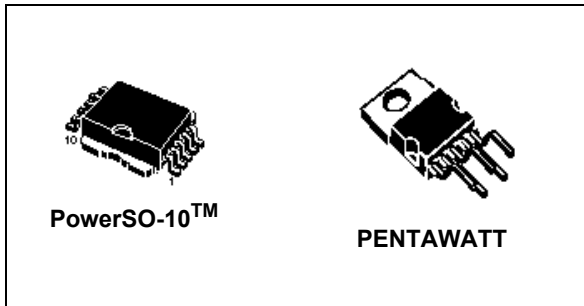


Single high-side smart power solid state relay

Datasheet - production data



- Protection against:
 - Loss of ground
 - Shorted load and overtemperature
- Built-in current limiter
- Undervoltage shutdown
- Open drain diagnostic output
- Fast demagnetization of inductive loads

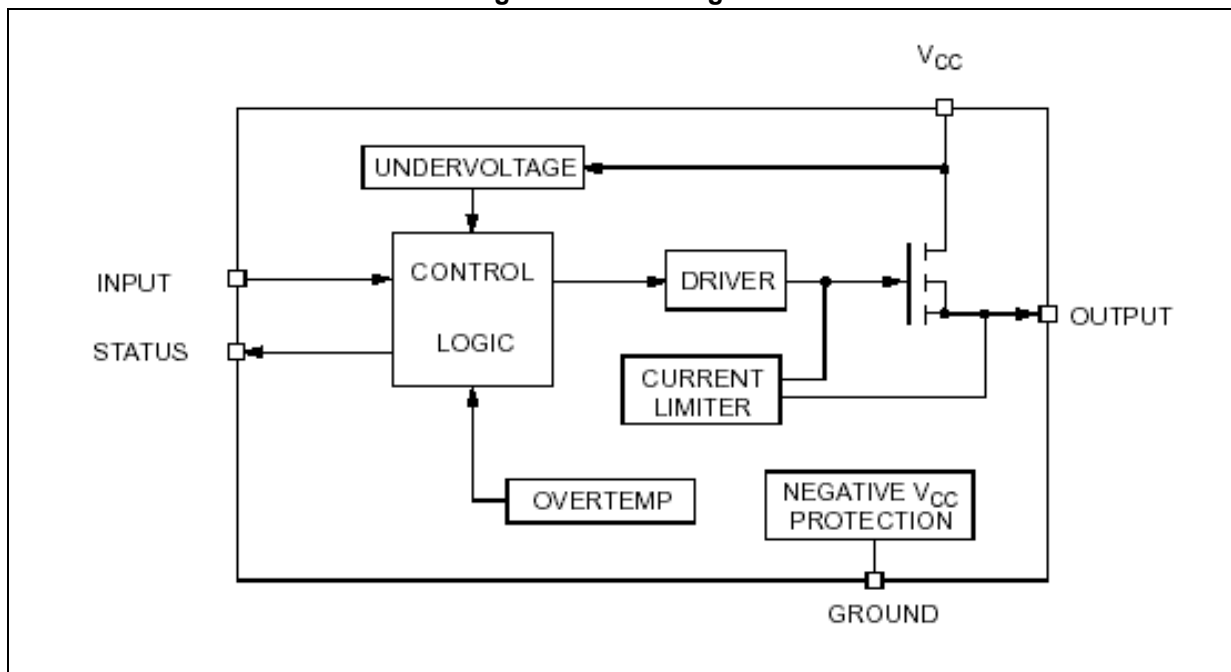
Features

- 10 V to 36 V supply voltage range
- Up to $I_{OUT} = 2.8$ A operating current
- $R_{DS(on)}$: 50 m Ω
- $V_{demag} = V_{CC} - 55$ V
- Digital input clamped at 32 V

Description

The VN540-E and VN540SP-E are monolithic devices designed in STMicroelectronics VIPower technology, intended for driving resistive or inductive loads with one side connected to ground. Active current limitation avoids the system power supply dropping in case of shorted load. Built-in thermal shutdown protects the chip from overtemperature. The open drain diagnostic output indicates overtemperature conditions.

Figure 1. Block diagram



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1 Absolute maximum rating

Table 1. Absolute maximum rating

| Symbol | Parameter | Value | Unit |
|------------|---|--------------------|------|
| V_{CC} | Power supply voltage | 45 | V |
| $-V_{CC}$ | Reverse supply voltage | -4.0 | V |
| I_{OUT} | Maximum DC load current | Internally limited | A |
| I_R | Reverse output current | -10 | A |
| I_{IN} | Input current | ± 10 | mA |
| I_{STAT} | Status pin current | ± 10 | mA |
| V_{ESD} | Electrostatic discharge (R = 1.5 KW; C = 100 pF) | 2000 | V |
| P_{TOT} | Power dissipation (see thermal thresholds in Table 6 on page 7) | Internally limited | W |
| T_J | Junction operating temperature | Internally limited | °C |
| T_{STG} | Storage temperature | -55 to 150 | °C |
| E_{AS} | Single pulse avalanche energy ($T_{amb} = 125\text{ °C}$, $V_{CC} = 24\text{ V}$, $I_{load} = 2.0\text{ A}$) | 12 | J |

2 Pin connections

Figure 2. Connection diagram (top view)

