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# SC Protector

Self Control Protector

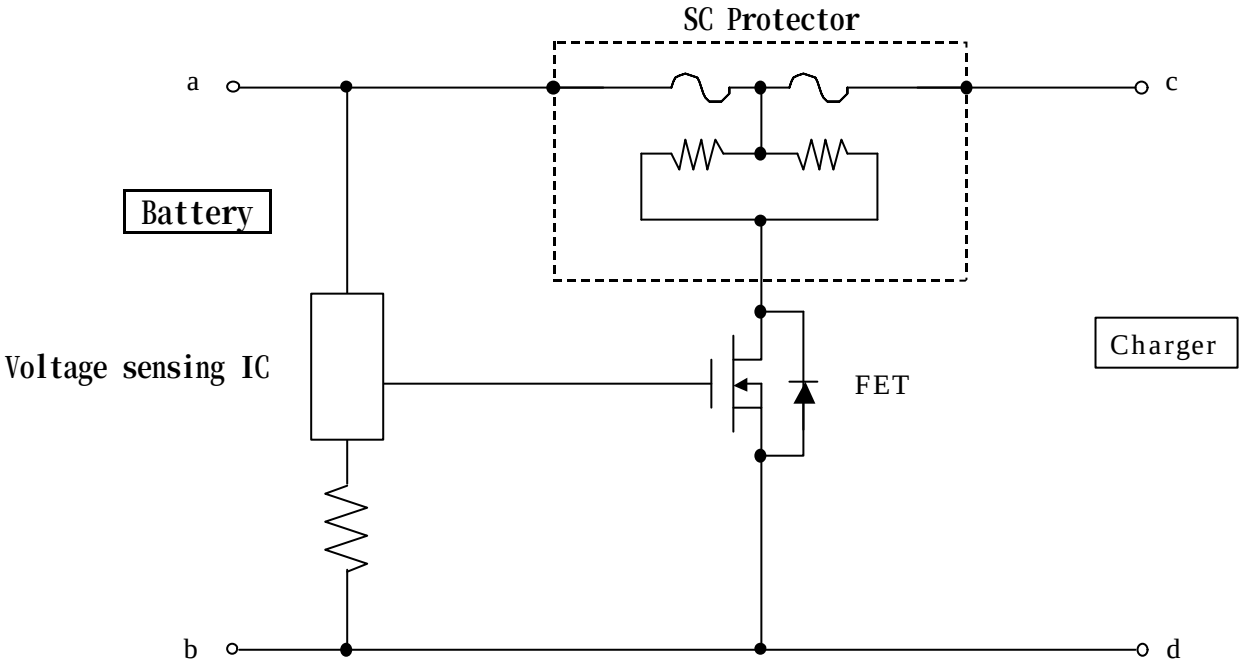
## Innovative way of safety control for Li-ion rechargeable battery

At any moment, SC Protector system monitors the voltage of Li-ion rechargeable battery and its heater fuses the fuse at the same instant when the system detects the overcharge. Usual protection element takes long time to work because it works due to temperature rise of battery cells.

The difference of SC Protector provides you high degree of freedom in the design of protection circuit.

### 1. Application

Typical application of protection for a Lithium ion rechargeable battery from overcharging is shown in the figure below.




When the voltage between a and b exceeds the pre-set limit value, the output of the voltage detector IC becomes high and the FET is switched on. As a result, current flow through the heater of the protector, the fuses melt, and the battery stops to be charged any longer.

Since the two fuses cut-off the voltage supplies from the charger and the battery, the SC Protector stops to be heated immediately and thus, the safety control protection is provided against both excess voltage and excessive heating.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## 2. Characteristics of SC Protector

### 2.1. Necessity

#### 2.1.1. Reliability of the protection circuit

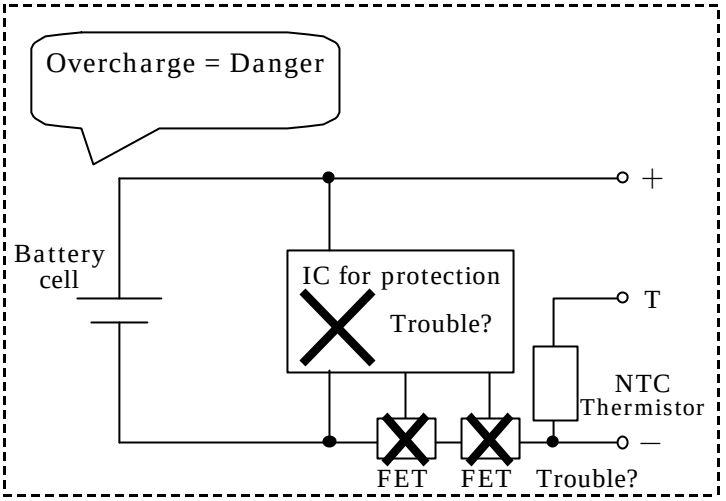
All Li-ion rechargeable battery packs are equipped with at least one protection circuit (ex.IC+FET).

In this case, when an IC or FET breaks, overcharge can't be controlled any more, and the temperature rise of the battery cell can invite very dangerous thermo-runaway leading to smoking or firing.

The trouble of the IC and FET actually occurs.

Therefore, double protection is needed to ensure the safety of Li-ion battery packs.

Basic circuit with troubles




#### 2.1.2. The weak points of conventional double protection elements.

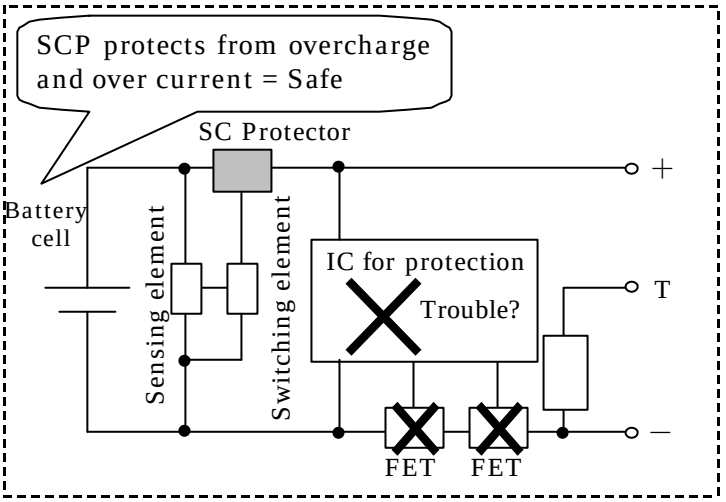
Protection devices such as temperature fuses and bimetals work by conducting the temperature rise in the battery to the inside of it via package or lead wire. Hence, they have a disadvantage that the response speed is slow, and the response speed fluctuates depending on the installation location of the device.

These elements obstruct a cost reduction since it is incompatible with the reflow soldering due to their structures, and must depend on manual soldering.

<u>By using SC Protector, the battery cells won't become dangerous condition even if IC or FET breaks.</u>

### 2.2. Characteristics

Double protection circuit using SC Protector




1) <u>One device can protect against both overcharging and overcurrent.</u>

2) <u>Protection against overcharging is directly performed by the battery cell voltage</u>, ensuring high accuracy and quick response, and the response speed does not fluctuate depending on the location and condition of installation.

3) At the same time of protection against overcharging, since it is constructed to send current to the heater via the fuse element, the fuse element forcibly fused by the heating of the heater and, upon the cutoff of charging circuit, the current to the heater automatically stops, and hence, SC Protector itself never overheated.

4) Abundant product lineup allows the selection of protector with optimal operating voltage and operating current depending on the cell structure of battery pack, ensuring high degree of freedom in the design of protection circuit.

5) It is compatible with <u>automatic mounting using general-purpose chip mounter, and at the same time, compatible with the reflow soldering</u>, contributing to the reduction of parts mounting cost.

SC Protector has the strong points as shown above and it meets the safety requirement without spoiling the strong point of miniature of the Li-ion battery.

