TECHNICAL DATA
DATASHEET 5019, Rev-

DC Solid State Power Controller Module

Description:

These Solid State Power Controller (SSPC) Modules are designed to operate without any heatsink requirements. They are microcontroller-based Solid State Relays rated up to 10A designed to be used in high reliability 270V DC applications. These modules have integrated current sensing with no derating over the full operating temperature range. These modules are the electronic equivalent to electromechanical circuit breakers with isolated control and status.

This series is supplied in 2 SSPC families, with each family being programmable over a 30% to 100% current range:

SPDP03D270: Programmable from 0.9A to 3A
SPDP10D270: Programmable from 3A to 10A
This series also allows programming the Instant Trip level from 400% to 800% of maximum rating.

Battle Override Option: SPDPxxD270-B
MIL-STD-1760 Trip Curve Option: SPDPxxD270-M

Compliant Documents & Standards:

MIL-STD-704F	Aircraft Electrical Power Characteristics, 12 March 2004
MIL-STD-217F, Notice 2	Reliability Prediction of Electronic Equipment, 28 Feb 1995

Module Features:

- No additional heat sinking or external cooling required!
- Extremely Low Power, No Derating Over the Full Temperature Range
- Low Weight (40 gms)
- Epoxy Shell Construction
- Solid State Reliability
- High Power Density

Electrical Features (SPDPXXD270 Series):

- 270VDC Input with Very Low Voltage Drop; 220mV, typ. @ 10A for SPDP10D270
- True I^2t Protection up to 8X rating with Nuisance Trip Suppression
- I^2t Protection level externally programmable to 30% of the maximum rating
- Instant Trip Protection level externally programmable from 400% to 800% of maximum rating
- Reports Loss of Line Voltage
- Reports Over Temperature condition and turns off during this condition
- Output Leakage Sink for safe output voltage when SPDPxxD270 turned off
- No trip operation upto 220µF of output capacitance
- Instant Trip Protection (40 µsec typ) for Loads Above programmed Instant Trip level
- Unlimited Interrupt Capability; Repetitive Fault Handling Capability
- Thermal Memory
- Internally Generated Isolated Supply to Drive the Switch
- Low Bias Supply Current: 15 mA typ @ 5V DC
- High Control Circuit Isolation: 750V DC Control to Power Circuit
- Soft Turn-On to Reduce EMC Issues
- EMI Tolerant
- Module Reset with a Low Level Signal; Reset Circuit is Trip-Free
- TTL/CMOS Compatible, Optically Isolated, Input and Outputs
- Schmitt-Trigger Control Input for Noise Immunity

Table 1 - Electrical Characteristics (at 25 °C and V_{bias} = 5.0V DC unless otherwise specified)

Control & Status (TTL/CMOS Compatible)	
BIAS (Vcc)	5.0V DC Nominal, 7.0V DC Absolute Maximum 4.5V to 5.5 VDC
BIAS (Vcc) Current	15 mA typ 25 mA max
S1 and S2 Status Signals	V_{oh}=3.7V, min, at I_{oh}=-20mA V_{ol}=0.4V, max, at I_{ol}=20mA
CONTROL Signal V_{T+} (Positive-going input threshold voltage) V_{T-} (Negative-going input threshold voltage) ΔV_T Hysteresis (V_T+ V_T−)	 2.0V, min, 3.5V, max 1.2V, min, 2.3V, max 0.6V, min, 1.4V, max
Reset	Cycle CONTROL Signal

Power	
Input Voltage – Continuous – Transient	0 to 300V DC, 500V DC Absolute Maximum +600V or –600V Spike (≤ 10 uS)
Power Dissipation	See Table 4
Current	See Table 4 See Figure 1, Trip Curve
Max Voltage Drop	See Table 4
Trip Level	110% of rating

Trip time	See Figure 1, Trip Curve
Output Rise Time (turn ON)	600 µsec typ
Output Fall Time under normal turn-off	100 usec typ
Output Fall Time under Fault	50 usec typ
Min Load Requirement	Nil

Protection	
Short Circuit Protection	Unlimited
Instant Trip	400% - 800%, programmable

Table 2 - Physical Characteristics

Temperature	
Operating Temperature	T_A = -55 °C to +125 °C
Storage Temperature	T_A = -55 °C to +125 °C

Environmental	
Altitude	Up to 30,000 ft Can be installed in an unpressurized area
Case Dimensions	2.50"L x 1.00"W x 0.50"H
Operating Orientation	Any
Weight	40 gms
MTBF (Estimate: MIL STD 217F)	400,000 hrs at 25°C Full load

