

## HIGH SIDE SMART POWER SOLID STATE RELAY

| TYPE   | V <sub>DSS</sub> | R <sub>DS(on)</sub> | I <sub>n</sub> (*) | V <sub>CC</sub> |
|--------|------------------|---------------------|--------------------|-----------------|
| VN06SP | 60 V             | 0.18 Ω              | 1.9 A              | 26 V            |

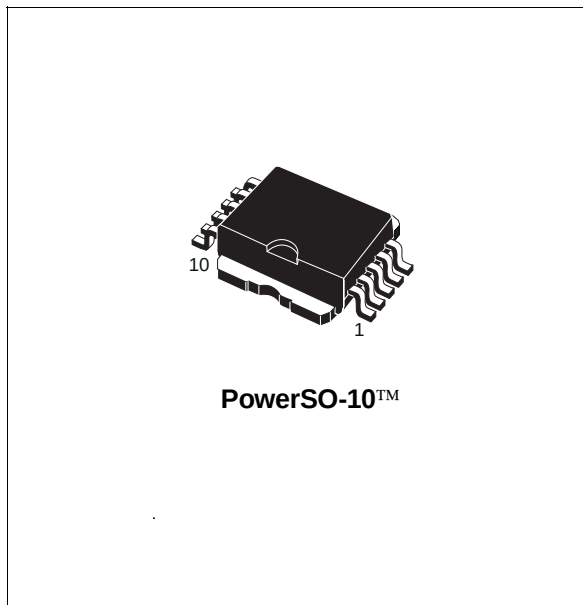
- MAXIMUM CONTINUOUS OUTPUT CURRENT (#): 9 A @ T<sub>c</sub>=85°C
- 5 V LOGIC LEVEL COMPATIBLE INPUT
- THERMAL SHUT-DOWN
- UNDER VOLTAGE PROTECTION
- OPEN DRAIN DIAGNOSTIC OUTPUT
- INDUCTIVE LOAD FAST DEMAGNETIZATION
- VERY LOW STAND-BY POWER DISSIPATION

### DESCRIPTION

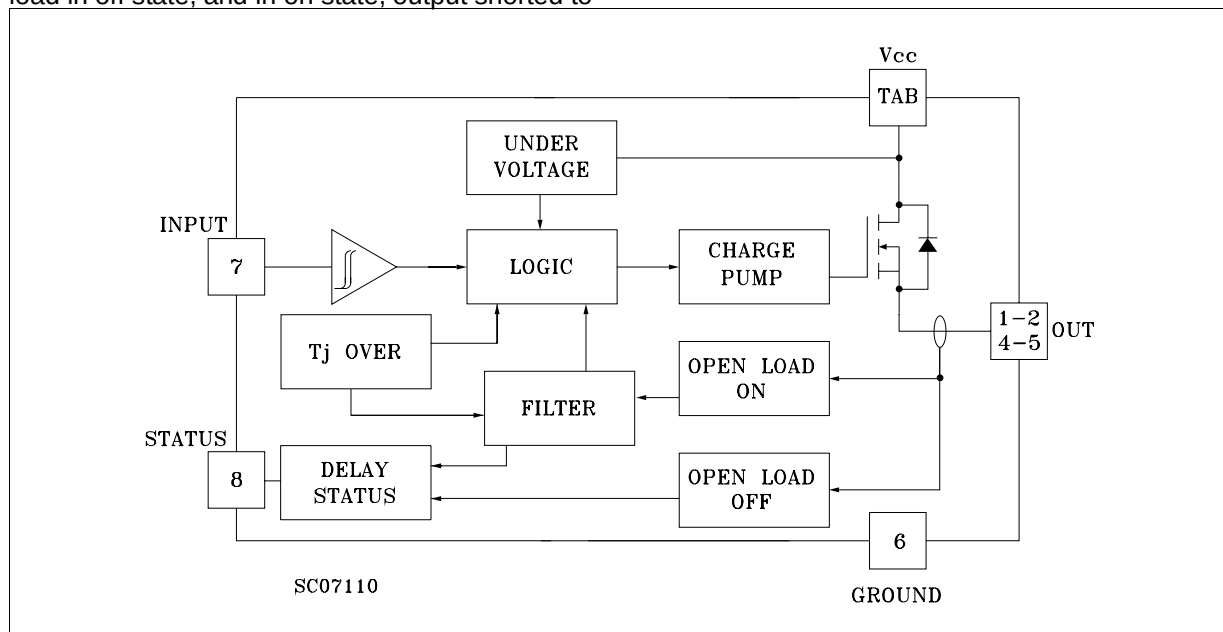
The VN06SP is a monolithic device made using STMicroelectronics VIPower Technology, intended for driving resistive or inductive loads with one side grounded.

Built-in thermal shut-down protects the chip from over temperature and short circuit.

The open drain diagnostic output indicates: open load in off state, and in on state, output shorted to



V<sub>CC</sub> and overtemperature. Fast demagnetization of inductive loads is achieved by negative (-18V) load voltage at turn-off.



