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TECHNICAL DATA
DATASHEET 5116, Rev C

28V DC Solid State Power Controller Module

Description:

These high power Solid State Power Controller (SSPC) Modules are designed to operate with minimal losses and heat-sinking / airflow. They have an isolated case easing the installation process. High current bus bar terminals are used to provide good, low-drop interface for the high current input / output. They are microcontroller-based Solid State Relays rated up to 150A designed to be used in high reliability 28V DC applications. These modules have integrated current sensing with no de-rating 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 current ratings of 150A and 130A.

SPDC150D28: 150A current rating
SPDC130D28: 130A current rating

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:

- Extremely Low Power Loss, No De-rating Over the Full Temperature Range
- Avalanche rated mosfets to handle high levels of line spike
- Low Weight (325 gms typ)
- Potted Module
- Solid State Reliability
- High Power Density

Electrical Features:

- 28VDC Input with Very Low Voltage Drop; 100mV, typ. @ 150A
- True I^2t Protection up to 8X rating with Nuisance Trip Suppression
- Instant Trip Protection (1 msec typ) for Loads Above 8X rating
- Unlimited Interrupt Capability; Repetitive Fault Handling Capability
- Thermal Memory
- Internally Generated Isolated Supply to Drive the Switch
- Low VBias Current: 75mA 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, Digitally Isolated, Input and Outputs
- Input filter for Noise Immunity
- Battle Short to override the Trip condition

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

Control & Status (TTL/CMOS Compatible)	
Vbias Supply (Vcc)	5.0V DC Nominal, 6.5V DC Absolute Maximum 4.5V to 5.5 VDC
Vbias Supply (Vcc) Current	75 mA typ 90 mA, max
LOAD STATUS & SWITCH STATUS Signals	V_{oh}=4.6V, min, at I_{oh}=-4mA V_{ol}=0.4V, max, at I_{ol}=4mA
CONTROL Signal / BATTLE SHORT Signal	V_{IH} = 2.0V min V_{IL}= 0.8V max
Reset	Cycle CONTROL Signal

Power	
Input Voltage – Continuous – Transient	0 to 40V DC, 60V DC Absolute Maximum +600V or –600V Spike (≤ 10 µs)
Power Dissipation	See Table 4
Current	See Table 4 See Figure 1, Trip Curve
Max Voltage Drop	See Table 4
Max current without tripping	110% min

Trip time	See Figure 1, Trip Curve
Output Rise Time (turn ON)	350 µsec typ
Output Fall Time under normal turn-off	300 µsec typ
Output Fall Time under Fault	50 µsec typ
Min Load Requirement	Nil

Protection	
Short Circuit Protection	Unlimited
Instant Trip	700%, min; 900%, max

Table 2 - Physical Characteristics

Temperature	
Operating Temperature	T_C = -55 °C to +100 °C
Storage Temperature	T_C = -55 °C to +125 °C

Environmental	
Altitude	Operation: -450 to 10,500 ft Storage: 35,000 ft. Can be installed in an unpressurized area
Case Dimensions	3.99” x 2.55” x 0.66”
Operating Orientation	Any
Weight	375 grams max
MTBF (Estimate: MIL STD 217F)	34 kHrs at Full Load, 70^{0}C, Ground Mobile

