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Load Overcurrent & Short Circuit Protection in the SunSaver™ Gen 3 Controller

ABSTRACT: The new Morningstar Generation 3 SunSaver Controller improves upon the previous Generation 2 model by introducing new operational features and circuit protections. The purpose this whitepaper is to discuss the new SunSaver's Load Overcurrent & Load Short Circuit Protections. (For a complete list of the SunSaver's new features & protections, please refer to the following document available on the Morningstar Technical Support Website: www.morningstarcorp.com/en/support > "SunSaver Gen 3 Overview 8.12.pdf")

The SunSaver Gen 3 (referred to as 'Gen 3') includes new Load Overcurrent and Load Short Circuit Protections, previously not available in the SunSaver Gen 2 Controller (referred to as 'Gen 2'). These protections have proven to increase the reliability and robustness of the SunSaver load circuitry, particularly when the controller is used with large or highly capacitive loads. Customers may find that some loads, which previously ran on the Gen 2 controllers, are not suitable for use with the Gen 3 controllers. It is important to understand the purpose and characteristics of the Gen 3 Load circuit protections so that load compatibility issues can be minimized.

Load Overcurrent & Short Circuit Protection in the SunSaver Gen 3 Controller

Background

Both the Gen 2 and Gen 3 SunSaver controllers rely on power MOSFETs (transistors) to deliver current from the battery to the load terminals. Power MOSFET devices are very reliable so long as they are operated within their specified limits. Two important MOSFET characteristics for this discussion are current rating and maximum junction temperature (which are directly related). As current flows through the device, the device heats up and the silicon junction rises in temperature. If too much current is put through the device for too long a period, the junction may heat to the point of failure.

Both the Gen 2 and Gen 3 controllers are designed with a heatsink and epoxy potting to facilitate the extraction of heat from these MOSFET parts, thus allowing them to handle larger amounts of current than they could situated only in free air. Even so, there is still a maximum limit on the amount of current these parts can handle before high temperatures damage them.

The SunSaver models are rated according to their current handling capability. For example, the SS-20L-12V controller can handle 20A of solar current and 20A of load current. These ratings are based on the ability of that model's MOSFETs to withstand steady-state, continuous levels of current over the entire ambient operating temperature range of the controller (-40°C to 60°C).

Although a particular model may be rated to 10A or 20A (continuous) load current, these current levels may be exceeded for brief periods of time without damage to the MOSFETs; it takes time for the device(s) to heat to the point of failure. Some types of loads, particularly loads with a large amount of input capacitance, may draw a startup current surge exceeding the continuous load current rating of the SunSaver model used. These surges are generally acceptable (within limits) because they are very brief in duration.

SunSaver Gen 2 Load Circuit

The Gen 2 SunSaver Controller does not contain any electronic protections for overcurrent conditions. It will not disconnect or de-energize the load if the load draws more current than the nameplate rating of the controller model (e.g. if the SS-10L-12V were being used, its nameplate load current rating is 10A). If a load continuously draws more than the nameplate current rating of the Gen 2 controller, there is a high risk of overheating and failure of the power transistor components responsible for delivering power to the load terminals.

Similarly, there is no protection against heavy startup current surges. Large current surges, albeit brief in duration, will also pose a high risk to the power transistors.

SunSaver Gen 3 Load Circuit

The Gen 3 circuit improves upon the Gen 2 circuit with the addition of Overcurrent and Short Circuit Protection. Each is implemented using a different method.

Overcurrent Protection is implemented in software and is intended to protect against slow increases in load current. The Gen 3 SunSaver Controller continuously measures the load current and when it exceeds the nameplate current rating, will cause a software-triggered shutdown of the load terminals. An example of this would be a user sequentially turning on small loads until the total load current exceeded the controller's rating.

Short Circuit Protection is implemented in hardware and is intended to protect against rapid increases in load current. Rapid increases in current can be caused by a sudden short circuit of the load terminals or switching on a load with high capacitance. This hardware protection circuit is tuned to allow the highest amount of current possible (for as long as possible) without damage to the MOSFETs. Only when the current (or duration thereof) approaches a harmful level does the hardware protection activate to shut down the load terminals. Extensive destructive testing was conducted in order to determine the optimal tuning point for the protections circuit.

Figure 1 shows an oscilloscope capture of a SS-10L-12V controller turning on a bank of incandescent lights. The yellow curve represents the load terminal voltage of the Gen 3 SunSaver (SS). The blue curve represents the load current. As the SS turns on the load (indicated by the jump in load terminal voltage), the cold incandescent bulbs draw a current surge of approximately 60A. As the bulbs rapidly heat up, the current decreases and settles at the bulbs' continuous draw of ~10A.

