

# AS Series

## INRUSH CURRENT LIMITERS

### Thermistor Protection for Precharge Circuit on Lithium Ion Batteries

When a battery is connected to a load with capacitive input, there is an Inrush current surge as the capacitance is being charged to the battery voltage. The Input current depends on the input capacitance; the larger the batteries and the more powerful the load, the larger the input capacitance. A large Inrush current (in the precharge circuit, without protection) can cause the following:

- Damage to input filter capacitors
- Blowing of the main fuse if asked to carry the inrush current without protection
- Contact failure (as well as reduction in current carrying capacity) due to arcing and pitting that results from high inrush current
- Damage to the battery cell, which is not rated for inrush current

A typical precharge circuitry for battery operation is below with the timing diagram, showing how the circuit operates. (Courtesy of Lithium -ION BMS)



In its most basic form, the Precharge circuit operates as follows:

- **OFF:** When the system is OFF all relays / contactors are off.
- **Precharge:** When the system is first turned on, K1 and K3 are turned on to Precharge the load, until the Inrush current has subsided. R1 shows the location of Thermistor in the Precharge circuit.
- **ON:** After Precharge, contactor K2 is turned on (relay K1, must be off to save coil power)

For this application note, let us limit our discussion to the selection of the Thermistor

### SELECTION OF THE THERMISTOR

The minimum resistance of the thermistor is determined by the following:

1. Ambient temperature
2. Input capacitance value (of the precharge circuit)
3. Battery voltage

The precharge surge current reaches 63.2% (1/e) of its initial value after a time  $\tau = RC$ .

In the selection of the thermistor, we consider a time value of "five time-constant" when the capacitances are fully charged and the surge current reaches the normal operating current.

For the purpose of our design, let us assume the following quantitative values:

Precharge time: 20 millisecond

Ambient operating temperature: Varies between 10°C to 50°C.

Battery voltage: 100 volt

Capacitor bank : 50,000  $\mu$ F

$5\tau = RC$

$R = 5\tau / C = 5 (0.02 \text{ sec}) / 0.05F = 2.0 \Omega$ .

Now, look at the at R-T curves for Ametherm thermistor at ambient of 50°C. The material "C" exhibits

$R @ 50^\circ\text{C} / R @ 25^\circ\text{C} = 0.412 @ R @ 10^\circ\text{C} / R @ 25^\circ\text{C} = 1.70$

Therefore, minimum resistance @ 25°C =  $2.0 / 0.454 = 4.40\Omega$ , so our standard part has 5.0 ohm nominal resistance

At 10°C, the standard part will have a resistance of  $5.0 \Omega \times 1.70 = 8.50 \Omega$ , which will meet our minimum resistance.

Determine the energy the thermistor needs to handle with out self-destruction,

$E = \frac{1}{2} C V^2 = \frac{1}{2} (0.05) (100)^2 = 250 \text{ Joules}$ .

The steady state current is not calculated because in most precharge circuits the steady state current goes through the contactor.

The part, which would meet your specification, is AS32 5R020.

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### Key Benefits of Ametherm AS Inrush Current Limiters

- Lower current density (as compared to traditional types of inrush current limiters)
- Faster reset time
- No hot spots from fatigue, because of lower current density and uniform temperature gradient throughout the disc
- Wider temperature range of operation with out de-rating