Figure 1 - Trip Curve

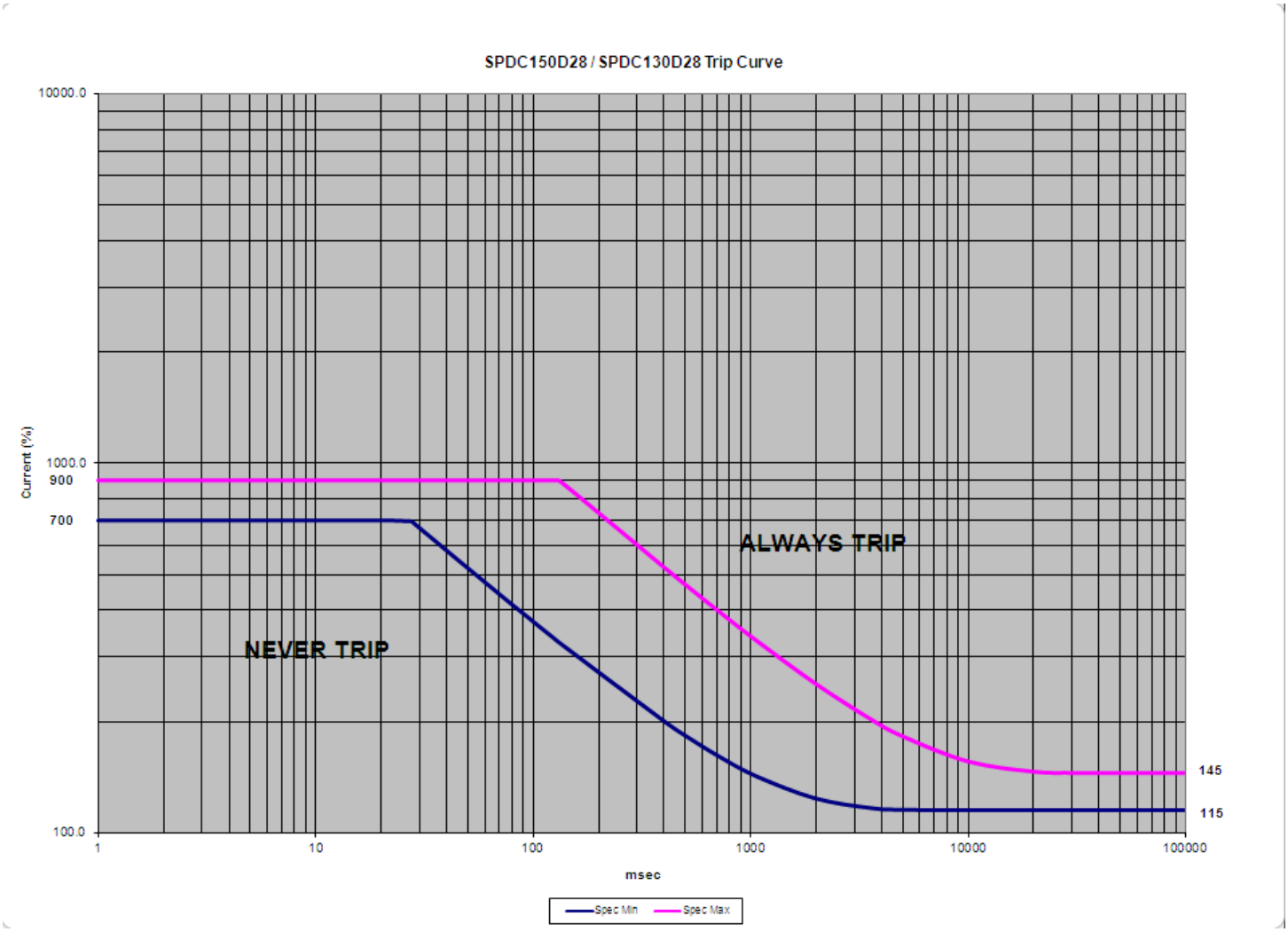


Figure 2 – Timing Diagram

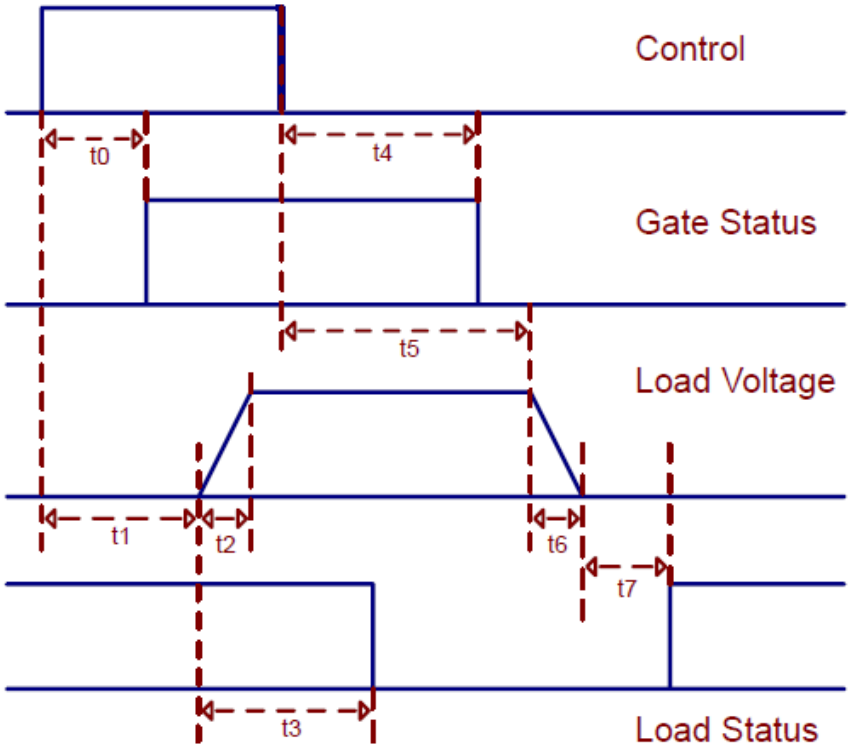


Table 3 - Signal Timing – (-55 °C to 100 °C @ LINE = 28V DC)