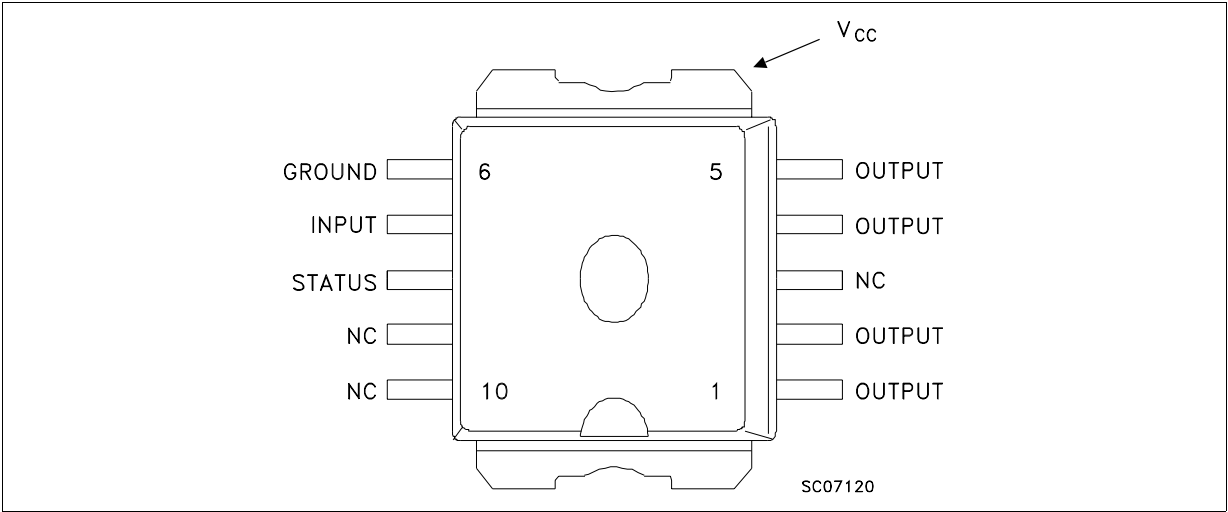
(\*) I<sub>n</sub> = Nominal current according to ISO definition for high side automotive switch (see note 1)

(#) The maximum continuous output current is the the current at T<sub>c</sub> = 85 °C for a battery voltage of 13V which does not activate self protection.

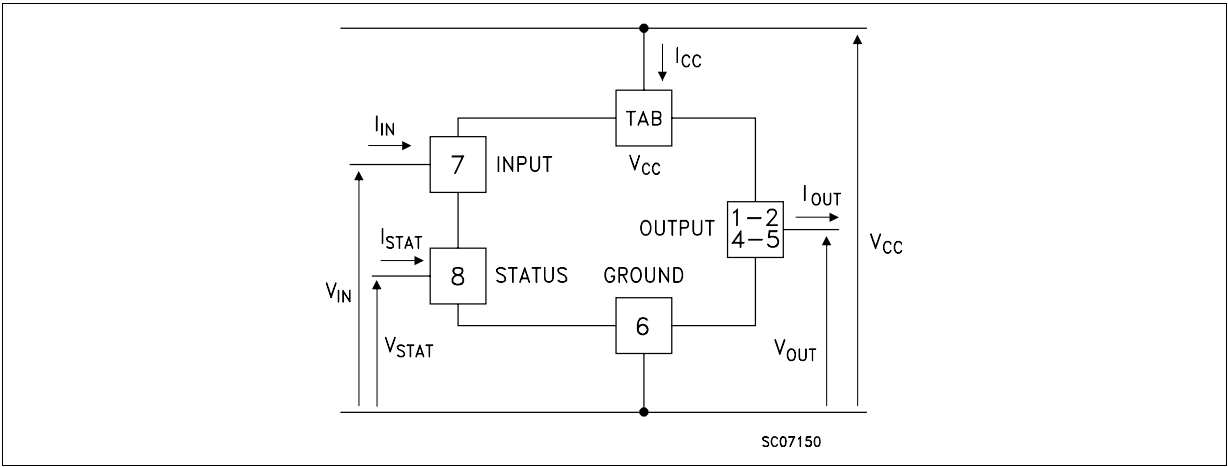
ABSOLUTE MAXIMUM RATING

| Symbol        | Parameter                                                    | Value      | Unit               |
|---------------|--------------------------------------------------------------|------------|--------------------|
| $V_{(BR)DSS}$ | Drain-Source Breakdown Voltage                               | 60         | V                  |
| $I_{OUT}$     | Output Current (cont.) at $T_c = 85\text{ }^{\circ}\text{C}$ | 9          | A                  |
| $I_R$         | Reverse Output Current at $T_c = 85\text{ }^{\circ}\text{C}$ | -9         | A                  |
| $I_{IN}$      | Input Current                                                | $\pm 10$   | mA                 |
| $-V_{CC}$     | Reverse Supply Voltage                                       | -4         | V                  |
| $I_{STAT}$    | Status Current                                               | $\pm 10$   | mA                 |
| $V_{ESD}$     | Electrostatic Discharge (1.5 k $\Omega$ , 100 pF)            | 2000       | V                  |
| $P_{tot}$     | Power Dissipation at $T_c = 85\text{ }^{\circ}\text{C}$      | 27         | W                  |
| $T_j$         | Junction Operating Temperature                               | -40 to 150 | $^{\circ}\text{C}$ |
| $T_{stg}$     | Storage Temperature                                          | -55 to 150 | $^{\circ}\text{C}$ |