### ELECTRICAL SPECIFICATIONS

| Part Number | R@25°C (Ω) | MAX I (A) | HOT R (Ω) | MAX ENERGY (JOULES) | Max Cap @680VAC | Cooldown time (sec) | R - T curve | DC mW/°C | Body Temp @ Max SSI (°C) |
|-------------|------------|-----------|-----------|---------------------|-----------------|---------------------|-------------|----------|--------------------------|
| *AS32 0R530 | 0.50       | 30        | 0.011     | 300                 | 650             | 120                 | A           | 78.20    | 199                      |
| *AS32 0R536 | 0.50       | 36        | 0.009     | 300                 | 650             | 120                 | A           | 78.20    | 199                      |
| *AS32 1R030 | 1.0        | 30        | 0.013     | 300                 | 650             | 120                 | B           | 79.40    | 215                      |
| *AS32 1R036 | 1.0        | 36        | 0.010     | 300                 | 650             | 120                 | B           | 79.40    | 215                      |
| AS32 2R025  | 2.0        | 25        | 0.020     | 300                 | 650             | 120                 | C           | 78.20    | 220                      |
| AS32 5R020  | 5.0        | 20        | 0.027     | 300                 | 650             | 120                 | G           | 78.20    | 255                      |
| AS32 10015  | 10.0       | 15        | 0.052     | 250                 | 500             | 120                 | H           | 85.20    | 185                      |
| AS32 20010  | 20.0       | 10        | 0.095     | 250                 | 500             | 120                 | I           | 58.00    | 192                      |
| AS32 50006  | 50.0       | 6         | 0.380     | 250                 | 540             | 120                 | M           | 78.20    | 212                      |
| AS35 0R550  | 0.50       | 50        | 0.0074    | 800                 | 1730            | 200                 | A           | 129.44   | 210                      |
| AS35 1R040  | 1.0        | 40        | 0.0113    | 800                 | 1730            | 200                 | B           | 127.00   | 212                      |
| AS35 2R035  | 2.0        | 35        | 0.0147    | 700                 | 1500            | 200                 | C           | 119.20   | 210                      |
| AS35 3R030  | 3.0        | 30        | 0.0135    | 600                 | 1300            | 200                 | C           | 116.40   | 215                      |
| AS35 5R025  | 5.0        | 25        | 0.0288    | 600                 | 1300            | 200                 | G           | 112.2    | 208                      |
| AS35 10018  | 10.0       | 18        | 0.0556    | 500                 | 1080            | 200                 | I           | 122.80   | 220                      |
| AS35 20010  | 20.0       | 10        | 0.1760    | 500                 | 1080            | 200                 | M           | 101.10   | 177                      |

### MECHANICAL SPECIFICATIONS

| Part Number | D (mm) | T (mm) | S (mm) | L (mm) | A (mm) | B (mm) | C (mm) | X (mm) | Y (mm) |
|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| *AS32 0R530 | 30.0   | 7.8    | 17.1   | 22.0   | 2.2    | 4.8    | 0.8    | 17.1   | 4.8    |
| *AS32 0R536 | 30.0   | 7.8    | 17.1   | 22.0   | 2.2    | 4.8    | 0.8    | 17.1   | 4.8    |
| *AS32 1R030 | 30.0   | 7.8    | 17.1   | 22.0   | 2.2    | 4.8    | 0.8    | 17.1   | 4.8    |
| *AS32 1R036 | 30.0   | 7.8    | 17.1   | 22.0   | 2.2    | 4.8    | 0.8    | 17.1   | 4.8    |
| AS32 2R025  | 30.0   | 7.8    | 17.1   | 22.0   | 2.2    | 4.8    | 0.8    | 17.1   | 4.8    |
| AS32 5R020  | 30.0   | 8.2    | 17.1   | 22.0   | 2.2    | 5.4    | 0.8    | 17.1   | 5.4    |
| AS32 10015  | 30.0   | 9.0    | 17.1   | 22.0   | 2.2    | 6.8    | 0.8    | 17.1   | 6.8    |
| AS32 20010  | 30.0   | 8.5    | 17.1   | 22.0   | 2.2    | 6.4    | 0.8    | 17.1   | 6.4    |
| AS32 50006  | 30.0   | 8.2    | 17.1   | 22.0   | 2.2    | 5.4    | 0.8    | 17.1   | 5.4    |
| AS35 0R550  | 36.0   | 6.4    | 19.0   | 22.0   | 2.2    | 3.4    | 0.8    | 19.0   | 3.4    |
| AS35 1R040  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |
| AS35 2R035  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |
| AS35 3R030  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |
| AS35 5R025  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |
| AS35 10018  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |
| AS35 20010  | 36.0   | 8.5    | 19.0   | 22.0   | 2.2    | 5.5    | 0.8    | 19.0   | 5.5    |

\*(UL Approved)



PAD LAYOUT



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