## 3. Relations between the fusion state and the operation mode

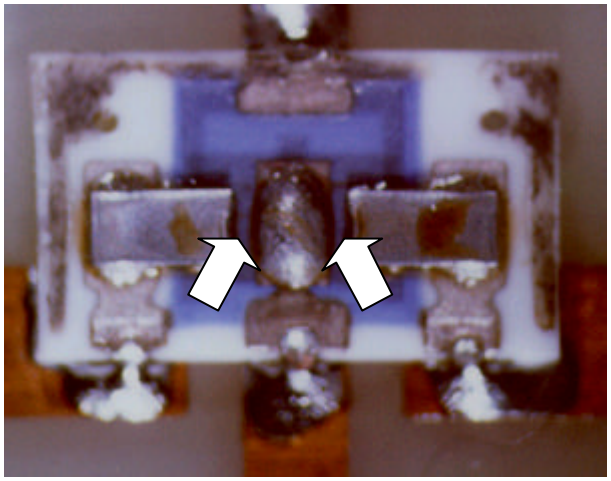
"The operation mode" can be estimated by the fusion state of the fuse element.

### 3.1. Heater operation

In the case of overvoltage, "Both two sides of the middle electrode" are fused by the heater operation. Because the fuses are heated until the charge to the heater is stopped.

Only one side may be cut when the protection circuit is designed so that charging to the heater stops by cutting of one side of the middle electrode.

For the heater operation, it is characterized as "Fuses like flow into the middle electrode."



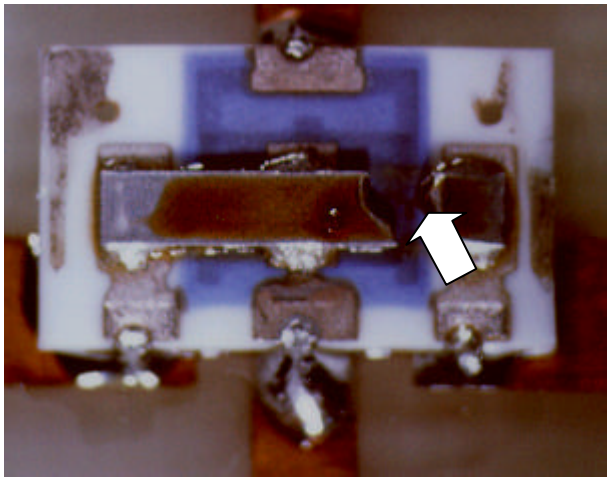
<Features of the heater operation>

- Fuses like flow into the middle electrode
- Both two side (or one side) is fused

### 3.2. Current operation

In the case of overcurrent operation, "only one position of the fuse is cut" because it is the same operation mode as the conventional electric current fuse.

For the current operation, it is characterized as "The cutting position isn't fixed", "It cuts like bursting".



<Features of the current operation>

- One position is cut
- Cutting position isn't fixed
- It cuts like bursting

## 4. Basis of selection

| Price (*1) | Soldering | Nominal Rated current | Current-carrying capacity (*2) | | | Current-rush withstand (*4) | Number of cells in series | | | | Special edition (*6) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 25°C | 40°C | 60°C | | 1cell | 2cells | 3cells | 4cells | 20V or more |
| Standard (Exclude SFD-16x) | Reflow Max 260°C | 5A | 7.0A | 6.0A | 5.0A | 30A-5ms | SFD-045A | | SFD-125A | SFD-145B | SFD-165A |
| | | 7A | 8.0A | 7.0A | 6.5A | 80A-5ms | SFD-047A | | SFD-127A | SFD-147B | SFD-167A |
| | | 8A | 9.0A | 8.5A | 7.0A | 80A-5ms | SFD-048A | | SFD-128B | SFD-148B | - |
| | | 12A (*3) | 13.5A (15.5A) | 12.0A (14.0A) | 10.0A (12.0A) | 80A-5ms or more | - | | SFG-1212A | SFG-1412A | - |
| Low | Reflow Max 245°C | 6A | 7.0A | 6.5A | 5.5A | 36A-5ms | SFE-046A | SFE-086A | SFE-126A | SFE-146A | SFE-246A |
| | | 8A | 9.0A | 8.5A | 7.0A | 50A-5ms 100A-0.5ms (*5) | SFE-048A | SFE-088A | SFE-128A | SFE-148A | - |

Common model of thermal fuse with heater

| | | | |
|---|---|---|---|
| Soldering iron Spot reflow | 10A | 7A at 40°C (Fusing-off by 9A at 40°C) | - |

(*1) It is a relative expression between SFD/SFG and SFE.

(*2) It is the typical value that is calculated from 100℃, the temperature that we confirmed the reliability with our company's standard PCB (0.6t Glass Epoxy single-sided copper-clad laminates). It is influenced by thermal capacity of PCB and so we recommend checking it with your PCB.

25℃, 40℃ and 60℃ are ambient temperature.

The temperature that we confirmed the reliability is not a critical condition. SCP fusing-off temperature is 200℃ or more.

Current-carrying capacity is measured in thermal equilibrium condition. Therefore, if Current-carrying time is short, Current-carrying capacity will increase.

(*3) When the protection module admit 120℃, Current-carrying capacity becomes in ( )

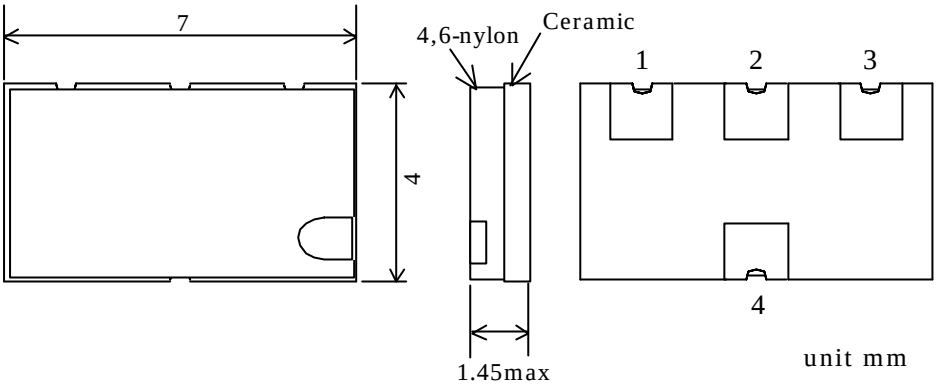
(*4) It is the test condition (5ms-On, 995ms-Off, 5000cycle) that we confirmed the reliability. But it is not necessarily a critical condition for SCP.

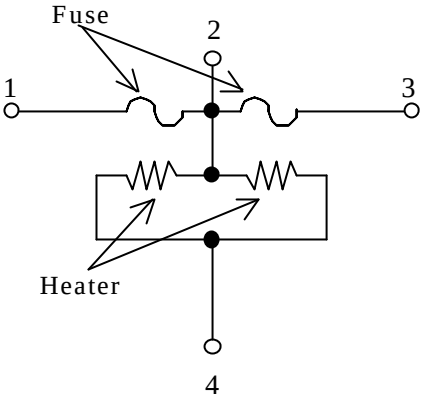
(*5) We recommend using IC that can interrupt current by 0.5ms or less when SFE-xx8A is adopted in the module that has 80A or more rush current.

(*6) SFD-16xA is special edition that has high operating voltage. Therefore, we recommend using SFx-14xx for 4cells in series.