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Figure 1 - Trip Curve

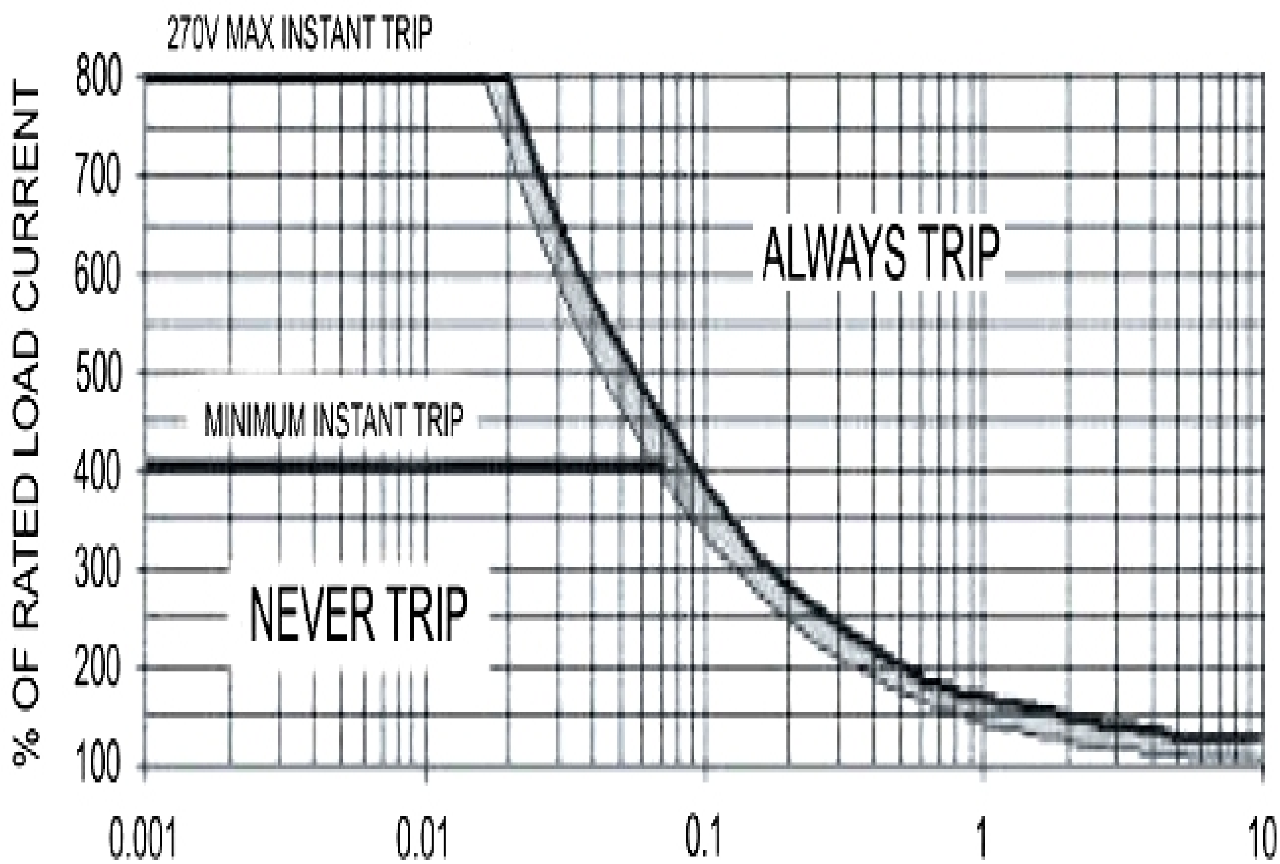


Table 3 - Signal Timing – (-55 °C to 100 °C @ LINE = 270V DC)

Parameter	Min	Max	Units
Turn ON Delay	0.05	1	ms
Load Current Rise Time	0.05	1	ms
Turn OFF Delay	0.05	1	ms
Load Current Fall Time	50	200	µs

