MODULAR DEVICES, INC.
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# Inrush Limiters and Inrush/Outrush Limit Switches

Electrical power systems on spacecraft are relatively small and often place severe limitations on peak inrush current when the downstream loads, such as DC-DC Converters are initially powered. DC-DC converters that include built in EMI filters, as well as stand alone EMI filters tend to have large input capacitances that can draw high currents at turn on.

Inrush limiters limit the current flowing into a discharged capacitor when voltage is applied. Linear inrush limiter modules and inrush limit switch modules were developed by MDI to provide a high reliability solution which controls specified inrush requirements.

MDI's inrush limiting devices are available in two types (linear and switches), but both types operate on the same principle that a resistive element is used to control the inrush current.

Charging a capacitor through a resistive element or FET always incurs a power dissipation. Energy stored in a charged capacitor has the dimensions of watt-seconds and it takes an equivalent amount of watt seconds dissipated to charge an uncharged capacitor through a resistor, semiconductor or switch.

When charging a capacitor through a resistive device, such as a FET in the linear mode or a resistor to be bypassed by a switch, the capacitor receives and stores energy ½ $C^{*2}$ , usually measured in watt-seconds. That same amount of energy is lost in the series current limiting device. The peak power dissipated in the FET is equal to the watt seconds received by the capacitor, divided by the charging time (in seconds).

## Linear Inrush Limiter

For relatively low stored energy, the limiting dissipative element can be a semiconductor (transistor of FET). An active constant current limiter can charge the capacitor linearly whereas the resistor current limiter charges the capacitor exponentially. So, an active current limiter can offer faster charge times.

Intended for lor lower power applications, MDI's model *3635 family and Model 3860 are constant current limiting inrush modules available for different input bus voltages. The inrush current is linearly limited using an FET constant current circuit. The limiting current may be user adjusted downward by connection of an external resistor.

The power dissipation generated during inrush current limiting is normally a short term transient effect. MDI's linear inrush limiters have a thermal mass that integrates the power absorbed by the FET.

In a DC-DC converter capacitive charging application, the steady state current drawn by the load is usually much lower than the current limited inrush charging current. Therefore, the inrush limiter FET is saturated after the initial capacitor charging/ inrush limiting and dissipates relatively little power after the charging interval. This allows the inrush limiter to have a small package size.

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## Higher Power Inrush Limiting

However, for higher inrush limiter dissipations, the best limiter may be a resistor. Resistors may have much larger surge power ratings for their than semiconductors because they can withstand higher peak temperatures. When the input capacitance is very large, it may be more advantageous to dissipate the power loss incurred in a power resistor, instead of in a semiconductor. In this case, *an inrush limiter switch* combined with an external power resistor may be used.

The function of an *inrush limiter switch* is to charge a capacitor through an external resistor, then bypass the resistor with a low resistance semiconductor switch. An inrush limiter switch is functionally an electronic time delay relay (delay on power on) with a low resistance high side switch. As compared to an inrush limiter with an active semiconductor dissipator, the inrush limiter switch uses an external resistor to dissipate the power lost when charging the capacitive load.

An inrush limiter switch includes a high side switch that is normally open, a time delay (externally programmable) and a ground referenced inhibit release for downstream DC-DC converters. The high side switch is used to bypass the external limit resistor. The time delay is usually set for three or four time constants of the limit resistance and the capacitance to be charged.

MDI's inrush limiter switches also have an inhibit input and an inhibit output. The inhibit output remains low (at the input return voltage) unit the delay interval is complete and the high side switch closes. Then, the inhibit output goes open collector. The inhibit output allows sequencing of input or output DC-DC converters. When the time delay passes and the high side switch closes, the inhibit is released and allows downstream DC-DC converters to operate.

For higher power applications, the inrush limiting device is an external power resistor, which is bypassed by a high side FET switch after a pre-determined time delay. This is the function of Inrush Limiter Switch Model 3844, 3862 and others.

## Inrush Limiter Switch used as an outrush limiter

High amplitude, low duty cycle pulse currents with lower average current requirements are common in RF or Laser applications. In many such applications, it is common for the peak currents to come from a large value capacitor and the average current to be supplied from a DC-DC converter.

Depending on the output rise time of the DC-DC converter and the overcurrent protection in the DC-DC converter, the DC-DC converter may not be able to charge the large output capacitor to the desired output voltage due to being current limited.

By using an Inrush Limiter Switch such as MDI Model 3844 on the output of a DC-DC converter, the output capacitor can be completely charged through an external limiting resistor. At the end of the time delay, the charging resistor is bypassed by the low resistance of the 3844 output switch. When the 3844 switch closes, the inhibit output of the 3844 goes open circuit and may be used to initiate the pulsed loading of the output capacitor. When using the Model 3844, the output voltage of the DC-DC converter can be in the range of 18 to 160 VDC. The average load DC-DC output current can be up to 10 amperes.

The Data Sheet can be found here.