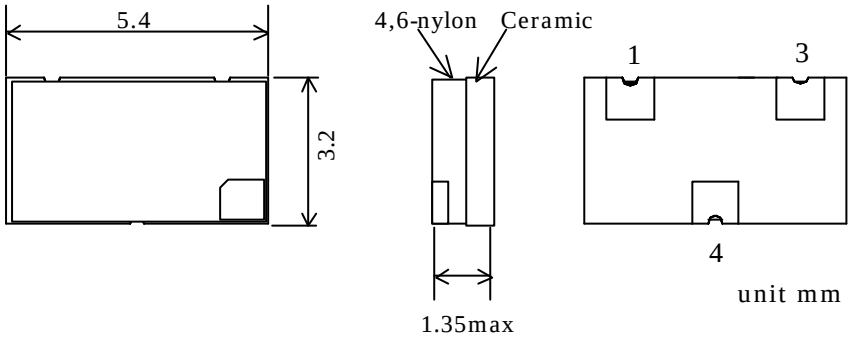
## 5. External view & Equivalent circuit

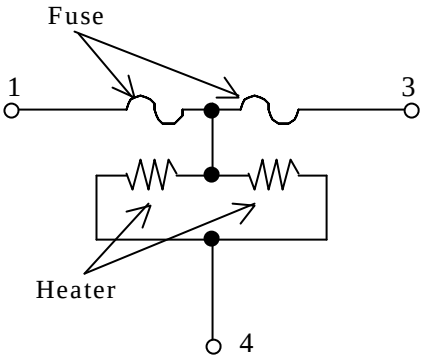
### 5.1. SFC series (Rated current 5A)



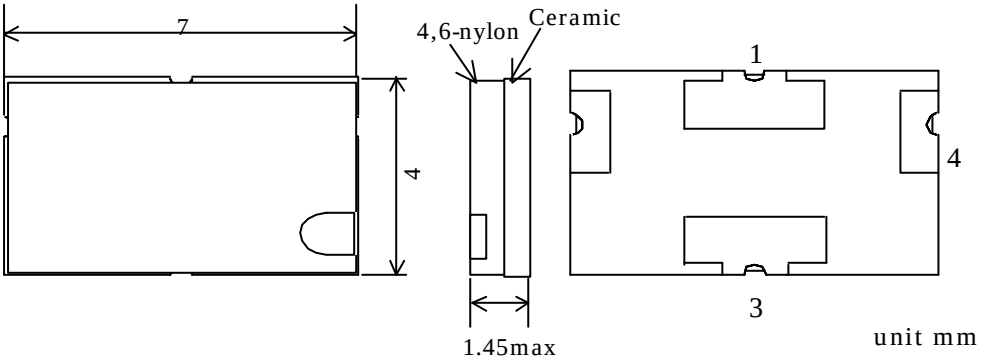



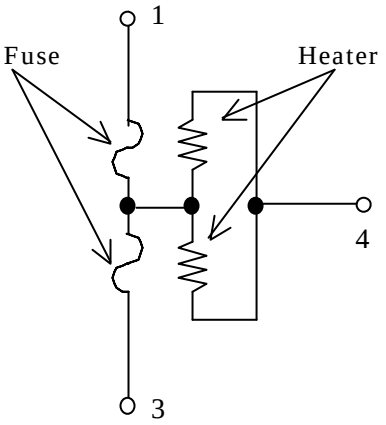

### 5.2. SFD/SFE series (Rated current 5-8A)



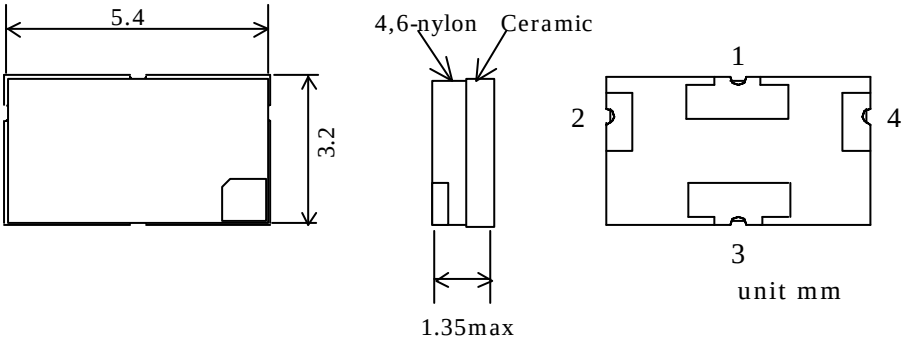



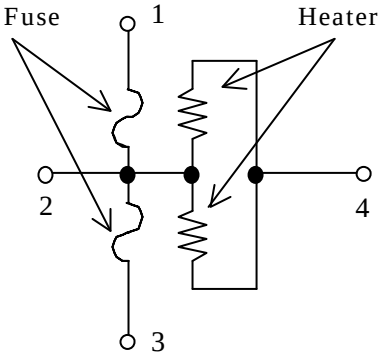

### 5.3. SFG series (Rated current 12A)



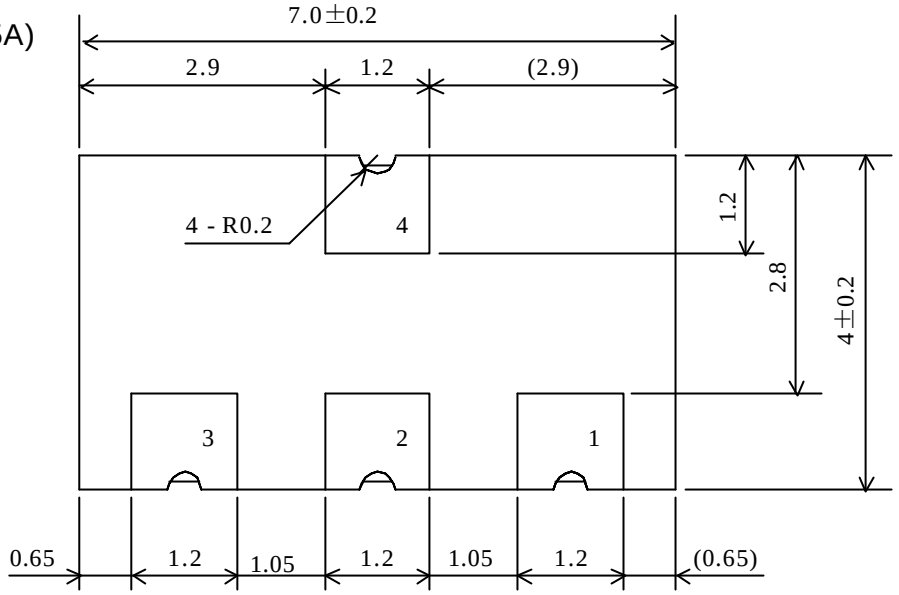

### 5.4. SFH series (Rated current 12A)



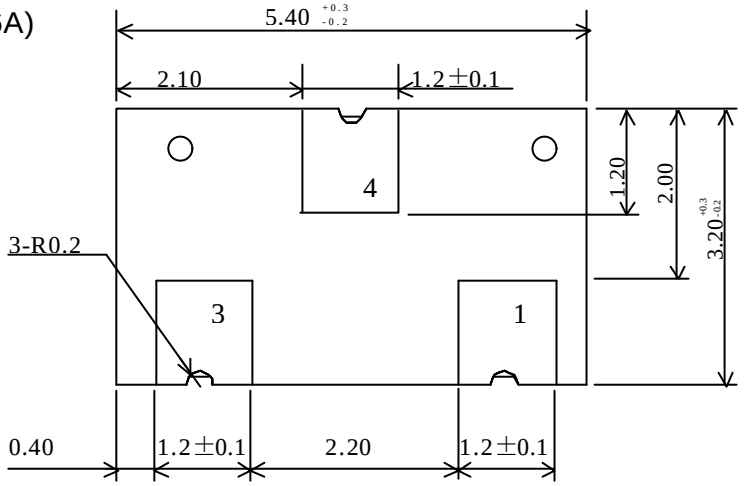



6. Terminal Size (Unit: mm. Not in scale.)

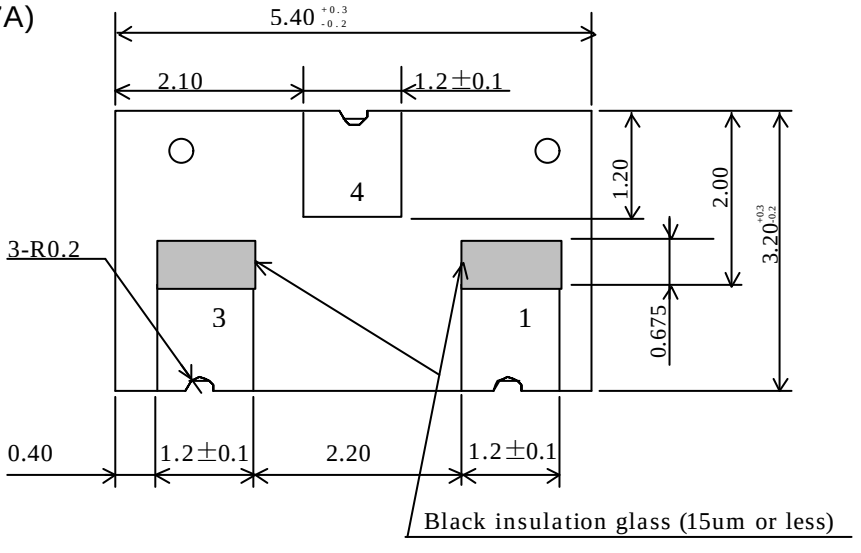
6.1. SFC series (Rated current 5A)