CONNECTION DIAGRAMS



CURRENT AND VOLTAGE CONVENTIONS



## THERMAL DATA

|                       |                                     |     |     |      |
|-----------------------|-------------------------------------|-----|-----|------|
| R <sub>thj-case</sub> | Thermal Resistance Junction-case    | Max | 2.4 | °C/W |
| R <sub>thj-amb</sub>  | Thermal Resistance Junction-ambient | Max | 50  | °C/W |

When mounted using minimum recommended pad size on FR-4 board

ELECTRICAL CHARACTERISTICS (V<sub>CC</sub> = 13 V; -40 ≤ T<sub>j</sub> ≤ 125 °C unless otherwise specified)

## POWER

| Symbol               | Parameter            | Test Conditions                                                             | Min. | Typ. | Max.         | Unit     |
|----------------------|----------------------|-----------------------------------------------------------------------------|------|------|--------------|----------|
| V <sub>CC</sub>      | Supply Voltage       |                                                                             | 5.5  | 13   | 26           | V        |
| I <sub>n</sub> (*)   | Nominal Current      | T <sub>c</sub> = 85 °C V <sub>DS(on)</sub> ≤ 0.5 (note 1)                   | 1.9  |      |              | A        |
| R <sub>on</sub>      | On State Resistance  | I <sub>OUT</sub> = 1.9 A<br>I <sub>OUT</sub> = 1.9 A T <sub>j</sub> = 25 °C |      |      | 0.36<br>0.18 | Ω<br>Ω   |
| I <sub>s</sub>       | Supply Current       | Off State T <sub>j</sub> ≥ 25 °C<br>On State                                |      |      | 50<br>15     | μA<br>mA |
| V <sub>DS(MAX)</sub> | Maximum Voltage Drop | I <sub>OUT</sub> = 8.5 A T <sub>c</sub> = 85 °C                             |      |      | 2.75         | V        |

## SWITCHING

| Symbol                  | Parameter                             | Test Conditions                                                     | Min. | Typ. | Max.     | Unit         |
|-------------------------|---------------------------------------|---------------------------------------------------------------------|------|------|----------|--------------|
| t <sub>d(on)</sub> (^)  | Turn-on Delay Time Of Output Current  | I <sub>OUT</sub> = 1.9 A Resistive Load<br>Input Rise Time < 0.1 μs |      | 20   |          | μs           |
| t <sub>r</sub> (^)      | Rise Time Of Output Current           | I <sub>OUT</sub> = 1.9 A Resistive Load<br>Input Rise Time < 0.1 μs |      | 20   |          | μs           |
| t <sub>d(off)</sub> (^) | Turn-off Delay Time Of Output Current | I <sub>OUT</sub> = 1.9 A Resistive Load<br>Input Rise Time < 0.1 μs |      | 25   |          | μs           |
| t <sub>f</sub> (^)      | Fall Time Of Output Current           | I <sub>OUT</sub> = 1.9 A Resistive Load<br>Input Rise Time < 0.1 μs |      | 6    |          | μs           |
| (di/dt) <sub>on</sub>   | Turn-on Current Slope                 | I <sub>OUT</sub> = 1.9 A<br>I <sub>OUT</sub> = I <sub>OV</sub>      |      | 0.08 | 0.5<br>1 | A/μs<br>A/μs |
| (di/dt) <sub>off</sub>  | Turn-off Current Slope                | I <sub>OUT</sub> = 1.9 A<br>I <sub>OUT</sub> = I <sub>OV</sub>      |      | 0.2  | 3<br>3   | A/μs<br>A/μs |
| V <sub>demag</sub>      | Inductive Load Clamp Voltage          | I <sub>OUT</sub> = 1.9 A L = 1 mH                                   | -24  | -18  | -14      | V            |

## LOGIC INPUT

| Symbol                | Parameter                | Test Conditions                                                           | Min. | Typ.      | Max.       | Unit           |
|-----------------------|--------------------------|---------------------------------------------------------------------------|------|-----------|------------|----------------|
| V <sub>IL</sub>       | Input Low Level Voltage  |                                                                           |      |           | 0.8        | V              |
| V <sub>IH</sub>       | Input High Level Voltage |                                                                           | 2    |           | (•)        | V              |
| V <sub>I(hyst.)</sub> | Input Hysteresis Voltage |                                                                           |      | 0.5       |            | V              |
| I <sub>IN</sub>       | Input Current            | V <sub>IN</sub> = 5 V<br>V <sub>IN</sub> = 2 V<br>V <sub>IN</sub> = 0.8 V | 25   | 250       | 500<br>250 | μA<br>μA<br>μA |
| V <sub>ICL</sub>      | Input Clamp Voltage      | I <sub>IN</sub> = 10 mA<br>I <sub>IN</sub> = -10 mA                       | 5.5  | 6<br>-0.7 | -0.3       | V<br>V         |