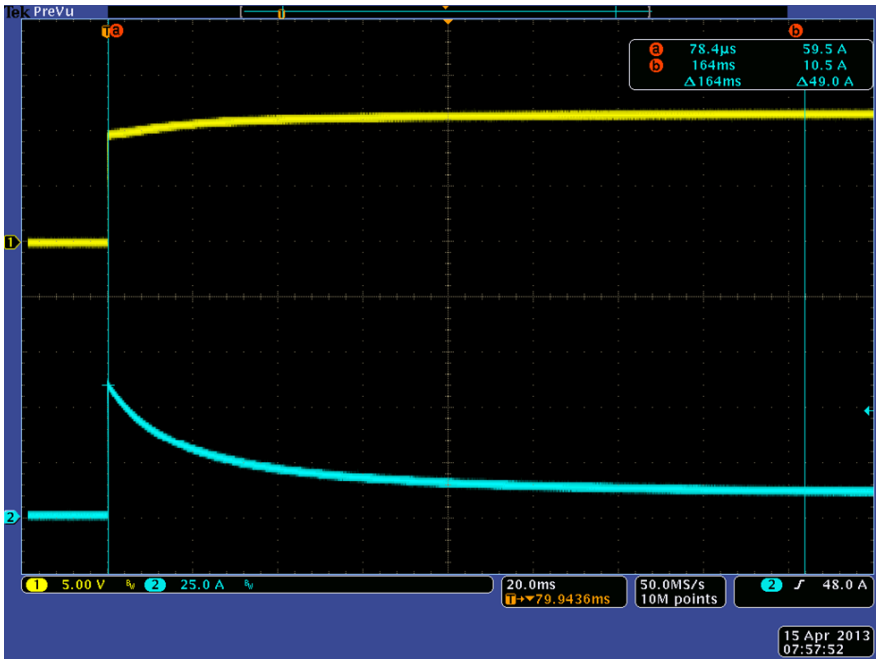


Figure 1. The oscilloscope capture of a SS-10L-12V controller turning on a bank of incandescent lights.

Figure 2 shows the same SS-10L-12V controller as in Figure 1. This time, a greater number of cold incandescent lights are used than in our Figure 1 test. The startup current surge of this larger bank approaches 68A. This amount of current is too much for the controller's transistors to safely handle and the hardware Short Circuit Protection has activated. This is indicated by the rapid drop in both load terminal voltage (yellow) and load current waveforms (blue).

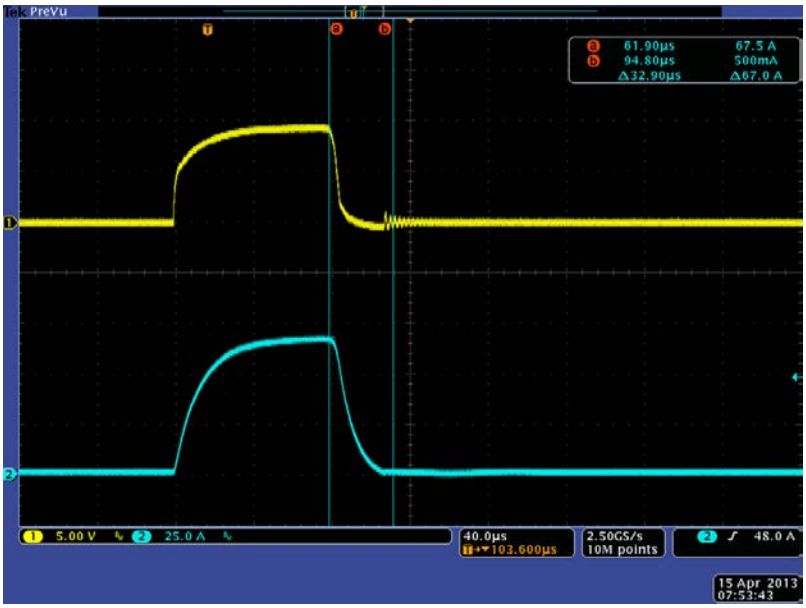


Figure 2. The same SS-10L-12V controller as in Figure 1; this time, a greater number of cold incandescent lights are used than in our Figure 1 test.