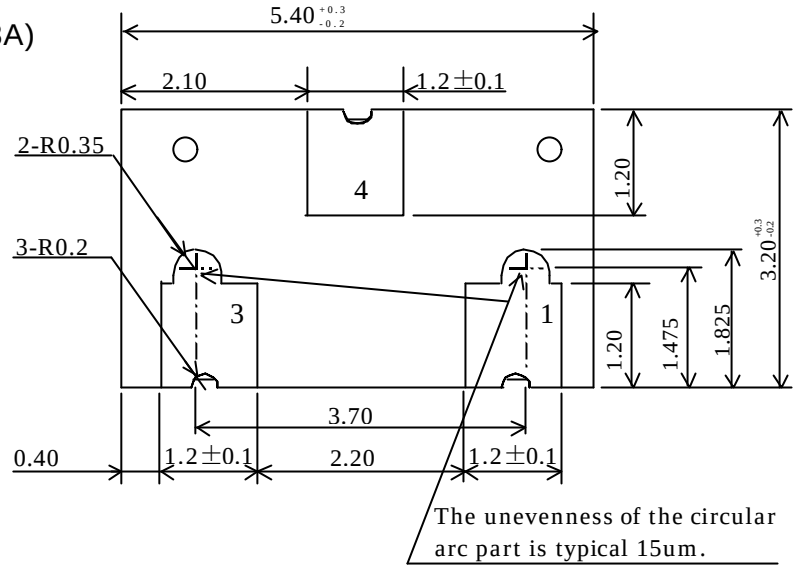

6.2. SFD/SFE series (Rated current 5-6A)



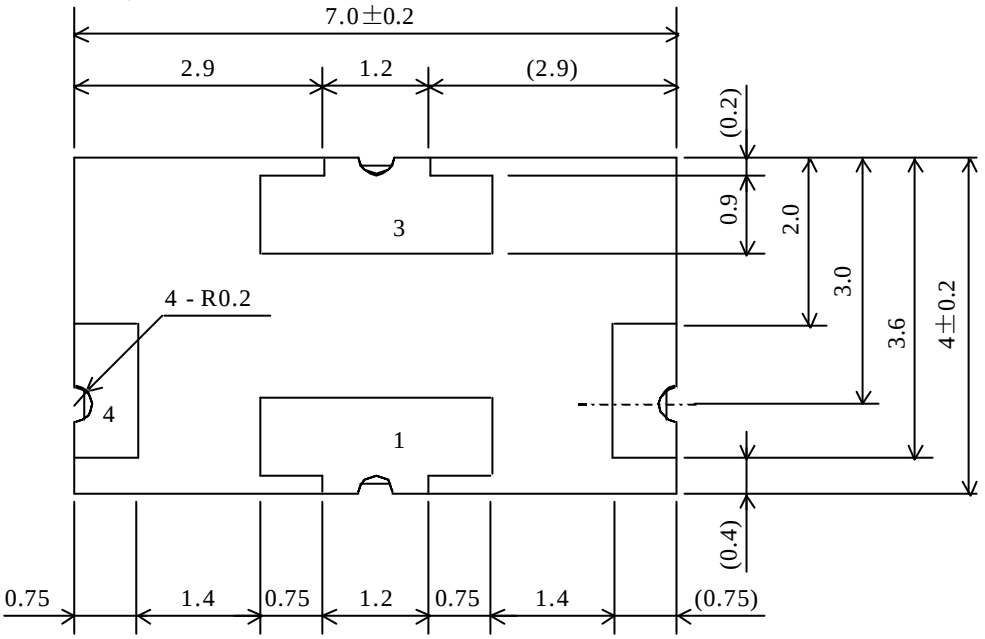

6.3. SFD series (Rated current 7A)



## 6.4. SFD/SFE series (Rated current 8A)




## 6.5. SFG series (Rated current 12A)



## 7. Specification

### 7.1. General

| | SC Protector |
|---|---|
| Qualification | UL248-14 (File No. E167588), TUV (Certificate No. J9650637) |
| Rated voltage(*) | 36VDC |
| Rated breaking capacity | 50A |

(*) is the maximum voltage can be cut off by fuse. It is not the operational voltage of the heater.

### 7.2. SFC series

| | for 1-2 cells in series | for 3 cells in series | for 4 cells in series |
|---|---|---|---|
| | SFC-0405B | SFC-1205A | SFC-1605A |
| Rated current | 5A | | |
| Size | 7.0×4.0×1.45 | | |
| Electrode | Ag-Pd | | |
| Fuse resistance 1-3 (Typical) | 15±3mΩ | | |
| Operating electric power | 3.5～22W | | |
| Operating voltage | 4.0～9.0V | 7.8～17.9V | 8.5～19.3V |
| Heater resistance | 4.1±0.4Ω | 16.0±1.5Ω | 18.9±1.9Ω |
| Marking | SC 5A SF 0405B | SC 5A SF 1205A | SC 5A SF 1605A |
| Reflowing temperature (MAX) | 260℃ | | |

### 7.3. SFD series

| SFD-04X for 1-2 cells in series | SFD-045A | SFD-047A | SFD-048A |
|---|---|---|---|
| Rated current | 5A | 7A | 8A |
| Size | 5.4×3.2×1.35 | | |
| Electrode | Au plated Ag-Pt | | |
| Fuse resistance (Typical) | 12±2mΩ | 6.5±1.5mΩ | 5.5±1.0mΩ |
| Operating electric power | 3.5～22W | | 4.0～22W |
| Operating voltage | 4.0～9.0V | | 4.3～9.0V |
| Heater resistance | 4.1±0.4Ω | | |
| Marking | 5A SF SC 10 | 7A SF SC 10 | 8A SF SC 10 |
| Reflowing temperature (MAX) | 260℃ | | |

| SFD-12X for 3 cells in series | SFD-125A | SFD-127A | SFD-128B |
|---|---|---|---|
| Rated current | 5A | 7A | 8A |
| Size | 5.4×3.2×1.35 | | |
| Electrode | Au plated Ag-Pt | | |
| Fuse resistance (Typical) | 12±2mΩ | 6.5±1.5mΩ | 5.5±1.0mΩ |
| Operating electric power | 3.5～22W | | 4.0～22W |
| Operating voltage | 7.5～17.0V | | 6.5～13.6V |
| Heater resistance | 14.6±1.5Ω | | 9.4±0.9Ω |
| Marking | 5A SF SC 30 | 7A SF SC 30 | 8A SF SC 31 |
| Reflowing temperature (MAX) | 260℃ | | |

| SFD-14X for 4 cells in series | SFD-145B | SFD-147B | SFD-148B |
|---|---|---|---|
| Rated current | 5A | 7A | 8A |
| Size | 5.4×3.2×1.35 | | |
| Electrode | Au plated Ag-Pt | | |
| Fuse resistance (Typical) | 12±2mΩ | 6.5±1.5mΩ | 5.5±1.0mΩ |
| Operating electric power | 3.5～22W | | 4.0～22W |
| Operating voltage | 9.7～19.6V | | 10.3～19.6V |
| Heater resistance | 22.0±4.4Ω | | |
| Marking | 5A SF<br>SC 51 | 7A SF<br>SC 51 | 8A SF<br>SC 51 |
| Reflowing temperature (MAX) | 260℃ | | |

| SFD-16X for High Voltage | SFD-165A | SFD-167A |
|---|---|---|
| Rated current | 5A | 7A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Au plated Ag-Pt | |
| Fuse resistance (Typical) | 12±2mΩ | 6.5±1.5mΩ |
| Operating electric power | 3.5～22W | |
| Operating voltage | 11.1～25.0V | |
| Heater resistance | 31.6±3.2Ω | |
| Marking | 5A SF<br>SC 40 | 7A SF<br>SC 40 |
| Reflowing temperature (MAX) | 260℃ | |