Note: Current Fall Time from trip dependent on magnitude of overload

Figure 2 - Mechanical Dimensions and Pin Assignments

All dimensions are in inches

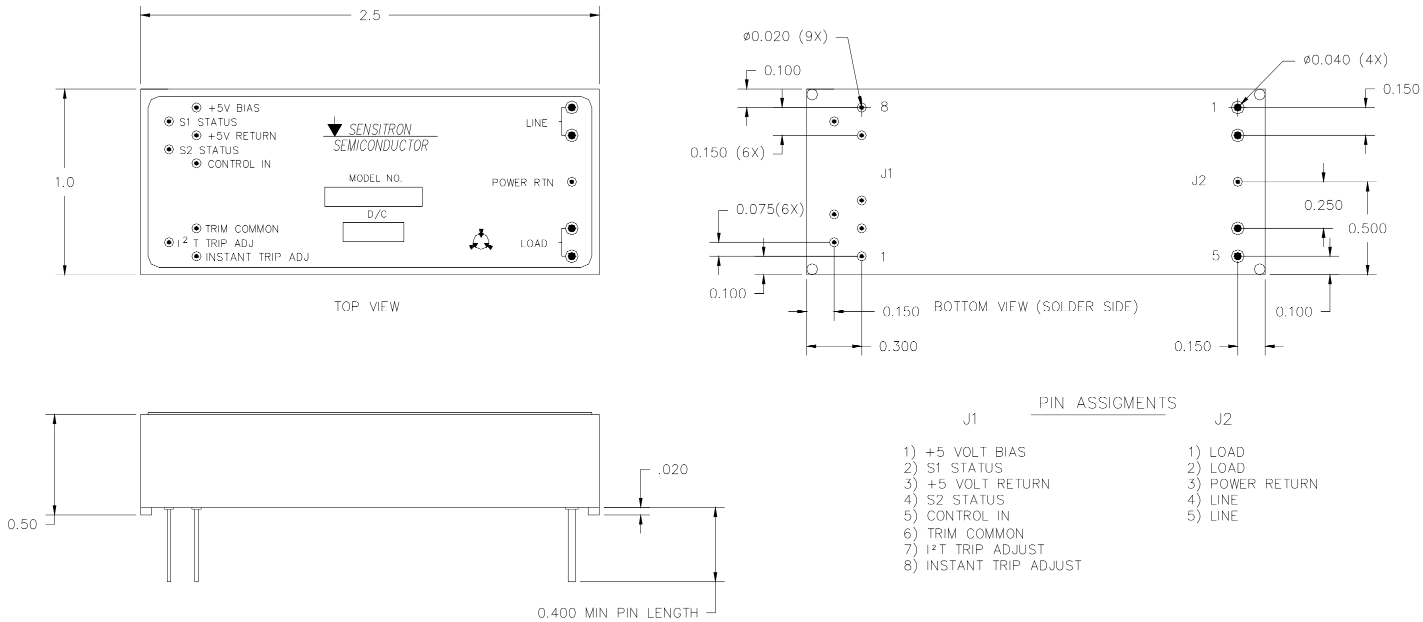


Table 4 – Individual Power Dissipation Data (includes Vbias Power)