Parameter	Symbol	Min (μs)	Max (μs)
CONTROL to SWITCH STATUS Delay for Turn On	t0	100	300
Turn ON Delay	t1	100	400
LOAD Current Rise Time	t2	150	450
Turn ON to LOAD STATUS Delay	t3	350	600
CONTROL to SWITCH STATUS Delay for Turn Off	t4	200	450
Turn OFF Delay	t5	200	500
Load Current Fall Time	t6	150	400
Turn OFF to LOAD STATUS Delay	t7	350	650

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

Figure 3 - Mechanical Dimensions

All dimensions are in inches

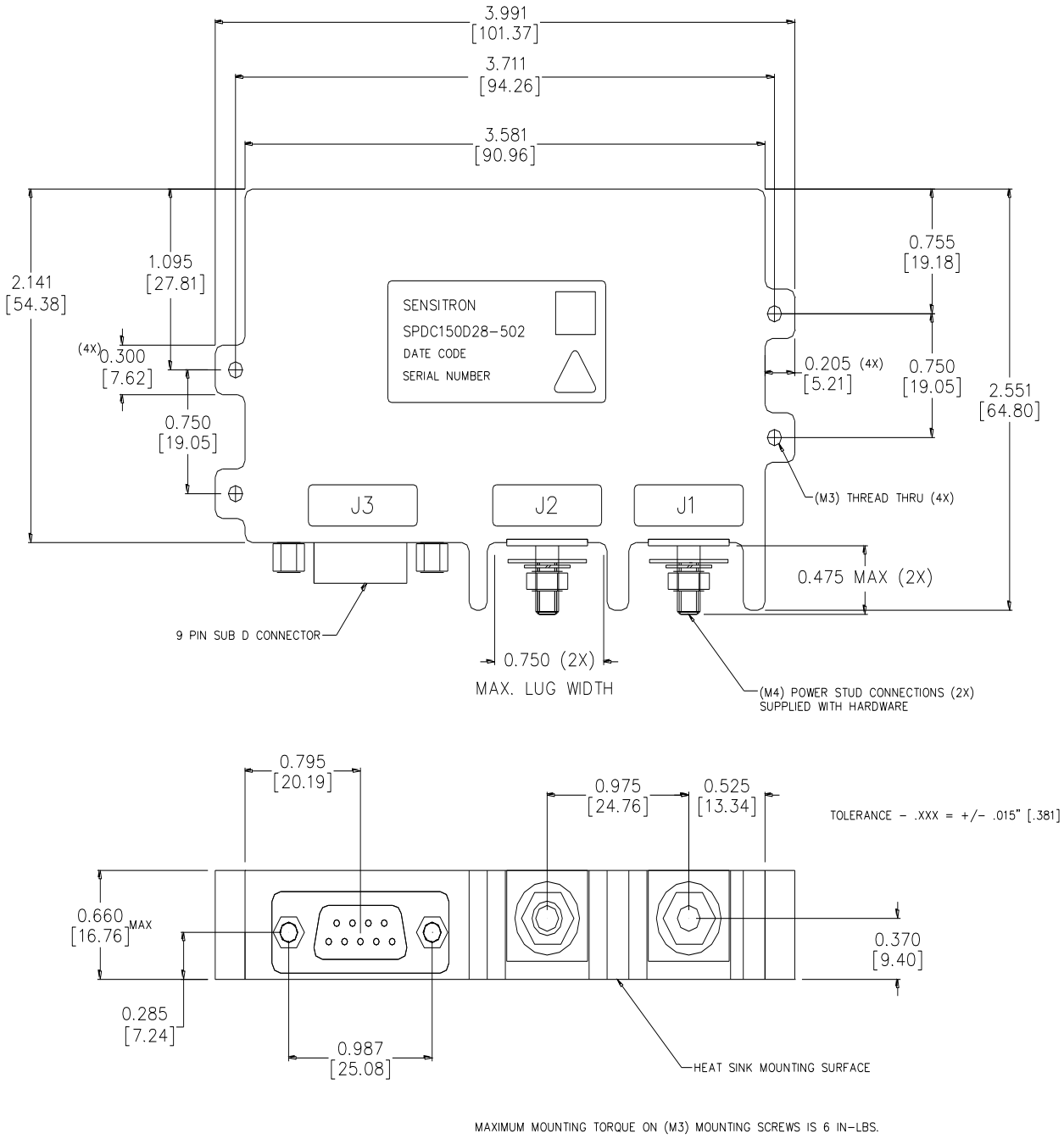
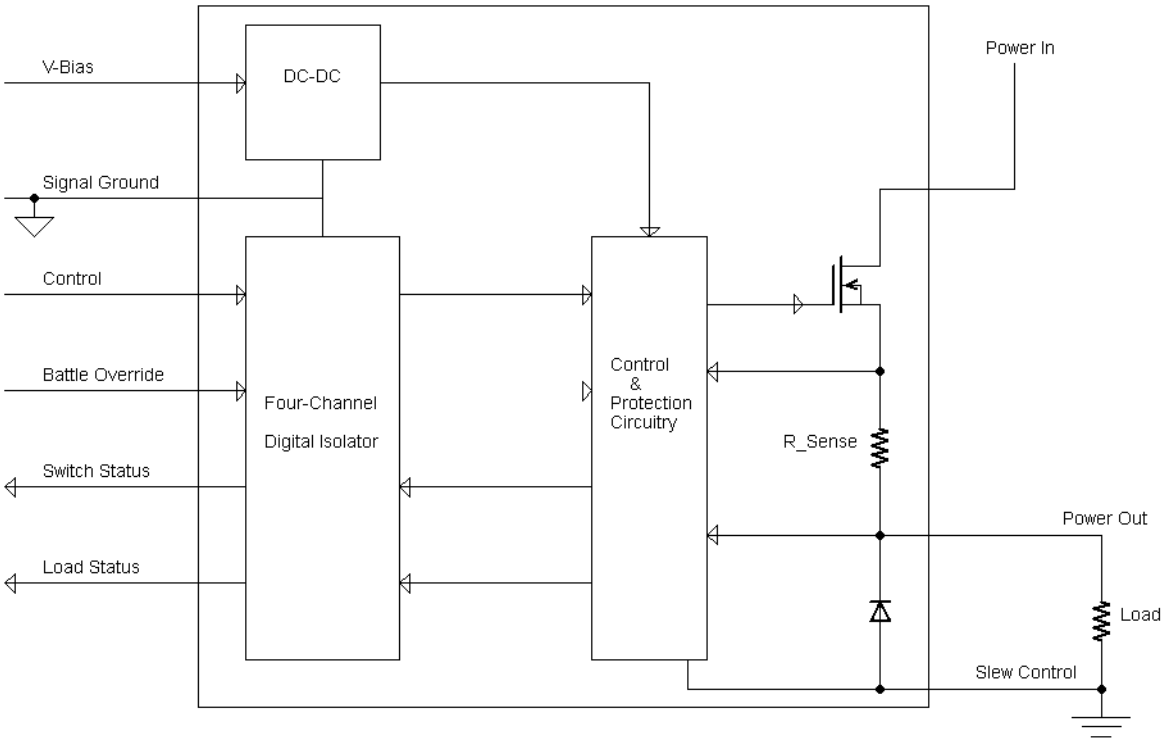