## 7.4. SFE series

| SFE-04X for 1 cell in series | SFE-046A | SFE-048A |
|---|---|---|
| Rated current | 6A | 8A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Ag-Pt | |
| Fuse resistance (Typical) | 9±2mΩ | 5±1.5mΩ |
| Operating electric power | 3.5～22W | 3.5～20W |
| Operating voltage | 4.0～8.2V | 4.0～7.0V |
| Heater resistance | 3.8±0.7Ω | 3.5±1.0Ω |
| Marking | 6A SF<br>SC 1B | 8A SF<br>SC 1B |
| Reflowing temperature (MAX) | 245℃ | |

| SFE-08X for 2 cells in series | SFE-086A | SFE-088A |
|---|---|---|
| Rated current | 6A | 8A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Ag-Pt | |
| Fuse resistance (Typical) | 9±2mΩ | 5±1.5mΩ |
| Operating electric power | 3.5～22W | 3.5～20W |
| Operating voltage | 5.6～10.2V | 5.6～9.8V |
| Heater resistance | 6.9±2.1Ω | |
| Marking | 6A SF<br>SC 2B | 8A SF<br>SC 2B |
| Reflowing temperature (MAX) | 245℃ | |

| SFE-12X for 3 cells in series | SFE-126A | SFE-128A |
|---|---|---|
| Rated current | 6A | 8A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Ag-Pt | |
| Fuse resistance (Typical) | 9±2mΩ | 5±1.5mΩ |
| Operating electric power | 3.5～22W | 3.5～20W |
| Operating voltage | 7.8～16.0V | 8.0～14.1V |
| Heater resistance | 14.6±2.9Ω | 14.2±4.2Ω |
| Marking | 6A SF<br>SC 3B | 8A SF<br>SC 3B |
| Reflowing temperature (MAX) | 245℃ | |

| SFE-14X for 4 cells in series | SFE-146A | SFE-148A |
|---|---|---|
| Rated current | 6A | 8A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Ag-Pt | |
| Fuse resistance (Typical) | 9±2mΩ | 5±1.5mΩ |
| Operating electric power | 3.5～22W | 3.5～20W |
| Operating voltage | 9.7～19.6V | 11.2～19.6V |
| Heater resistance | 22.0±4.4Ω | 27.6±8.3Ω |
| Marking | 6A SF<br>SC 5B | 8A SF<br>SC 5B |
| Reflowing temperature (MAX) | 245℃ | |

| SFE-24X for 5-6 cells in series | SFE-246A | SFE-248A(*) |
|---|---|---|
| Rated current | 6A | 8A |
| Size | 5.4×3.2×1.35 | |
| Electrode | Ag-Pt | |
| Fuse resistance (Typical) | 9±2mΩ | 5±1.5mΩ |
| Operating electric power | 3.5～22W | 3.5～18W |
| Operating voltage | 14.1～26.1V | 15.8～26.3V |
| Heater resistance | 44.0±13.0Ω | 55.0±16.5Ω |
| Marking | 6A SF<br>SC 6B | 8A SF<br>SC 6B |
| Reflowing temperature (MAX) | 245℃ | |

(*) under development

7.5. SFG series

| | for 1 cell in series | for 3 cells in series | for 4 cells in series |
|---|---|---|---|
| | SFG-0412A(*) | SFG-1212A | SFG-1412A |
| Rated current | 12A | | |
| Size | 7.0×4.0×1.45 | | |
| Electrode | Ag-Pt | | |
| Fuse resistance (Typical) | 3±1mΩ | | |
| Operating electric power | 6～35W | | |
| Operating voltage | 4.0～7.0V | 7.8～13.8V | 10.5～18.5V |
| Heater resistance | 2.0±0.6Ω | 7.8±2.3Ω | 14.0±4.2Ω |
| Marking | 12A G1<br>SC SF | 12A G3<br>SC SF | 12A G4<br>SC SF |
| Reflowing temperature (MAX) | 260℃ | | |

(*) under development

7.6. SFH series

| | for 1 cell in series | for 3 cells in series | for 4 cells in series |
|---|---|---|---|
| | SFH-0412A(*) | SFH-1212A(*) | SFH-1412A(*) |
| Rated current | 12A | | |
| Size | 5.4×3.2×1.35 | | |
| Electrode | Ag-Pt | | |
| Fuse resistance (Typical) | 3±1mΩ | | |
| Operating electric power | 5～30W | | |
| Operating voltage | 4.0～7.1V | 7.7～13.8V | 10.4～18.5V |
| Heater resistance | 2.4±0.7Ω | 9.1±2.7Ω | 16.4±4.9Ω |
| Marking | 12A H1<br>SC SF | 12A H3<br>SC SF | 12A H4<br>SC SF |
| Reflowing temperature (MAX) | 260℃ | | |

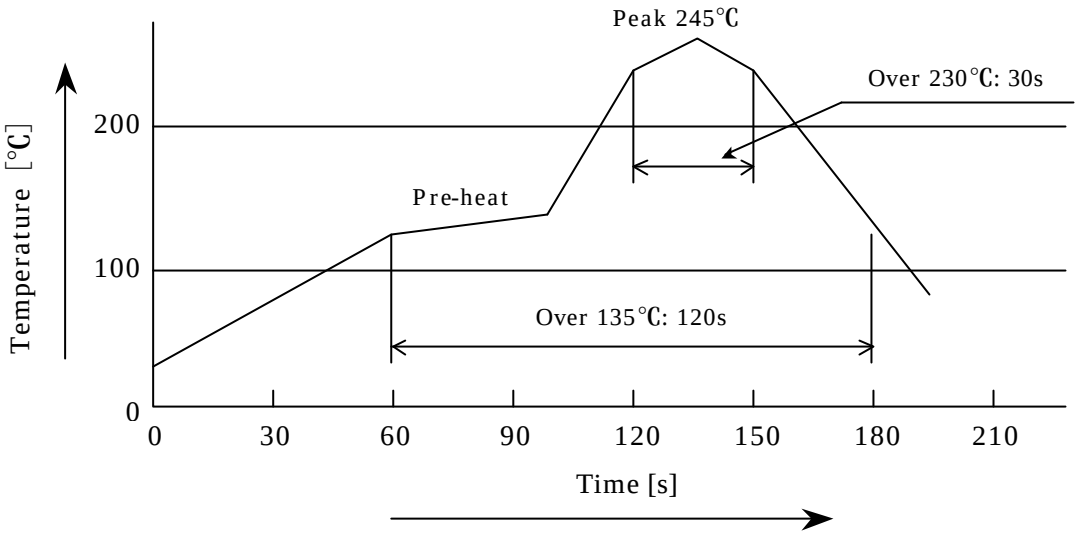
(*) under development

## 8. Temperature profile of reflow soldering

The temperature shown below is the temperature of the electrode portion of SC Protector.