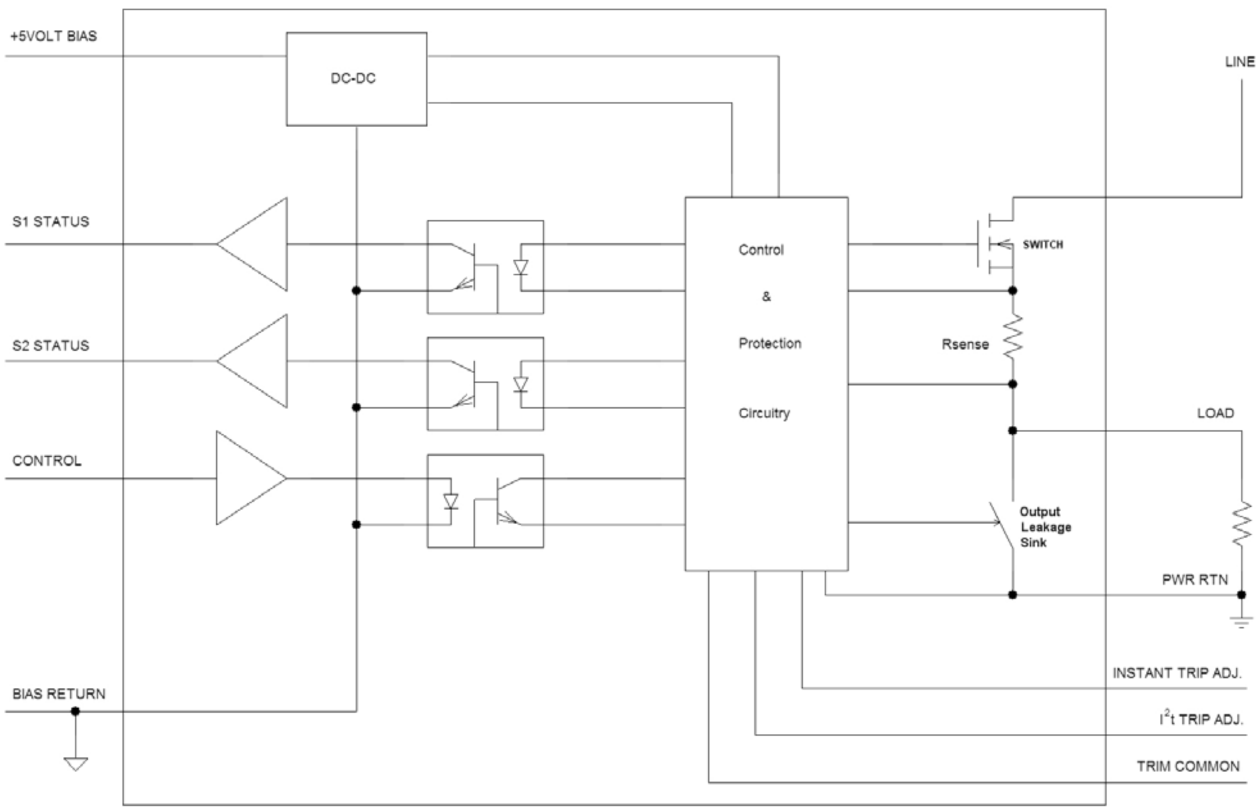
SPDP3D270

	SPDP3D270 Set for 0.9 Amp Rating	SPDP3D270 Set for 3 Amp Rating
Current Rating @ 125^{O}C	0.9A	3A
Power Dissipation	0.10W typ @ 0.6A 25^{O}C 0.19W max @ 0.9A 25^{O}C 0.25W max @ 0.9A 125^{O}C	0.32W typ @ 1.8A 25^{O}C 0.91W max @ 3A 25^{O}C 1.60W max @ 3A 125^{O}C
Max Voltage Drop	44mV typ @ 0.6A 25^{O}C 77mV max @ 0.9A 25^{O}C 140mV max @ 0.9A 125^{O}C	135mV typ @ 1.8A 25^{O}C 260mV max @ 3A 25^{O}C 490mV max @ 3A 125^{O}C

SPDP10D270

	SPDP10D270 Set for 3 Amp Rating	SPDP10D270 Set for 10 Amp Rating
Current Rating @ 125^{O}C	3A	10A
Power Dissipation	0.15W typ @ 1.8A 25^{O}C 0.34W max @ 3A 25^{O}C 0.50W max @ 3A 125^{O}C	0.83W typ @ 6A 25^{O}C 2.83W max @ 10A 25^{O}C 4.88W max @ 10A 125^{O}C
Max Voltage Drop	40mV typ @ 1.8A 25^{O}C 70mV max @3A 25^{O}C 125mV max @ 3A 125^{O}C	125mV typ @ 6A 25^{O}C 270mV max @ 10A 25^{O}C 475mV max @ 10A 125^{O}C

Figure 3 - Electrical Block Diagram



Description

Figure 3 shows the block diagram of the SPDPXXD270 SSPC Series. It uses a SN74LVC3G14 device for digital I/O. This TTL compatible device has a Schmitt-Trigger input to minimize the effects of noise on the input. Its outputs can each drive more than 10 standard TTL loads. It's also compatible with CMOS inputs and outputs. The SN74LVC3G14 is isolated from the remainder of the module circuitry by three optocouplers.

The block labeled "Control & Protection Circuitry" gets power from the DC-DC converter and is referenced to the output of the SSPC. This block contains an amplifier to gain up the voltage developed across the sense resistor. It also contains a microcontroller with on-board timers, A/D converter, clock generator and independent watchdog timer. The microcontroller implements a precision I^2t protection curve as well as an Instant Trip function to protect the wiring and to protect itself. It performs all of the functions of multiple analog comparators and discrete logic in one high-reliability component.

The code programmed in the microcontroller acquires the output of the internal A/D converter, squares the result and applies it to a simulated RC circuit. It checks the output of the simulated circuit to determine whether or not to trip (turn off the power Mosfets). Because the microcontroller simulates an analog RC circuit, the SSPC has 'thermal memory'. That is, it trips faster if there had been current flowing prior to the overload than if there hadn't been current flowing. This behavior imitates thermal circuit breakers and better protects the application's wiring since the wiring cannot take as much an overload if current had been flowing prior to the overload.

The watchdog timer operates from its own internal clock so a failure of the main clock will not stop the watchdog timer. The code programmed in the microcontroller will periodically reset the watchdog timer preventing it from timing out. If the code malfunctions for any reason, the watchdog timer is not reset and it times out. When the watchdog timer times out, it resets the microcontroller. Since the code is designed to detect levels and not edges, the output of the module, and therefore the output of the SPDPXXD270, immediately reflects the command on its input.

The "Control & Protection Circuitry" block also has the ability for the user to adjust the current rating by varying the trip point with a resistor between the "I^2t ADJ" pin and the "TRIM COMMON" pin and to adjust the Instant Trip current level with a resistor between the "INSTANT TRIP ADJ" pin and the "TRIM COMMON" pin. See Figures 4 and 5 to select the appropriate resistor for adjusting the current rating for the SPDP3D270 and SPDP10D270 models, respectively. See Figures 6 and 7 to select the appropriate resistor for adjusting the Instant Trip current level for the SPDP3D270 and SPDP10D270 models, respectively.