Table 4 – Individual Power Dissipation Data (includes Vbias Power)

	SPDC150D28	SPDC130D28
Current Rating @ 100^{O}C	150A	130A
Power Dissipation (including Control Power)	18W max @ 150A 25^{O}C 23W max @ 150A 100^{O}C	14W max @ 130A 25^{O}C 17W max @ 130A 100^{O}C
Max Voltage Drop	120mV max @ 150A 25^{O}C 150mV max @ 150A 100^{O}C	104mV max @ 130A 25^{O}C 130mV max @ 130A 100^{O}C
Switch Thermal Resistance ($R_{\theta JC}$)	0.1 ^{0}C/W	0.1 ^{0}C/W

Figure 4 - Electrical Block Diagram



Description

Figure 4 shows the block diagram of the SPDC150D28 module. It uses a low-power four channel digital isolator Si8442 device for digital I/O. These are CMOS devices that employ an RF coupler to transmit digital information across an isolation barrier. Very high speed operation at low power levels is achieved. The operation of a Si8442 channel is analogous to that of an opto coupler, except an RF carrier is modulated instead of light. This simple architecture provides a robust isolated data path and requires no special considerations or initialization at start-up. A channel consists of an RF Transmitter and RF Receiver separated by a semiconductor-based isolation barrier. Transmitter input modulates the carrier provided by an RF oscillator using on/off keying. The Receiver contains a demodulator that decodes the input state according to its RF energy content and applies the result to the output via the output driver. This RF on/off keying scheme is superior to pulse code schemes as it provides best-in-class noise immunity, low power consumption, and better immunity to magnetic fields.
Neither the Control or Battle Override inputs, nor the Status outputs, nor the 5VDC VBias are protected against shorts to the 28 VDC Power In voltages. Connecting any of those pins to the 28 VDC Power In voltage, even momentarily, will damage the SSPC, leaving it ON or OFF with incorrect status outputs.