# ELECTRICAL CHARACTERISTICS (continued) PROTECTION AND DIAGNOSTICS

| Symbol       | Parameter                        | Test Conditions                                                                                               | Min. | Typ.      | Max. | Unit             |
|--------------|----------------------------------|---------------------------------------------------------------------------------------------------------------|------|-----------|------|------------------|
| $V_{STAT}$   | Status Voltage Output Low        | $I_{STAT} = 1.6 \text{ mA}$                                                                                   |      |           | 0.4  | V                |
| $V_{USD}$    | Under Voltage Shut Down          |                                                                                                               |      | 5         |      | V                |
| $V_{SCL}$    | Status Clamp Voltage             | $I_{STAT} = 10 \text{ mA}$<br>$I_{STAT} = -10 \text{ mA}$                                                     |      | 6<br>-0.7 |      | V<br>V           |
| $I_{OV}$     | Over Current                     | $R_{LOAD} < 10 \text{ m}\Omega$ $-40 \text{ }^\circ\text{C} \text{ } T_c \text{ } 125 \text{ }^\circ\text{C}$ |      |           | 60   | A                |
| $I_{AV}$     | Average Current in Short Circuit | $R_{LOAD} < 10 \text{ m}\Omega$ $T_c = 85 \text{ }^\circ\text{C}$                                             |      | 1.4       |      | A                |
| $I_{OL}$     | Open Load Current Level          |                                                                                                               | 5    | 80        | 180  | mA               |
| $T_{TSD}$    | Thermal Shut-down Temperature    |                                                                                                               | 140  |           |      | $^\circ\text{C}$ |
| $T_R$        | Reset Temperature                |                                                                                                               | 125  |           |      | $^\circ\text{C}$ |
| $V_{OL}$     | Open Load Voltage Level          | Off-State (note 2)                                                                                            | 2.5  | 3.75      | 5    | V                |
| $t_{1(on)}$  | Open Load Filtering Time         | (note 3)                                                                                                      | 1    | 5         | 10   | ms               |
| $t_{1(off)}$ | Open Load Filtering Time         | (note 3)                                                                                                      | 1    | 5         | 10   | ms               |
| $t_{2(off)}$ | Open Load Filtering Time         | (note 3)                                                                                                      | 1    | 5         | 10   | ms               |
| $t_{povl}$   | Status Delay                     | (note 3)                                                                                                      |      | 5         | 10   | $\mu\text{s}$    |
| $t_{pol}$    | Status Delay                     | (note 3)                                                                                                      | 50   | 700       |      | $\mu\text{s}$    |

(^\*) See Switching Time Waveforms

() The  $V_{IH}$  is internally clamped at 6V about. It is possible to connect this pin to an higher voltage via an external resistor calculated to not exceed 10 mA at the input pin.

note 1: The Nominal Current is the current at  $T_c = 85 \text{ }^\circ\text{C}$  for battery voltage of 13V which produces a voltage drop of 0.5 V

note 2:  $I_{OL(off)} = (V_{CC} - V_{OL})/R_{OL}$  (see figure)

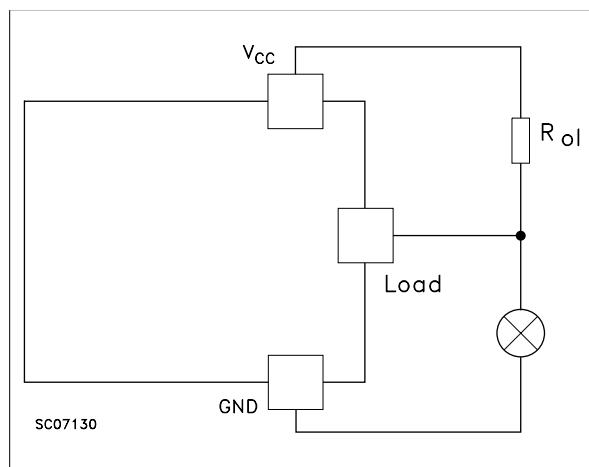
note 3:  $t_{1(on)}$ : minimum open load duration which activates the status output

$t_{1(off)}$ : minimum load recovery time which desactivates the status output

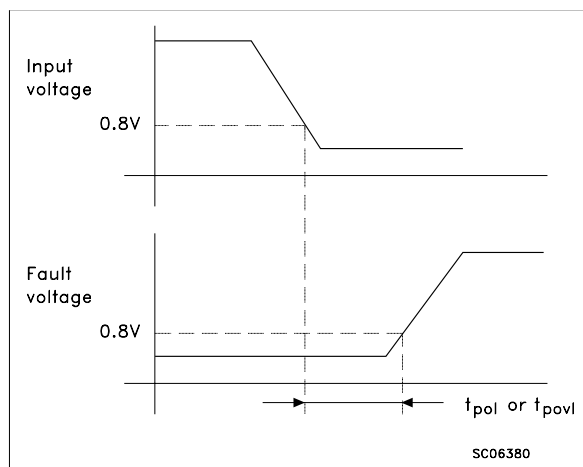
$t_{2(off)}$ : minimum on time after thermal shut down which desactivates status output

$t_{povl}$   $t_{pol}$ : ISO definition (see figure).