When setting the current rating, select a resistor according to Figures 4 and 5 for 10% above the desired rating. Example: to set the SPDP3D270 to a rating of 2 Amps, look on Figure 4 for 2.2 Amps and select a resistor of 2.7K.

Figure 4 – SPDP03D270 Current Rating Trim Resistor Selection

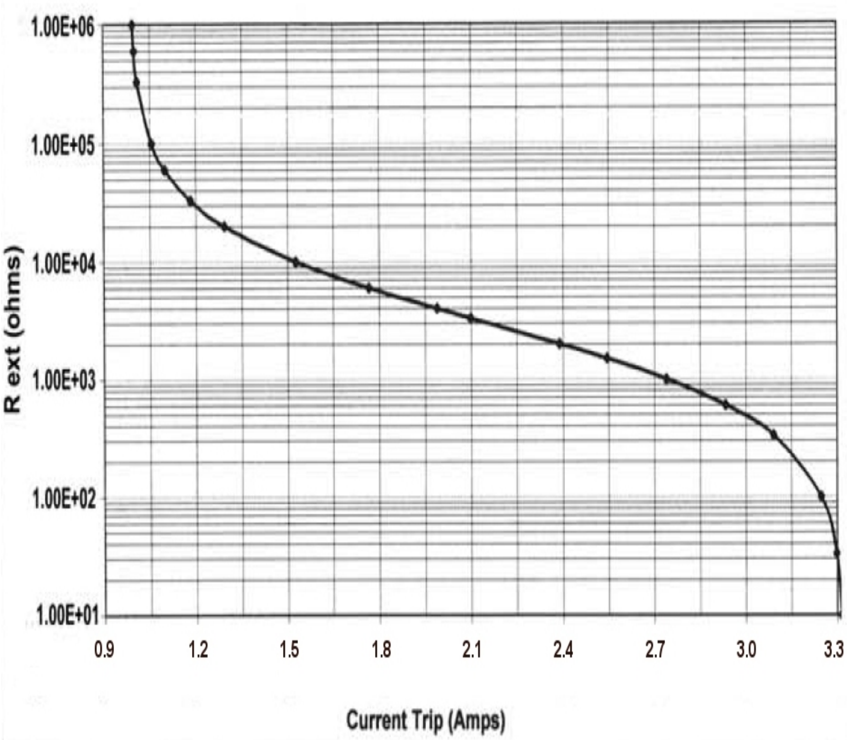


Figure 5 – SPDP10D270 Current Rating Trim Resistor Selection

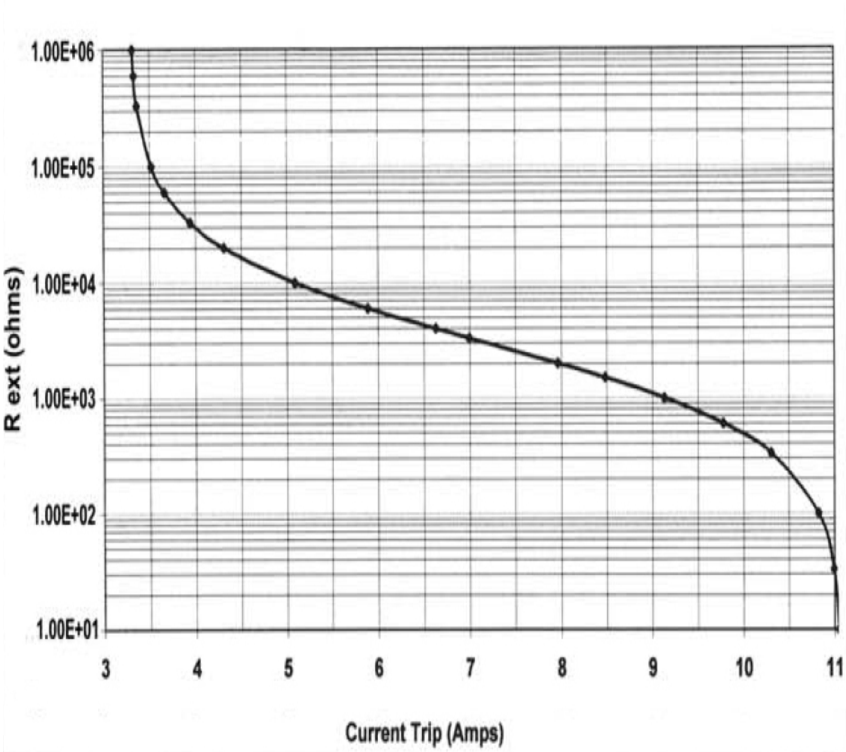


Figure 6 – SPDP03D270 Instant Trip Trim Resistor Selection

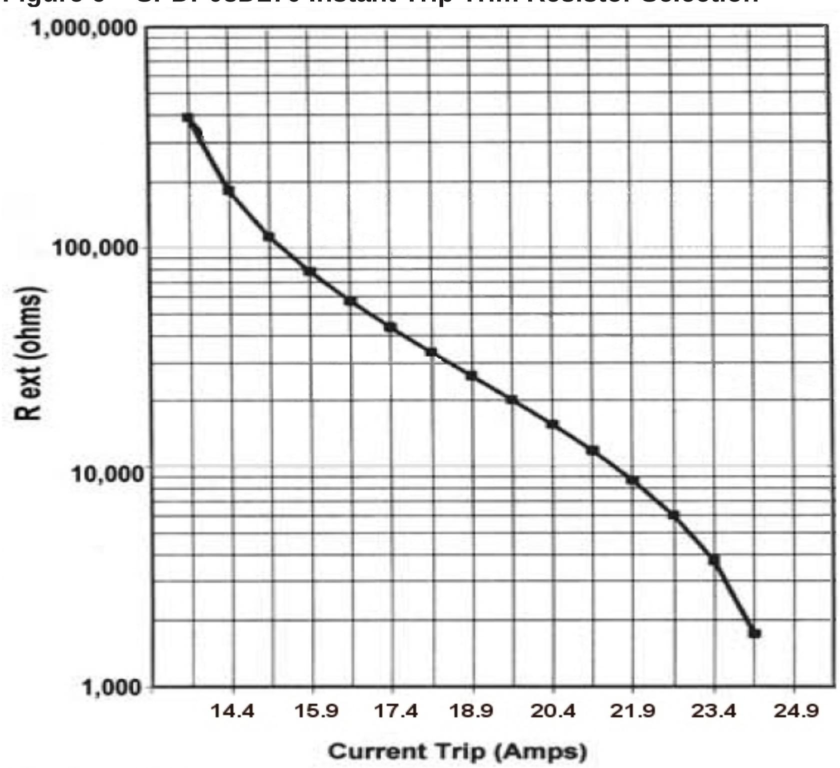
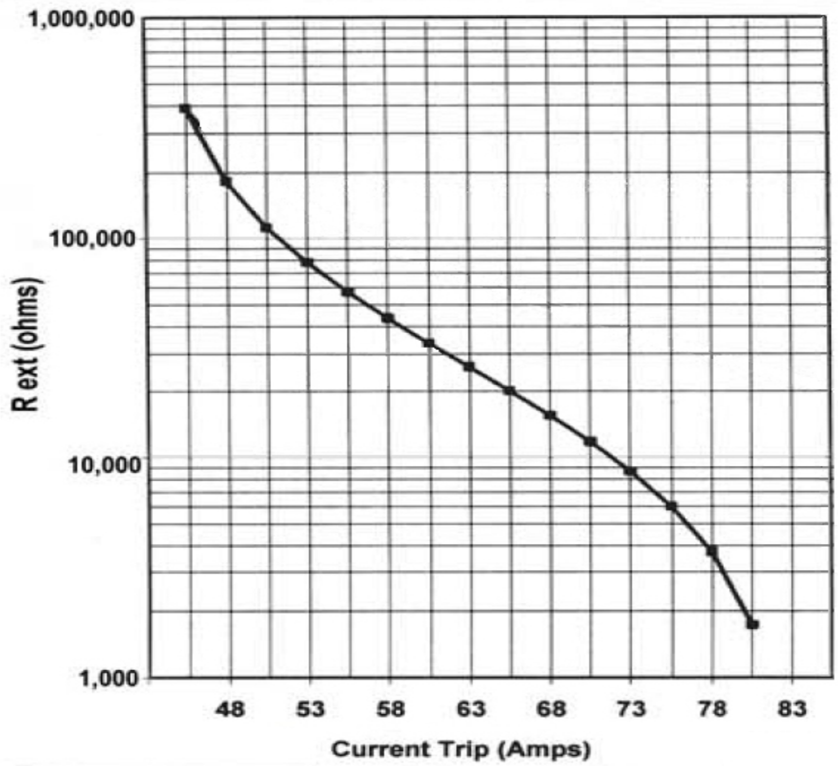


Figure 7 – SPDP10D270 Instant Trip Trim Resistor Selection



The Power Mosfets used in the SPDPXXD270 Series have been selected for very low $R_{ds(on)}$ and result in low voltage drop and low power dissipation. In most applications, the SPDPXXD270 will be operated at 50 – 60% of rated current to provide a safety margin. As can be seen in Table 4, when the SPDP10D270 is operated at 6 Amps, 60% of rated current, it dissipates less than 1.0 Watt at room temperature. No heatsinking is required for this condition. However, if the SPDP10D270 is to be operated at maximum rating and/or at elevated temperatures, the dissipation can exceed 4 Watts and heatsinking is required. Some heatsink can be accomplished by adding copper area to the "LINE" and "LOAD" pins, a heatsink can be epoxy attached to the surface of the module or a flat copper or aluminum heatsink can be sandwiched between the SPDP10D270 and the printed circuit board using a thermal pad to maximize heat transfer. Each application should be evaluated at maximum expected constant current. The SPDP3D270 Series does not require heat sinking under any condition.