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 firmware 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 SSPC, immediately reflects the command on its input.

BATTLESHORT Mode is asserted when this pin is pulled up, thereby preventing tripping and also causes previously tripped unit to turn back on. Do not use a switch to test this feature since the switch bouncing will likely cause the repeated entry/exit/entry to/form Battle Short Mode. This pin is sampled every 20mS so this effect will not last long but may cause tripped channels to cycle on and off and ending with them on. If not used, this pin may be left open.

Failure Mechanisms: Failures can occur in the DC-DC converter, the I/O logic chip, the microcontroller and the Mosfet switches. A failure in the DC-DC converter will likely turn off the Mosfet switches and leave both status outputs at a logic low. A failure in the logic chip can result in multiple failure modes leaving the Mosfet switches on or off and/or provide incorrect status outputs. A failure in the digital isolator will likely leave the Mosfet switches off or on; the Status outputs will be on or off also. A failure in the microcontroller can have multiple failure modes leaving the Mosfet switches on or off and/or provide incorrect status outputs. Failures in the Mosfets will likely leave the switches on; the Switch Status output will likely be wrong but the Load Status output would reflect the load current. It’s unlikely that the Control input can shut down the Mosfet switches in the event of a failure turning them on.

For overloads, no heat sinking is required provided the SSPC is allowed some time to cool down. The design has sufficient thermal mass that the temperature will rise only a few degrees under the worst-case overload. Repetitive overloads should be avoided, since this might cause the switches in the SSPC to overheat.

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

Logic Outputs

The LOAD STATUS and SWITCH STATUS pins of the SSPC show whether or not the load is drawing current and Power Mosfet switch is on. A logic high on the LOAD STATUS shows that the load draws $\leq$ 5% of rated load and a logic low shows that the load draws $\geq$ 15% of rated current. A load that draws between 5% and 15% of rated current could result in either a high or low logic level on the LOAD STATUS output. Logic high on the SWITCH STATUS indicates that the Power Mosfet switch is on while a logic low indicates that the switch is off.

As can be seen in Table 5, of the 8 possible states for the combination of CONTROL, LOAD STATUS and SWITCH STATUS only 3 states represent valid SSPC operation. The other 5 states indicate either a failed SSPC or, more likely, a short to Vbias Common or a short to the VBias supply of one of the logic outputs. By comparing the CONTROL input with the LOAD STATUS and SWITCH STATUS outputs, the user can determine whether or not the load is supposed to be ON, whether or not it's drawing current and whether or not the LOAD STATUS and SWITCH STATUS outputs are valid responses to the CONTROL input.

Table 5 – CONTROL, LOAD STATUS & SWITCH STATUS Truth Table

State	CONTROL	LOAD STATUS	SWITCH STATUS	Comments
1	L	L	L	SSPC failure or shorted POWER OUT to SIGNAL GROUND
2	L	L	H	SSPC failure
3	L	H	L	Normal OFF condition
4	L	H	H	SSPC failure or shorted LOAD STATUS to V-Bias
5	H	L	L	SSPC failure or shorted LOAD STATUS to SIGNAL GROUND
6	H	L	H	Normal ON condition with load current > 15% rated current
7	H	H	L	Tripped
8	H	H	H	Normal ON condition with load current < 5% rated current

Wire Size

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. 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. To calculate the maximum I^2t for SSPCs of other current rating, take the maximum Instant Trip level, in Amps, and square it and multiply it by the time at which the Instant Trip level intersects the falling I^2t curve. For these devices, the maximum Instant Trip level is at 1000% and it intersects the I^2t curve at 150mS. So, the maximum I^2t rating for the 150 and 130 Amp SSPC would be $(10*150)^2 * 0.15 = 3.375 \times 10^3$ Amp^2-Seconds and $(10*130)^2 * 0.15 = 2.535 \times 10^3$ Amp^2-Seconds respectively.

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Rise Time & Fall Time

The rise SSPC are pre-set at the factory for a nominal rise time of 350µS and a fall time of 300µS with a supply of 28VDC. The rise and fall times will vary linearly with supply voltage. The SLEW CONTROL pin is used to control the rise and fall times. If the SLEW CONTROL pin is left open, the rise and fall times will be about 50uS or less. Leaving the SLEW CONTROL pin open can be useful when a faster rise or fall time is desirable.