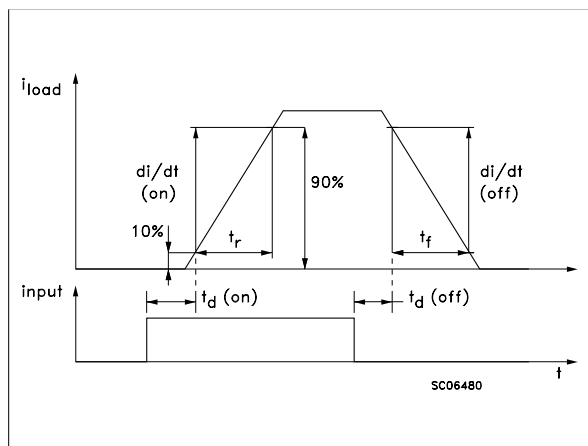
Note 2 Relevant Figure



Note 3 Relevant Figure



## Switching Time Waveforms



## FUNCTIONAL DESCRIPTION

The device has a diagnostic output which indicates open load conditions in off state as well as in on state, output shorted to  $V_{CC}$  and overtemperature. The truth table shows input, diagnostic and output voltage level in normal operation and in fault conditions. The output signals are processed by internal logic. The open load diagnostic output has a 5 ms filtering. The filter gives a continuous signal for the fault condition after an initial delay of about 5 ms. This means that a disconnection during normal operation, with a duration of less than 5 ms does not affect the status output. Equally, any re-connection of less than 5 ms during a disconnection duration does not affect the status output. No delay occurs for the status to go low in case of overtemperature conditions. From the falling edge of the input signal the status output initially low in fault condition (over temperature or open load) will go back with a delay ( $t_{povl}$ ) in case of overtemperature condition and a delay ( $t_{pol}$ ) in case of open load. These features fully comply with International Standard Organization (I.S.O.) requirements for automotive High Side Driver.

To protect the device against short circuit and over current conditions, the thermal protection turns the integrated Power MOS off at a minimum junction temperature of 140 °C. When the temperature returns to 125 °C the switch is automatically turned on again. In short circuit the protection reacts with virtually no delay, the sensor being located in the region of the die where the heat is generated. Driving inductive loads, an internal function of the device ensures the fast demagnetization with a

typical voltage ( $V_{demag}$ ) of -18V.

This function allows to greatly reduce the power dissipation according to the formula:

$$P_{dem} = 0.5 \cdot L_{load} \cdot (I_{load})^2 \cdot [(V_{CC} + V_{demag}) / V_{demag}] \cdot f$$

where  $f$  = switching frequency and  $V_{demag}$  = demagnetization voltage

Based on this formula it is possible to know the value of inductance and/or current to avoid a thermal shut-down. The maximum inductance which causes the chip temperature to reach the shut down temperature in a specific thermal environment, is in fact a function of the load current for a fixed  $V_{CC}$ ,  $V_{demag}$  and  $f$ .

## PROTECTING THE DEVICE AGAINST LOAD DUMP - TEST PULSE 5

The device is able to withstand the test pulse No. 5 at level II ( $V_s = 46.5V$ ) according to the ISO T/R 7637/1 without any external component. This means that all functions of the device are performed as designed after exposure to disturbance at level II. The VN06SP is able to withstand the test pulse No.5 at level III adding an external resistor of 150 ohm between GND pin and ground plus a filter capacitor of 1000  $\mu F$  between  $V_{CC}$  pin and ground (if  $R_{LOAD} \leq 20 \Omega$ ).

## PROTECTING THE DEVICE AGAINST REVERSE BATTERY

The simplest way to protect the device against a continuous reverse battery voltage (-26V) is to insert a Schottky diode between GND pin and ground, as shown in the typical application circuit (fig.3).

The consequences of the voltage drop across this diode are as follows:

If the input is pulled to power GND, a negative voltage of  $-V_f$  is seen by the device. ( $V_{il}$ ,  $V_{ih}$  thresholds and  $V_{stat}$  are increased by  $V_f$  with respect to power GND).

The undervoltage shutdown level is increased by  $V_f$ .

If there is no need for the control unit to handle external analog signals referred to the power GND, the best approach is to connect the reference potential of the control unit to node [6] (see application circuit in fig. 4), which becomes the common signal GND for the whole control board avoiding shift of  $V_{ih}$ ,  $V_{il}$  and  $V_{stat}$ . This solution allows the use of a standard diode.