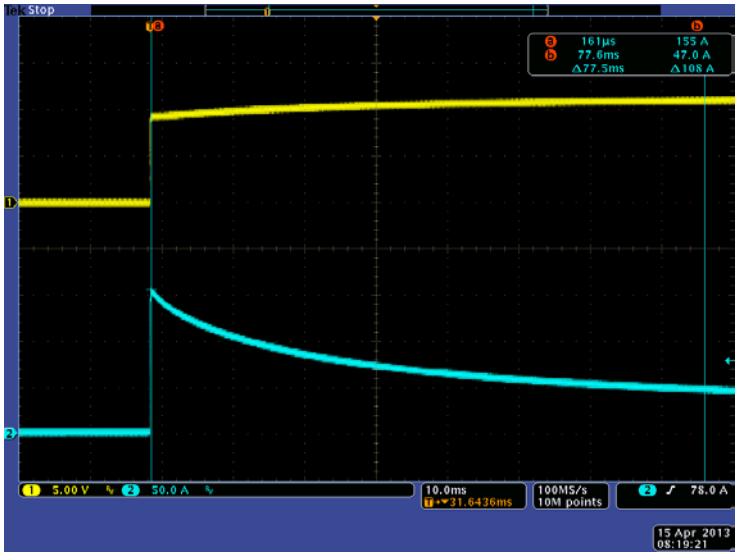


Figure 3 and Figure 4 show a SS-20L-12V controller turning on a much larger bank of incandescent lights. It can be seen that this 20A rated controller allows for a startup current surge of at least 155A. Figure 4 is a magnified look at what is happening in Figure 3 when the load turns on (when the yellow goes low-to-high).

Figure 3. A SS-20L-12V controller turning on a much larger bank of incandescent lights.

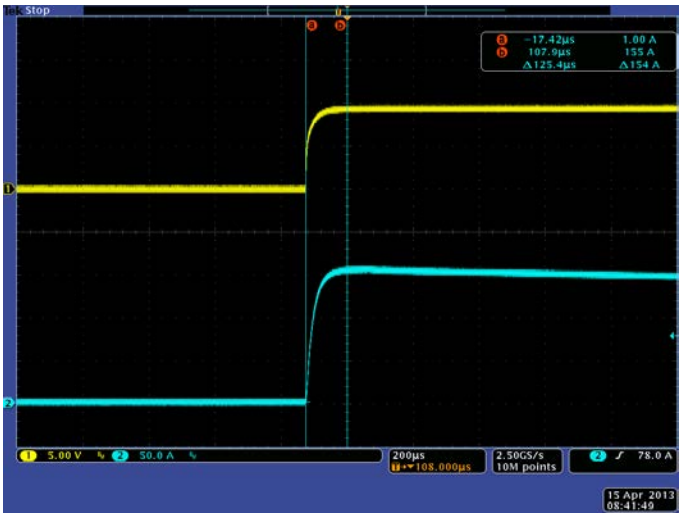


Figure 4. A magnified look at what is happening in Figure 3 when the load turns on (when the yellow goes low-to-high).

Figure 5 shows what happens if the same SS-20L-12V controller from Figures 3/4 tries to energize a 10,000uF capacitor load (uncharged). The load current (blue) approaches 185A before the controller's Short Circuit Protection turns off power to the load terminals. This protects the power transistors from damage.

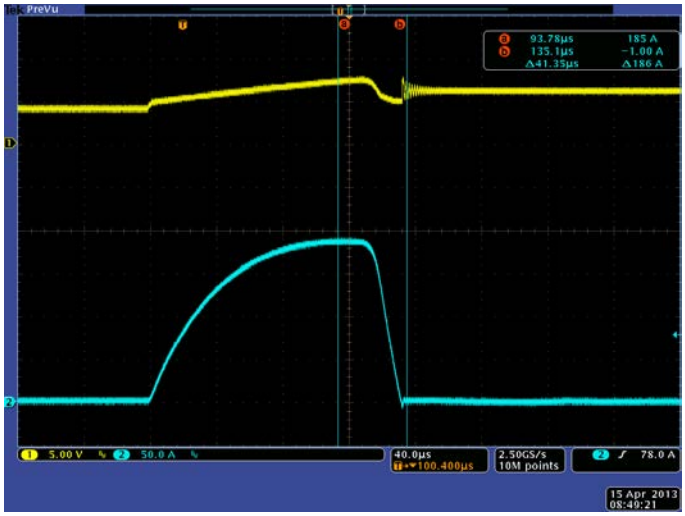


Figure 5.

'Non-L' Gen 3 Considerations

'Non-L' Gen 3 SunSaver versions are differentiated from the 'L' versions by having no load overcurrent or short circuit protections [nor do they have a Low Voltage Disconnect (LVD) feature].

- 'Non-L' versions are those with no 'L' in the model name (e.g. SS-10-12V).
- 'L' versions are those with an 'L' in the model name (e.g. SS-10L-12V).

Non-L versions replace the power transistors with an internal jumper connection. This connection is between the Battery (+) terminal and the Load (+) terminal, thereby allowing the loads to be powered directly from the Battery without power transistors. The internal jumper connection can handle approximately 15A continuous and is much less susceptible to load current surges than power transistors in the 'L' units.