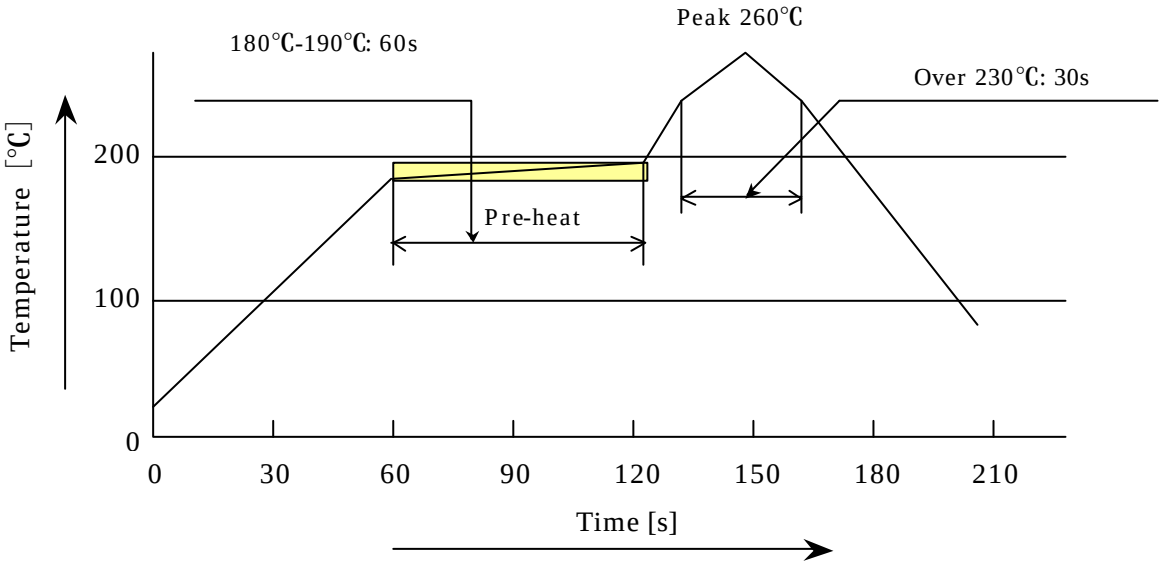
### 8.1. Temperature profile of 245℃ peak

Applicable to: SFC, SFD, SFE, SFG, SFH Type




### 8.2. Temperature profile of 260℃ peak

Applicable to: SFC, SFD, SFE, SFG, SFH Type (Not applicable to SFE Type)



## 9. Voltage operation

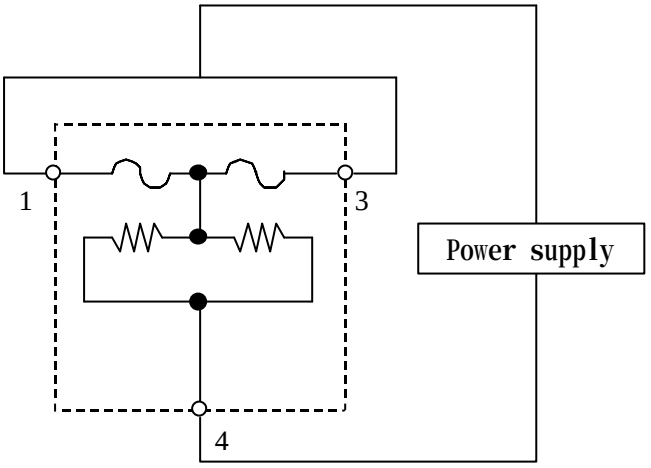
### 9.1. Operating electric power and Operating voltage

1) Operating electric power range: Electricity Power applied to heater

2) Operating voltage range: Values are calculated from operating electric power range and heater resistance. Protector operation is normal under voltage applied to heaters in these ranges. Operating voltage range is adjustable by regulating heater resistance.

(Operating voltage[V]= $\sqrt{\text{Operating electric power [W]} \times \text{Heater resistance}[\Omega]}$ )

### 9.2. Voltage operation test method

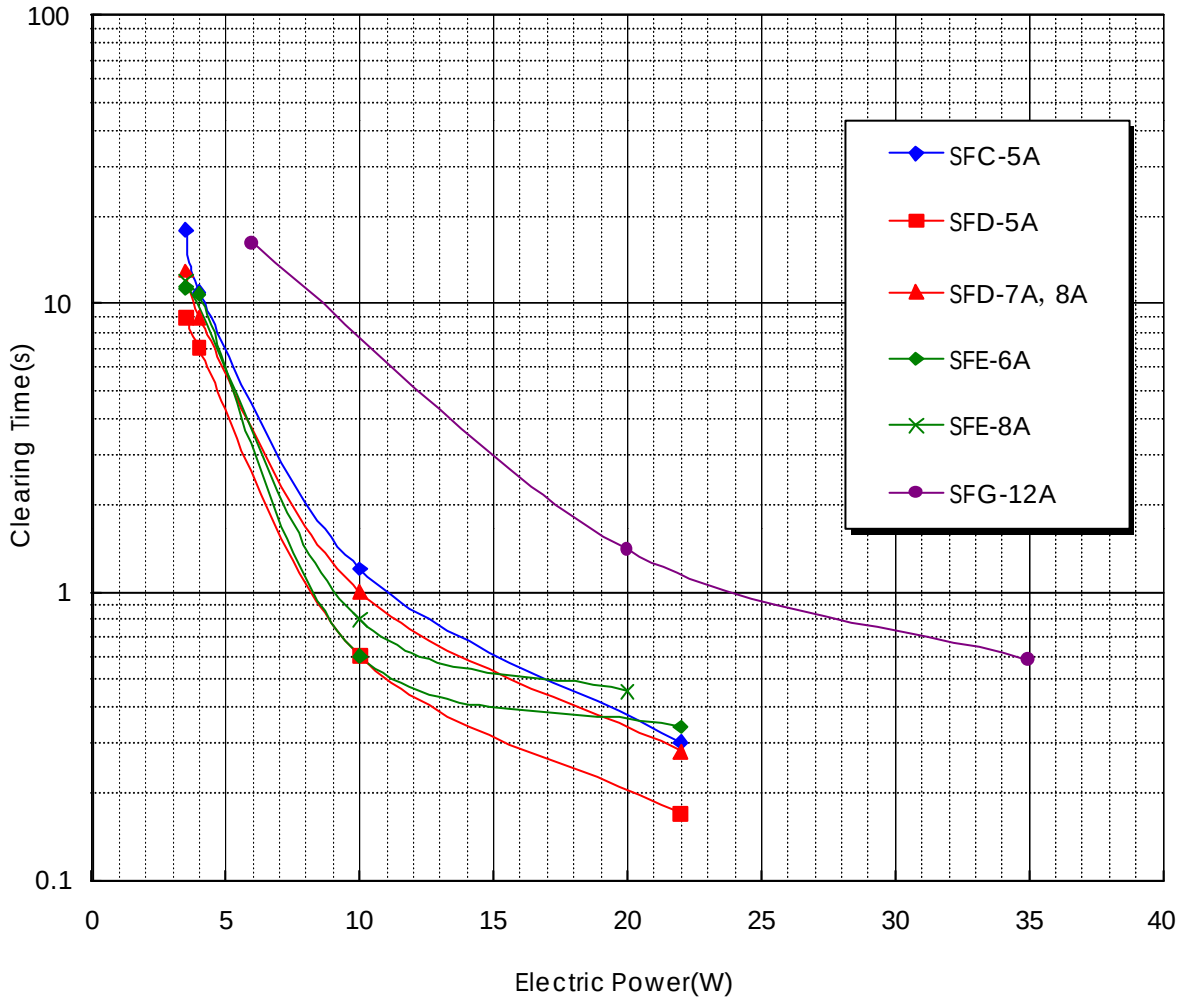



1) Connect SC Protector with a constant power supply.