For overloads, no heatsinking is required provided the SPDPXXD270 Series is allowed some time to cool down. The SPDPXXD270 has sufficient thermal mass that the temperature will rise only a few degrees under the worst-case overload. Repetitive overloads should be avoided. When the SPDPXXD270 reports a trip condition, the controller driving the SPDPXXD270 should allow no more than four repetitions and then allow thirty seconds to cool down before trying to turn on again.

The SPDPXXD270 will trip on overloads in the ALWAYS TRIP region shown in Figure 1 and will never trip when in the NEVER TRIP region. The SPDPXXD270 can be reset by bringing the CONTROL pin to a logic low. When the "CONTROL" pin is brought back to logic high, the SPDPXXD270 will turn back on. If the overload is still present, the SPDPXXD270 will trip again. Cycling the "5 Volt BIAS" power will also reset the SPDPXXD270. If the "CONTROL" pin is at logic high when the "5 Volt BIAS" power is cycled, the SPDPXXD270 will turn back on when the "5 Volt BIAS" power is re-applied.

Status Outputs

The "S1" and "S2" status outputs of the SPDPXXD270 show whether or not there is an over temperature condition and whether or not the line voltage is present. When an unsafe temperature condition is present, the "S2" status goes to a logic high state and the output of the SPDPXXD270 is turned off. When the temperature drops about 15 ^{o}C to a safe condition, the "S2" status output goes back low and the output of the SPDPXXD270 is turned back on. Both "S1" and "S2" status outputs go to a high level when the line voltage drops below 5 volts.

Table 5 shows the states of the "S1" and "S2" status outputs.

Table 5 – Control and Status

	COMMAND	CONTROL INPUT	STATUS S1	STATUS S2	OUTPUT	SSPC STATUS
1	OFF	0	0	0	OFF	Normal Off
2	OFF	0	0	1	OFF	Over Temp
3	OFF	0	1	0	ON	SSPC Fail
4	OFF	0	1	1	OFF	No Line Voltage
5	ON	1	0	0	ON	Normal On
6	ON	1	0	1	OFF	Over Temp
7	ON	1	1	0	OFF	Tripped
8	ON	1	1	1	OFF	SSPC Failure

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High Voltage Considerations

The SPDPxxD270 series is designed for 270VDC systems. The SPDPxxD270 contains an Output Leakage Sink to ensure that the output is at a safe voltage when the SPDPxxD270 is off (whether the SPDPxxD270 is turned off or is off due to loss of 5V BIAS Power). This circuitry absorbs the leakage current from the main switch and keeps the output voltage less than 1.5VDC over the temperature range. Figure 3 shows the Output Leakage Sink as a simple switch. However, the Output Leakage Sink is a transistor operating as a current source with a value of 83 mA. When the current into the output leakage sink is less than 83 mA, the transistor saturates and the output leakage sink looks like a resistor of about 16 Ohms. 83 mA can be used to determine how long it takes to discharge a particular load capacitance if the load is a pure capacitance. If the load is a combination of resistance and capacitance, it's likely that the RC time constant will discharge the capacitance faster than the output leakage sink.

Sufficient spacing should be allowed for on the user's PCB between the 270VDC line supply and the 270VDC power return and between the CONTROL and 5VDC Bias circuits and the 270VDC circuit to prevent arcing. Due to the small size of the SPDPXXD270 series, the spacing between pins is small so conformal coating should be used to prevent arcing, especially if transient voltages above 270VDC are possible.

Wire Size

MIL-W-5088L has a chart the shows wire size as a function of wire temperature and current. This chart is for a single copper wire in free air. For an ambient temperature of 70 ^{o}C, the chart allows a 24-gauge wire to handle 10 Amps continuously at a wire temperature of 200 ^{o}C – a wire temperature rise of 130 ^{o}C. For a wire temperature limited to 150 ^{o}C, the chart requires a 22-gauge wire and for a wire temperature of 105 ^{o}C, the chart requires a 20-gauge wire.

Amendment 1 of MIL-W-5088L has a table for copper wire in a bundle, group or harness with condition on the number of wires, percent of total harness capacity, etc. This table shows that an 18 gauge wire is necessary for 200 ^oC operation, 16-gauge for 150 ^oC and 14-gauge for 105 ^oC.