TRUTH TABLE

|                               | INPUT | OUTPUT | DIAGNOSTIC |
|-------------------------------|-------|--------|------------|
| Normal Operation              | L     | L      | H          |
|                               | H     | H      | H          |
| Open Circuit (No Load)        | H     | H      | L          |
| Over-temperature              | H     | L      | L          |
| Under-voltage                 | X     | L      | H          |
| Short load to V <sub>CC</sub> | L     | H      | L          |

Figure 1: Waveforms

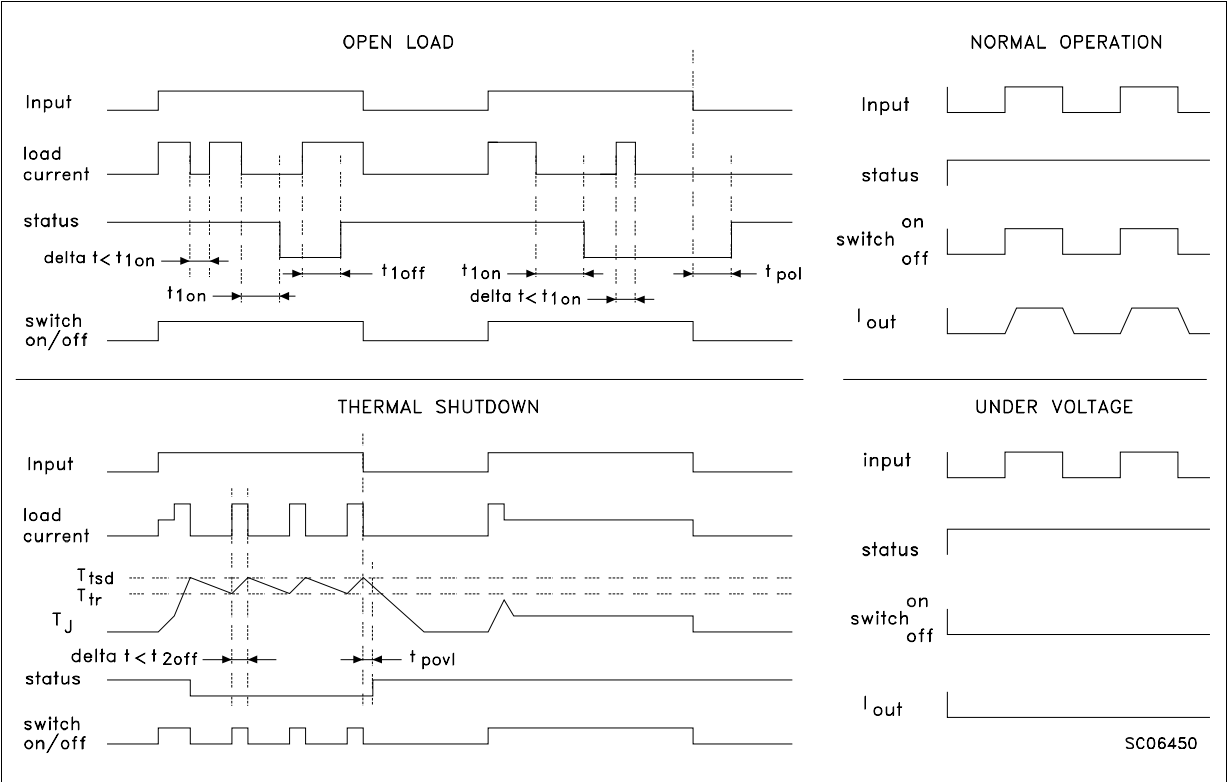
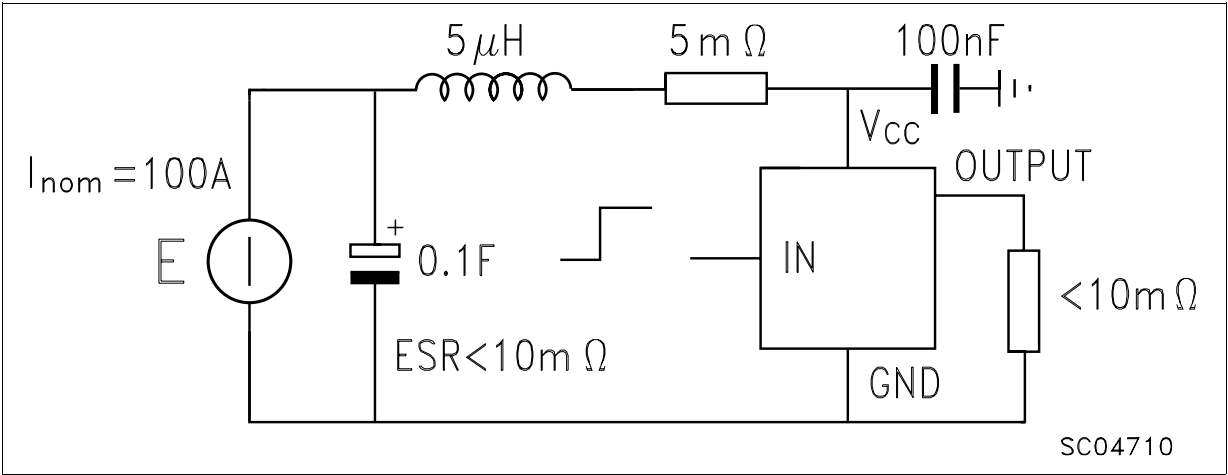
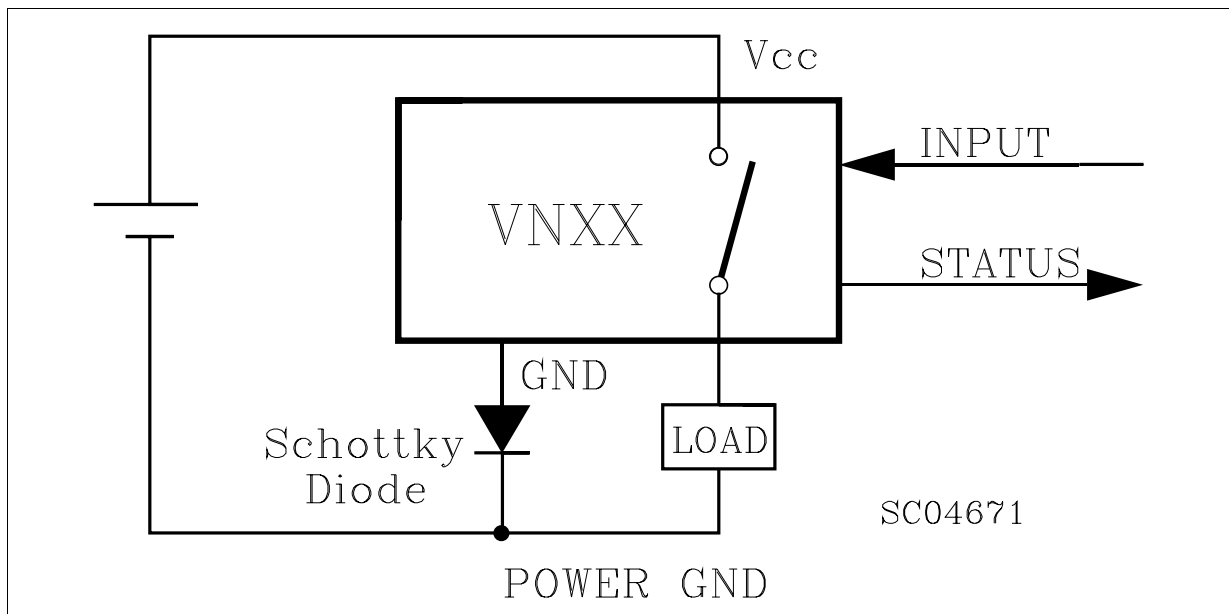
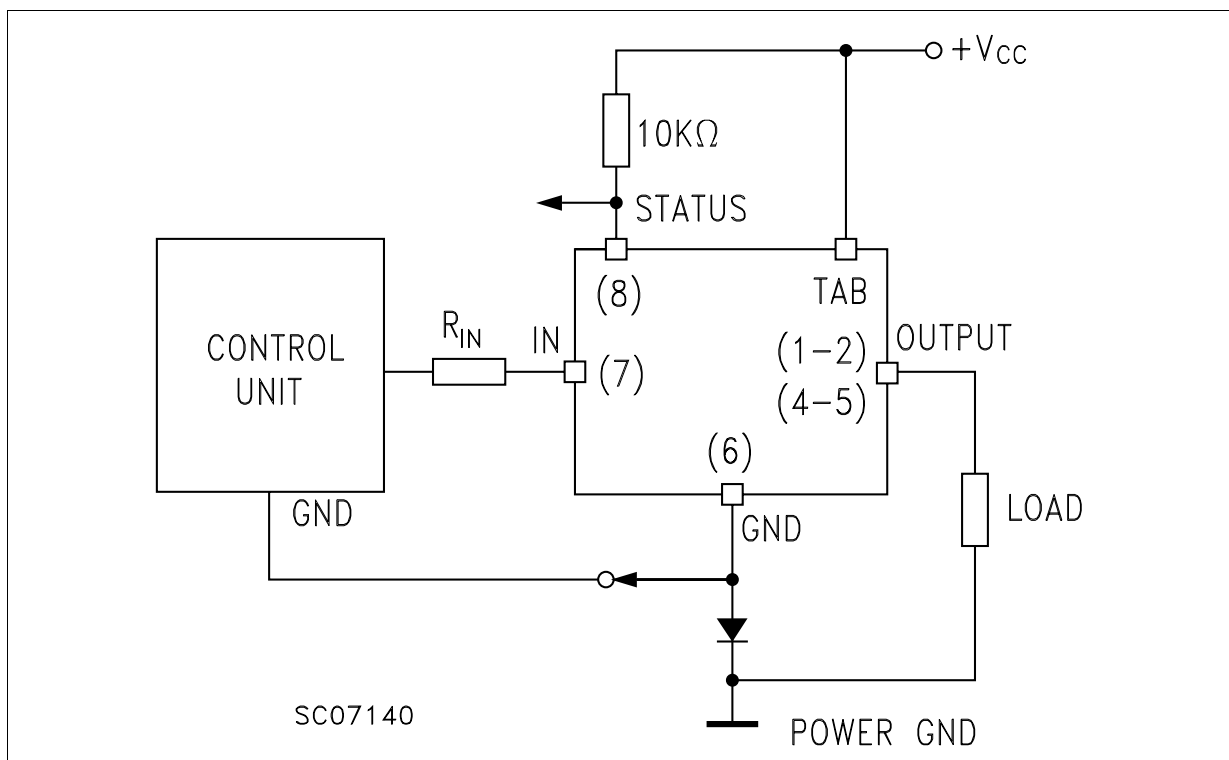


