	ok
	Para. 8.7 Insulation Resistance	15	15	ok
	Para. 8.16 Permanence of Marking	20	20	ok
	Para. 8.2 External Visual Inspection	20	20	ok
3	Para 8.14 Robustness of Termination	5	5	ok
	Para 8.4 Solderability	20	20	ok
	Para. 8.13 Resistance to Soldering Heat	20	20	ok
	Para 8.6 Verification of Overload Operation at DC Rated Voltage (Room Temperature)	20	20	ok
	Para 8.6 Verification of Overload Operation at DC Rated Voltage (Low Temperature)	20	20	ok
	Para. 8.7 Insulation Resistance	40	40	ok



Finally we obtained the initial ESA ESCC Certification in January 2016 ☺

HCSF 7.5 A

Project Review

“Long way to the final destination”

> The qualification test campaign lasted 9 month.
> The evaluation test campaign took 20 month.
> The design and construction phase (Prototype 1 and 2) took more than two years.

Unique fuse:

> The HCSF is the worldwide first space fuse for rated currents up to 15 A holds an ESA ESCC certificate
> The HCSF is the smallest SMD fuse for rated currents up to 15 A and with a breaking capacity of 1000 A at rated voltage.

SCHURTER ELECTRONIC COMPONENTS

Market

Since decades, telecommunication and navigation satellite applications drive the satellite market. In the last few years new requirements and topics like earth observation and global network communication are creating new markets in space application. These trends have an observable impact to the electronic requirements and of course on the circuit protection devices such as fuses.

The consequences on circuit protection requirements are as following:

Trend	**Consequence on circuit protection requirements**
High electrical power	Circuit protection device deal with even higher currents and high voltages – higher rated current and rated voltage, high breaking capacity
High integrated electronic system	SMD, small in size, low power dissipation
New functionalities	Customer specific fuse characteristic, current pulse resistivity
Non-functional requirements	Availability, high reliability, space qualified (ESCC 4008), additional long term data requested
Decreasing development time	Accurate and easy applicable Spice Model of the fuses

Thank you for your attention