MIL-W-5088L has various figures showing derating for harnesses as a function of the number of current carrying conductors for different altitudes. MIL-W-5088L only specifies wire for DC or RMS AC conditions, not for transient or overload conditions. MIL-W-5088L and its amendment should be consulted to determine minimum wire sizes for other currents and conditions.

For transient or overload conditions, the transient or overload happens so quickly that heat is not transferred from the wire to the surroundings. The heat caused by the I^2R heating of the wire causes the temperature to rise at a linear rate controlled by the heat capacity of the wire. The equation for this linear rise in temperature, with respect to time, can be solved as: I^2t = constant. Every wire has an I^2t rating that's dependent on the temperature rise allowed and the diameter of the wire. If the I^2t rating of the SSPC or circuit breaker is less than the I^2t rating of the wire, then the SSPC or circuit breaker can protect the wire. The maximum I^2t rating for the SPDxxD270 is 130 Amp^2-Seconds. Every wire size in the paragraphs above has an I^2t rating that exceeds the SPDPxxD270 I^2t rating for the temperature rises stated. Therefore, to select a wire size, it's simply a matter of determining the maximum temperature rise of the application and deciding whether or not the wire will be in a bundle and use the information above.

Application Connections

Due to the presence of the circuitry that keeps the output at safe voltage when the SPDPxxD270 series are off, the SPDPxxD270 Series may only be configured as a high-side switch as shown in Figure 3.

Rise Time & Fall Time

The rise and fall times of the SPDPxxD270 are pre-set at the factory for a nominal 600µS rise time and 100µS fall time with a LINE supply of 270VDC (see Table 1 for min/max limits). The rise and fall times will vary linearly with supply voltage. The “PWR RTN” pin is used to control the rise and fall times. If the “PWR RTN” pin is left open, the rise and fall times will be less than 25uS. Leaving the “PWR RTN” pin open can be useful when a faster rise or fall time is desirable; however, the Output Leakage Sink will not be functional with the “PWR RTN” pin open.

With the “PWR RTN” pin connected as in Figures 3, the SPDPxxD270, when set for a 10 Amp rating, can turn on into a capacitive load of 220µF, typ, without tripping for any power supply voltage within the ratings. The capacitive load capability is proportional to current rating and can be therefore easily calculated for each model and setting in the SPDPxxD270 Series.

Wiring and Load Inductance

Wiring inductance can cause voltage transients when the SPDPxxD270 is switched off due to an overload. Generally, these transients are small but must be considered when long wires are used on either the “LINE” or “LOAD” pins or both. A 30 foot length of wire in free air will cause a transient voltage of about 10 Volts when the SPDP10D270 trips at an Instant Trip level of 80 Amps. At the rated load current of 10 Amps, the voltage transient will be less than 1 Volt. If longer wire lengths are used, a transient suppressor may be used at the “LINE” pin so that the total voltage between the “LINE” and “LOAD” pins is less than 500 Volts. The SPDPxxD270V series includes a reverse biased diode from the “LOAD” to “PWR RTN” pins to prevent damaging transients on the output due to inductive loads.

Paralleling

For example, putting two SPDP10D270s in parallel will not double the rating to 20 Amps. Due to differences in the $R_{ds(on)}$ of the Power Mosfets in the SSPCs, the current will not share equally. In addition, there are unit-to-unit differences in the trip curves so that two SPDP10D270s in parallel may possibly trip at 15 Amps. Also, both SPDP10D270s will not trip together; the SPDP10D270 carrying the higher current will trip first followed by the other SPDP10D270. Multiple SPDP10D270s may be used in parallel as long as these complexities are appreciated. Due not parallel different models of this series as the current sharing will not be predictable.

Board Layout

The current-carrying power circuit should be kept well away from the control circuit and other low-level circuits in the system. It's unlikely, but possible, that magnetic coupling could affect the control circuit when turning normal loads on and off. However, in the case of an overload, the magnetic coupling could be 10 times greater than with normal loads. Effects of such coupling could cause 'chattering' when turning on and off, oscillation, and the possibility of turning the SPDPxxD270 back on after an overload. The SPDPxxD270 Series is a Trip-Free device. Once tripped it will not turn back on until reset and commanded on again. Reset is accomplished by bringing the "CONTROL" pin low and turning the SSPC back on is accomplished by bringing the "CONTROL" pin high. Sufficient magnetic coupling between the current-carrying power circuit and the control circuit can negate the Trip-Free characteristic.

MIL-STD-704F

This standard covers the characteristics of the electrical systems in Military Aircraft. The SPDPxxD270 Series meets all of the requirements of MIL-STD-704F including Normal, Emergency, Abnormal and Electric Starting conditions with the Ripple, Distortion Factor and Distortion Spectrum defined in the standard.
In addition, the SPDPxxD270 Series can withstand $\pm$ 600 V spikes for 10μS. This capability is beyond that required by MIL-STD-704F.