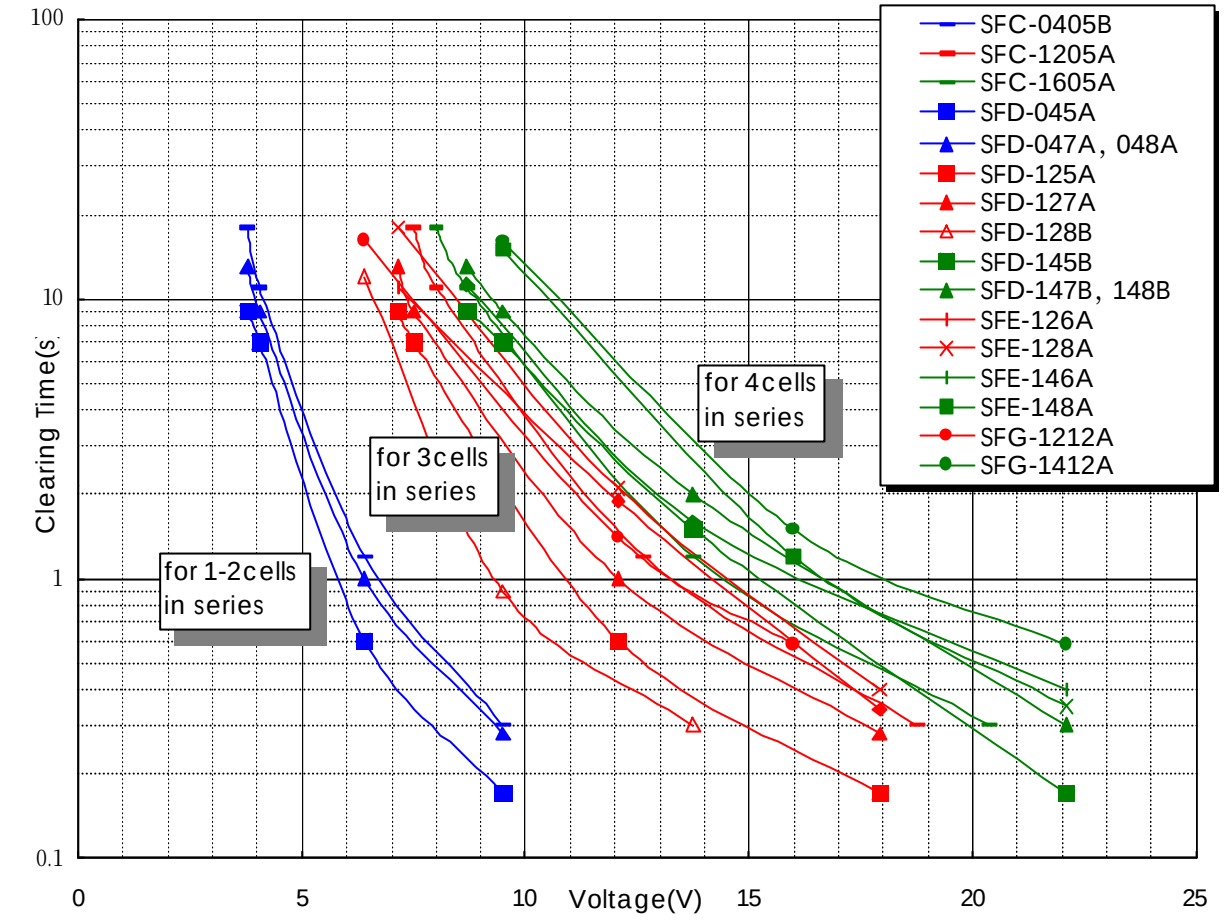
2) Apply a current to the heater.

3) Measure the time the fuses take to melt.

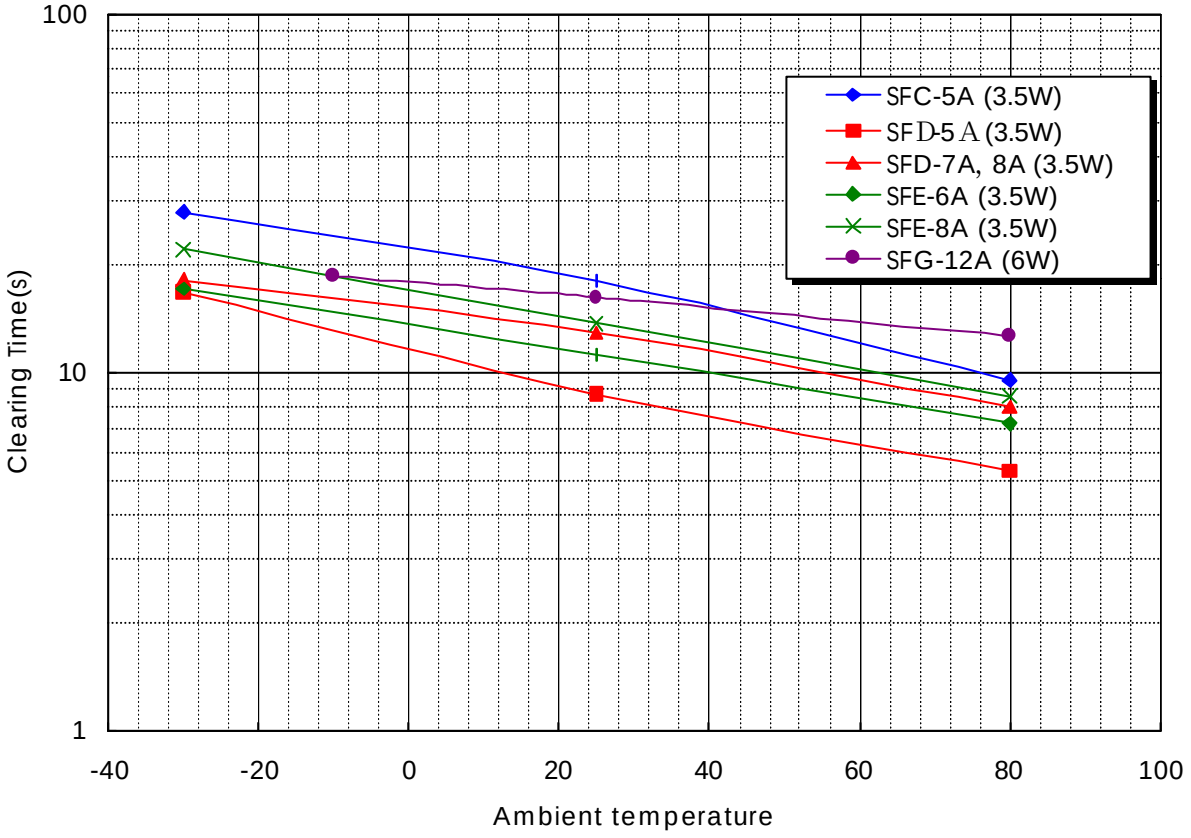
### 9.3. Operation time by the heater (Electricity vs. clearing time at 25℃)