Swapping Gen 2 for Gen 3

Previously designed SunSaver systems using the Gen 2 units may experience issues driving high startup current loads when using the Gen 3 replacements. This is a consequence of the new Short Circuit Protection in the Gen 3 units. Rather than be considered a design problem, this should be welcomed as an opportunity to design a more robust system. Many premature failures of the Gen 2 units can be traced to failed load power transistors and the lack of overcurrent / short circuit protection. These failures have shown (and may show) up several years into the product's service life; caused by degradation of the MOSFETs from repeated high-current surges. Reducing these types of failures through the use of electronic protections increases system reliability and lowers maintenance/replacement costs to designers and installers.

Preventing Gen 3 Load Short Circuit Shutdown

The only way to prevent the Short Circuit Protection from disconnecting the load is to control the amount of startup current surge from the system loads. This can be done by:

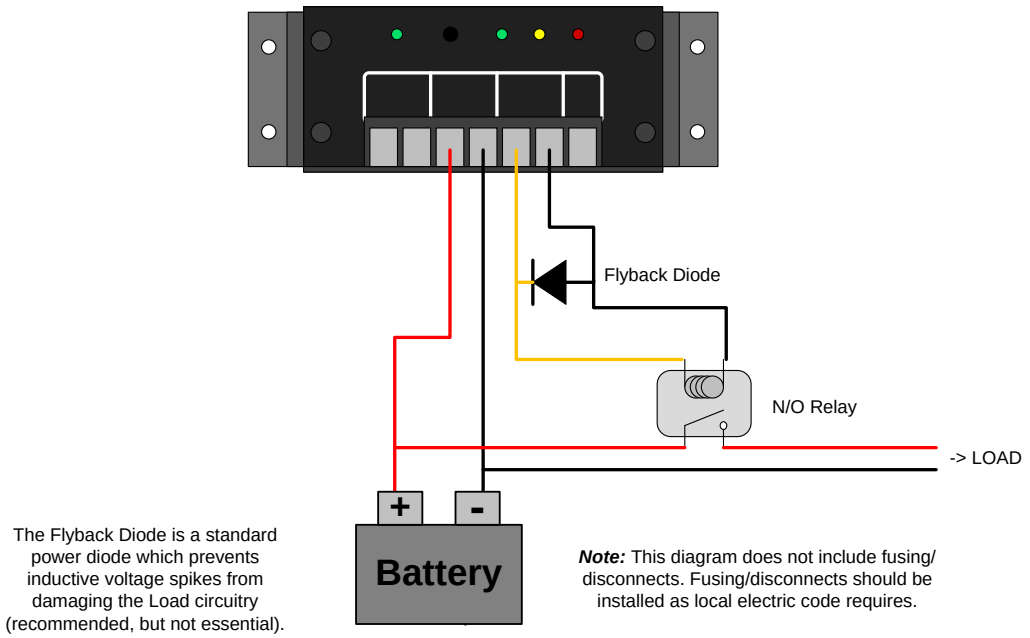
1) Choosing low input capacitance loads (no inverters!).
2) Reducing the startup surge from high input capacitance loads.
3) Using a relay to control the high startup surge load.
4) Connect the load directly to the battery rather than to the controller. Doing so will result in not having low voltage load disconnect (LVD).

To reduce startup surge from high capacitance loads, a resistor may be placed in series with the load. The resistor forms an R-C circuit with the load capacitance and serves to limit the magnitude and rise-time of the startup current. The resistor value(s) appropriate for a particular load depends upon the load input capacitance and the wire gauge / length being used to connect the load to the Load terminals. Current magnitude should be kept below the ratings in Table below to ensure the Short Circuit Protection does not activate.

Model	Inrush Current	Inrush x
SS-6L-12V	40A	6.5x
SS-10L-12V	60A	6x
SS-10L-24V	70A	7.5x
SS-20L-12V	150A	7.5x
SS-20L-24V	180A	9x

A relay can be used to isolate the Gen 3 Load terminals from the high startup surge of a capacitive load. Figure 6 below illustrates how a relay can be used for this purpose.

Figure 6.



By using a relay to control the load, the Gen 3 Load circuitry is not subject to the high startup surge stresses associated with capacitive loads. LVD functionality is maintained in this configuration.

Summary

The Generation 3 SunSaver 'L' Controllers employ both software-controlled steady-state overcurrent protection and hardware-controlled short circuit protection (for high current surges). These protections are two of many new features introduced in the Gen 3 SunSaver models. They have ***proven to increase the reliability and robustness of the SunSaver load circuitry*** over the long-term.

Loads, which once stressed the Gen 2 load circuitry into premature failure, may no longer operate when connected to Gen 3 units. The Gen 3 is designed to safely operate critical circuit components while still allowing for significant load startup surge handling. Steps should be taken to reduce surge current drawn from the loads if they trip overcurrent/short circuit protections. Doing so will allow the SunSaver Gen 3 system to run reliably, long into the future.