With the SLEW CONTROL pin connected as in Figures 5 through 8, the SSPC can turn on into a capacitive load of 22.6 mF typ for SPDC150D28 and 17.5 mF min, 19.6 mF typ for SPDC130D28, without tripping for any power supply voltage within the ratings. The capacitive load capability is proportional to current rating and is calculated as: $C = I_{IT} \times dt/dV$. I_{IT} is the Instant Trip level, dt is the rise time and dV = 22.4V (10 to 90% of 28V). In case of a resistive load in parallel with the capacitive load, simply subtract the resistive load current from I_{IT}.

Application Connections

The SSPC may be configured as a high-side or low-side switch and may be used in positive or negative supply applications.

Figure 5 – High-Side Switch, Positive Supply

Figure 5 shows the connections as a high-side switch with a positive power supply.

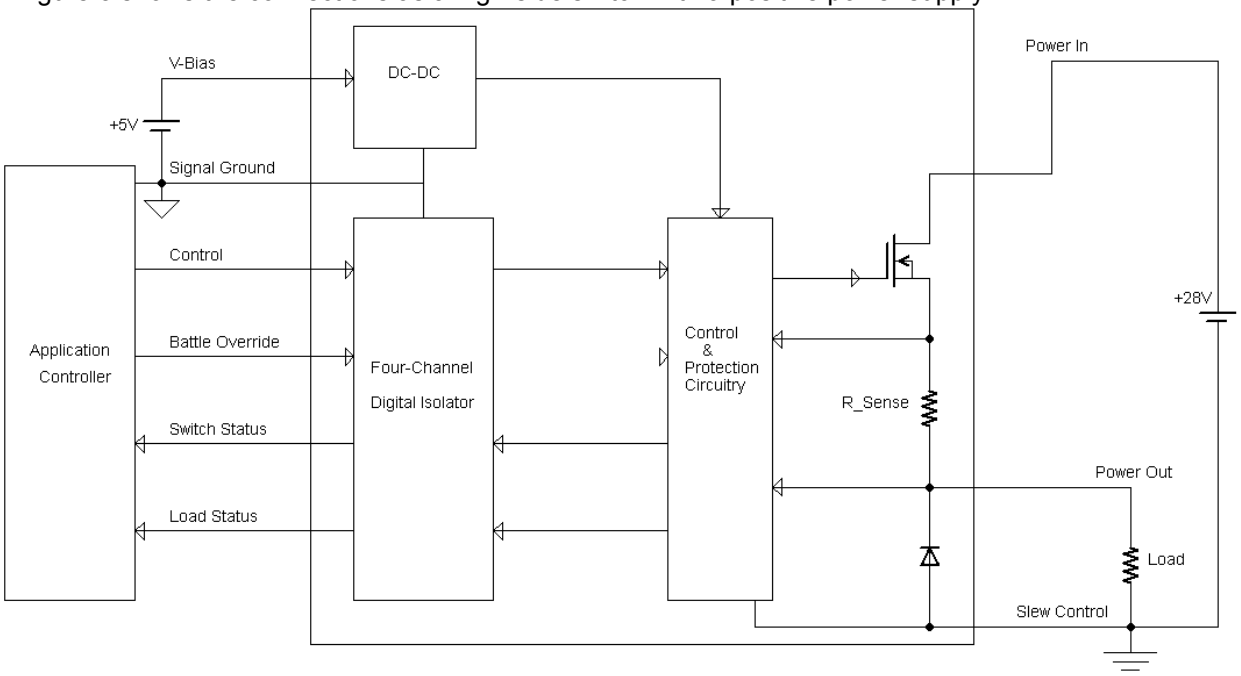
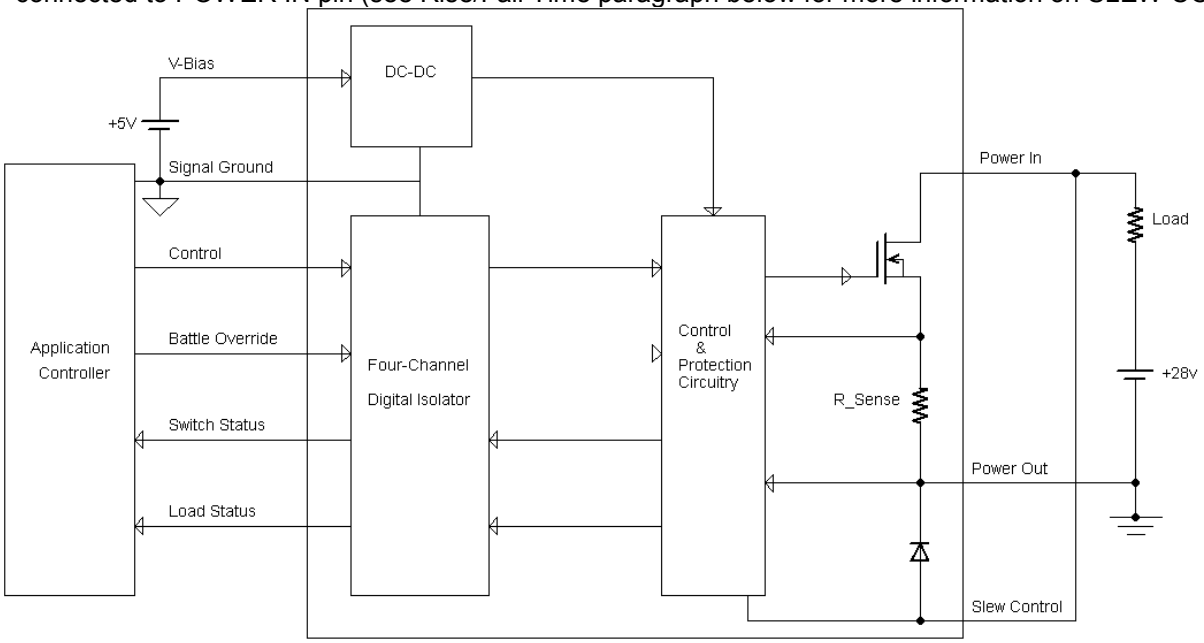