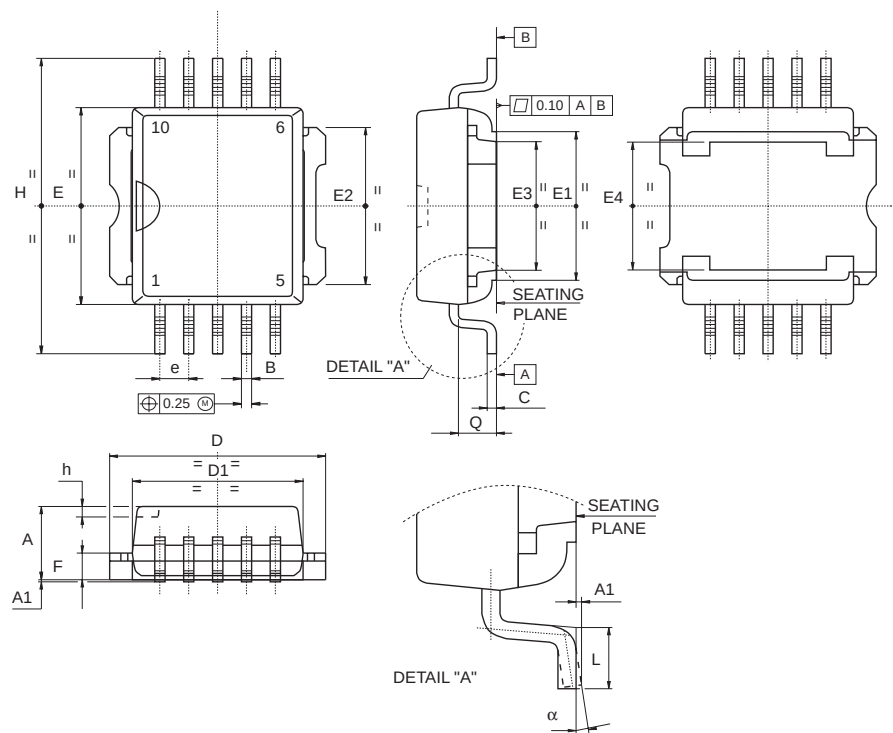
Figure 2: Over Current Test Circuit



**Figure 3:** Typical Application Circuit With A Schottky Diode For Reverse Supply Protection**Figure 4:** Typical Application Circuit With Separate Signal Ground

PowerSO-10 MECHANICAL DATA

| DIM.     | mm    |      |       | inch  |       |       |
|----------|-------|------|-------|-------|-------|-------|
|          | MIN.  | TYP. | MAX.  | MIN.  | TYP.  | MAX.  |
| A        | 3.35  |      | 3.65  | 0.132 |       | 0.144 |
| A1       | 0.00  |      | 0.10  | 0.000 |       | 0.004 |
| B        | 0.40  |      | 0.60  | 0.016 |       | 0.024 |
| c        | 0.35  |      | 0.55  | 0.013 |       | 0.022 |
| D        | 9.40  |      | 9.60  | 0.370 |       | 0.378 |
| D1       | 7.40  |      | 7.60  | 0.291 |       | 0.300 |
| E        | 9.30  |      | 9.50  | 0.366 |       | 0.374 |
| E1       | 7.20  |      | 7.40  | 0.283 |       | 0.291 |
| E2       | 7.20  |      | 7.60  | 0.283 |       | 0.300 |
| E3       | 6.10  |      | 6.35  | 0.240 |       | 0.250 |
| E4       | 5.90  |      | 6.10  | 0.232 |       | 0.240 |
| e        |       | 1.27 |       |       | 0.050 |       |
| F        | 1.25  |      | 1.35  | 0.049 |       | 0.053 |
| H        | 13.80 |      | 14.40 | 0.543 |       | 0.567 |
| h        |       | 0.50 |       |       | 0.002 |       |
| L        | 1.20  |      | 1.80  | 0.047 |       | 0.071 |
| q        |       | 1.70 |       |       | 0.067 |       |
| $\alpha$ | 0°    |      | 8°    |       |       |       |



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