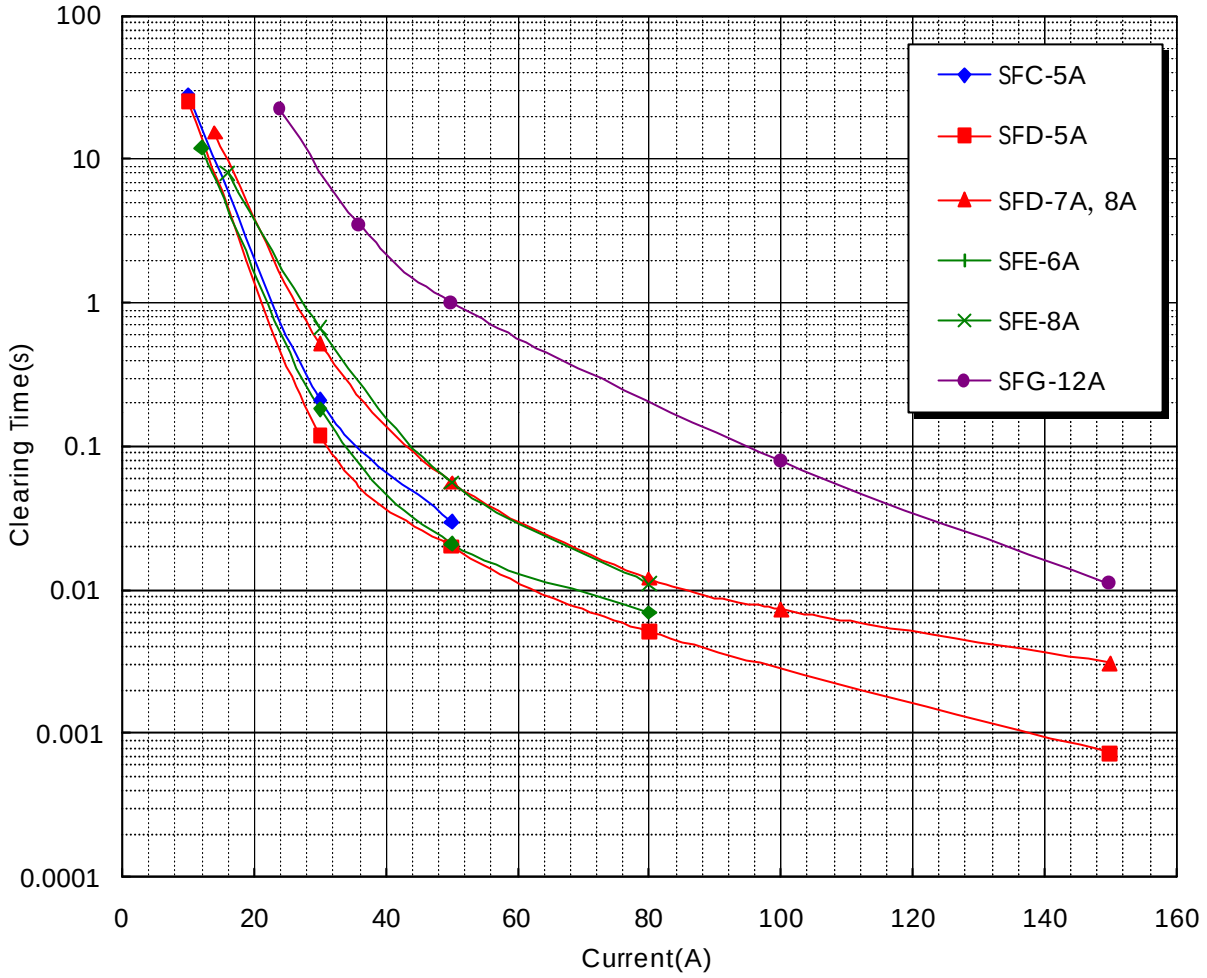
9.4. Operation time by the heater (Voltage vs. clearing time at 25℃)



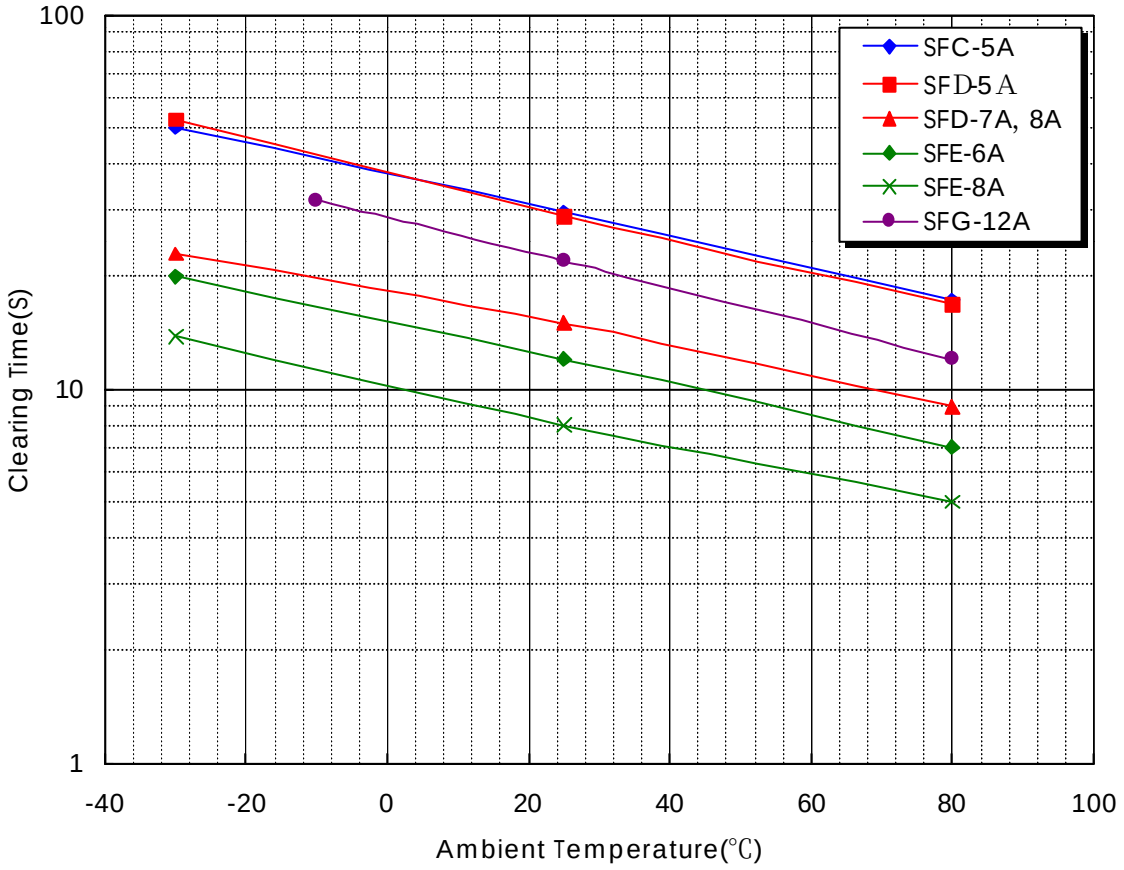

9.5. Operation time by the heater (Ambient temperature vs. clearing time)



10. Current interrupting time (at25℃)




10.1. Current interrupting time (Ambient temperature vs. Clearing time by Rated Current * 2)



### 11.1. Catalog data is the typical value.

1) Catalog data is not a guaranteed value.
2) Catalog data is measured with our company's standard PCB (0.6t Glass Epoxy single-sided copper-clad laminates). The characteristics are influenced by thermal capacity of PCB. Generally, when thermal capacity of PCB increases, Current-carrying capacity will increase and Clearing-time will be long.

### 11.2. Please select the product on the basis of [Current-carrying capacity].

1) Nominal rated current is provided on the basis of UL standard (The maximum temperature rise on body or contact that is passed the current shall not exceed 70°C) and so it is not Current-carrying capacity. Therefore, please select a product on the basis of Current-carrying capacity instead of Nominal rated current.
2) Current-carrying capacity is influenced by thermal capacity of PCB. Therefore we recommend checking it on your PCB.
3) We accept the test (Current-carrying capacity and Clearing-characteristics and so on) with your PCB. Please request to us unreservedly.

### 11.3. Current-carrying capacity

1) Current-carrying capacity is the current-carrying value that SCP reaches temperature that we confirmed the reliability in our company.
2) The temperature that we confirmed the reliability is 100℃ (120℃ in SFG series). But it is not a critical condition for SCP. For example, if SCP temperature exceeds it, SCP is not immediately fusing-off like a common thermal fuse. SCP fusing-off temperature is 200℃ or more and so it has much more capability for the temperature rise.
3) Current-carrying capacity is measured in thermal equilibrium condition so that if Current-carrying time is short, Current-carrying capacity will increase.

### 11.4. Precautions regarding handling

1) Make sure that the terminals of this product are connected on the lands of the circuit board, and that the resistance between terminal1-4 and 3-4 are rated heater resistance.
2) Ultrasonic cleansing or immersion cleansing must not be done for SCP. When cleansing is done, flux in element flows, and the specification will not be satisfied. These products after cleansing will be not guaranteed.

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