Figure 6 – Low-Side Switch, Positive Supply

Figure 6 shows a low-side switch with a negative power supply. Note that the SLEW CONTROL pin is now connected to POWER IN pin (see Rise/Fall Time paragraph below for more information on SLEW CONTROL).



Figures 7 and Figure 8 show negative supply high-side switch and low-side switch implementations. Again, note the connection of the SLEW CONTROL pin.

Figure 7 – High Side Switch, Negative Supply

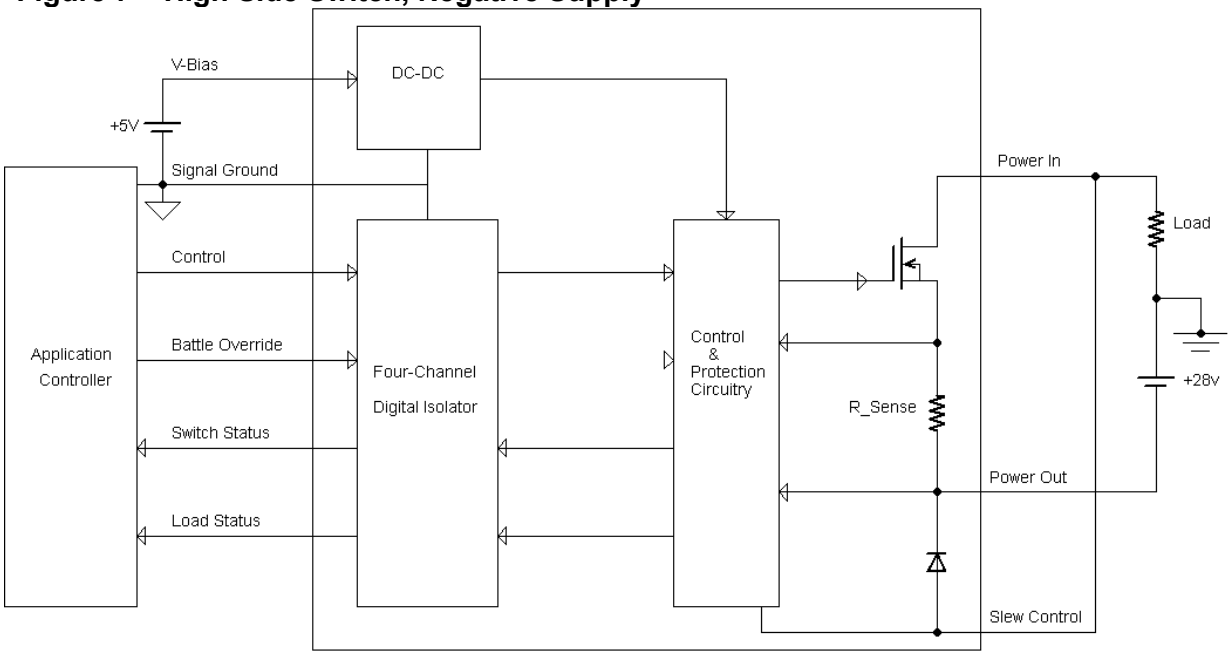
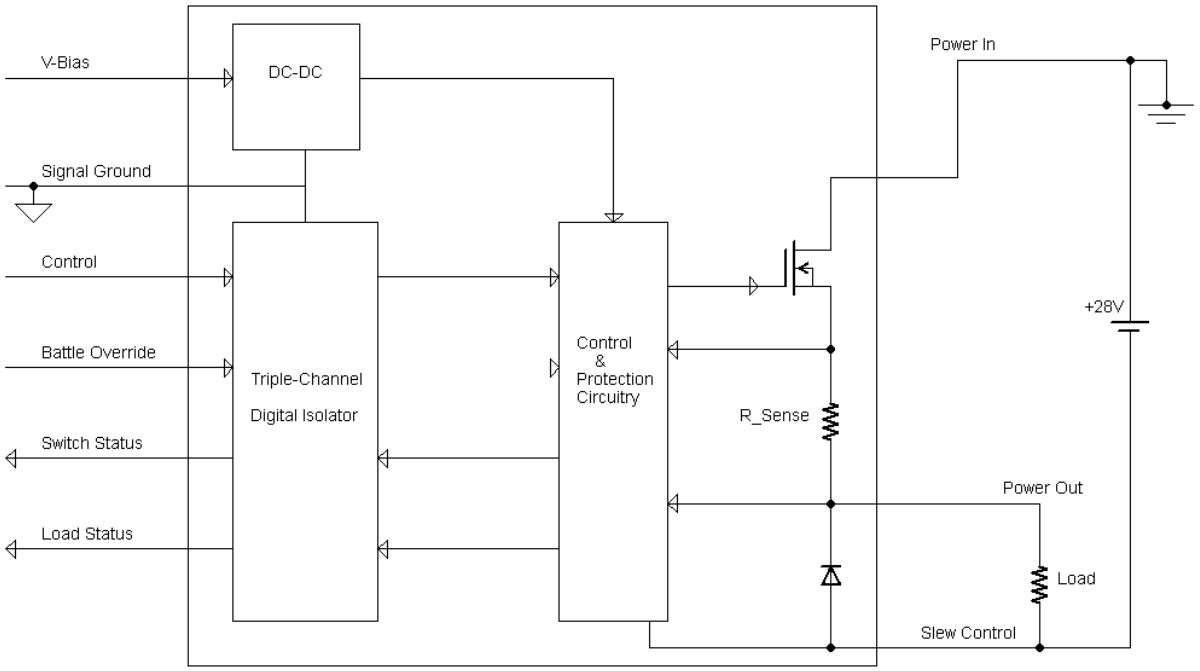


Figure 8 – Low Side Switch, Negative Supply



Wiring and Load Inductance

Wiring inductance can cause voltage transients when the SSPC is switched off due to an overload. Generally, these transients are small but must be considered when long wires are used on either the POWER IN or POWER OUT pins or both. A 2 foot length of wire in free air will cause a transient voltage of about 10 Volts when the 150A SSPC trips at an Instant Trip level of 1200 Amps. At the rated load current, the voltage transient will be about 1 Volt. If longer wire lengths are used, a transient suppressor may be used at the POWER IN pin and a power diode at the POWER OUT pin so that the total voltage between these pins is less than 50 V.

When powering inductive loads, the negative voltage transient at the POWER OUT pin can cause the voltage between POWER IN and POWER OUT to exceed the SSPC rating of 50 Volts and a power diode from the 28V DC LOAD pin to SLEW CONTROL must be used. The cathode of the power diode is connected to the POWER OUT pin with the anode connected to SLEW CONTROL. The power diode must be able to carry the load current when the SSPC switches off. Voltage transients due to wiring or load inductance are proportional to the operating current. Therefore, transients are less of a problem for the lower current SSPC models.

Paralleling

For example, putting two 150A SSPCs in parallel will not double the rating to 300 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 SSPCs in parallel may possibly trip at 225 Amps. Also, both SSPCs will not trip together; the SSPC carrying the higher current will trip first followed by the other SSPC. Multiple SSPCs may be used in parallel as long as these complexities are appreciated. Do not parallel different models of this series as the current sharing will not be predictable.

MIL-STD-704F and MIL-STD-1275B

These standards cover the characteristics of the electrical systems in Military Aircraft and Vehicles. The SSPC 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. The SSPCs also meets all of the requirements of MIL-STD-1275B including operation with Battery and Generator, Generator Only and Battery Only for all of the conditions described in the standard including Cranking, Surges, Spikes and Ripple. In addition, the SSPCs can withstand $\pm$ 600 V spikes for 10µS. This capability is beyond that required by the standards cited above.

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