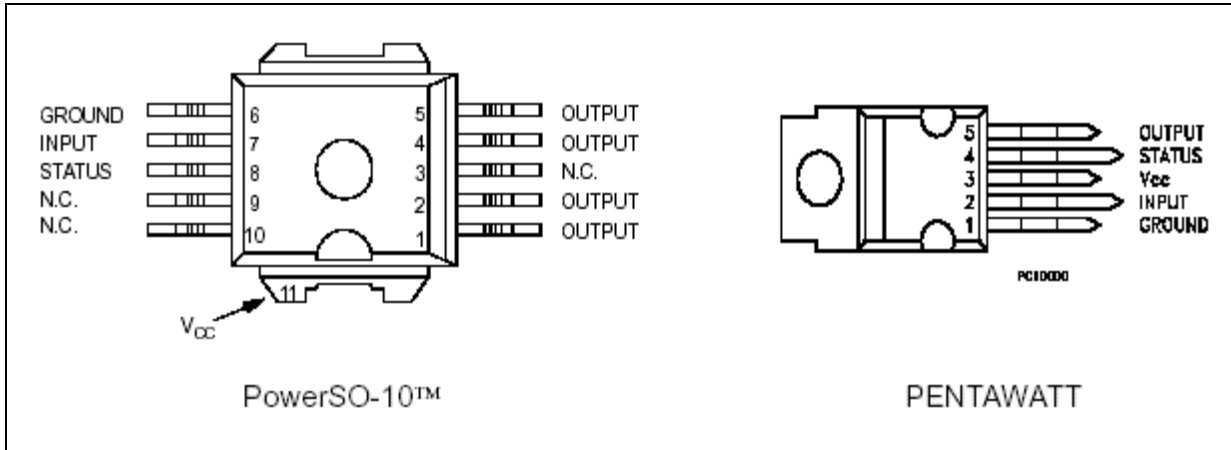
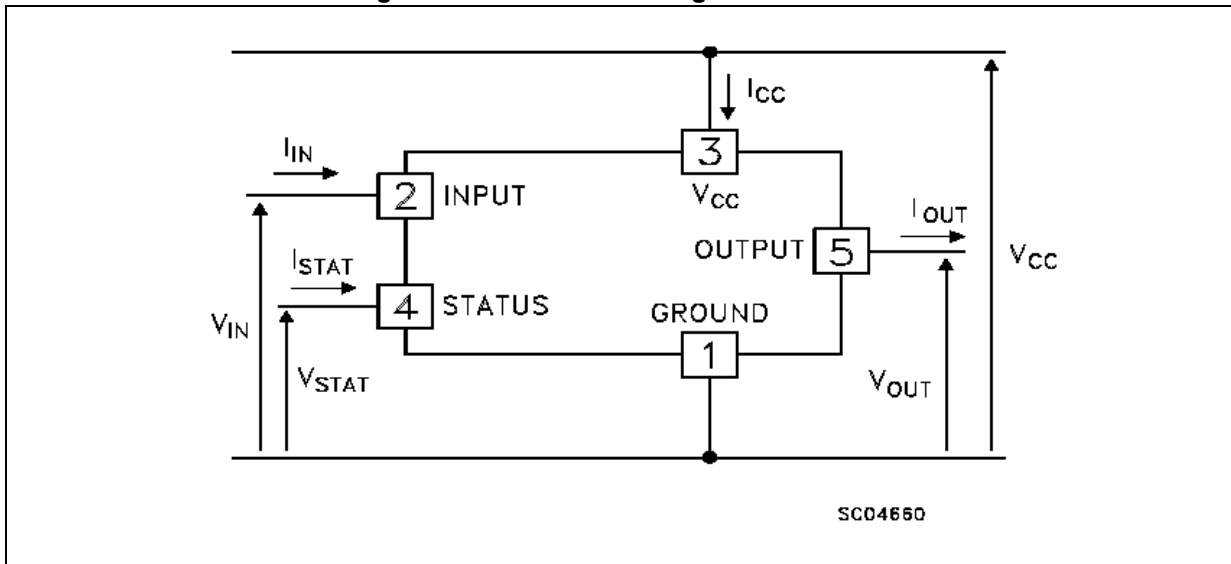


Figure 3. Current and voltage conventions



3 Thermal data

Table 2. Thermal data

| Symbol | Parameter | | Value | | Unit |
|------------|-------------------------------------|------|------------|-----------|---------------|
| | | | PowerSO-10 | PENTAWATT | |
| R_{thJC} | Thermal resistance junction-case | Max. | 1.5 | 2.0 | $^{\circ}C/W$ |
| R_{thJA} | Thermal resistance junction-ambient | Max. | 50 | 60 | $^{\circ}C/W$ |

4 Electrical characteristics

Electrical characteristics (10 V < V_{CC} < 36 V; -25 °C < T_J < 85 °C; unless otherwise specified).

Table 3. Power section

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|--------------------|----------------------------|--|----------------------|----------------------|----------------------|----------|
| V _{CC} | Supply voltage | | 10 | - | 36 | V |
| R _{ON} | On state resistance | I _{OUT} = 2.8 A; T _J = 25 °C I _{OUT} = 2.8 A | - | - | 50 90 | mΩ mΩ |
| I _S | Supply current | OFF state ON state; T _J = 125 °C I _{OUT} = 0 A | - | - | 1 3 | mA mA |
| I _{LS} | Output leakage current | Channel OFF V _{CC} = 45 V | - | - | 100 | μA |
| I _{LGND} | Output current at turn-off | V _{CC} = V _{IN} = V _{GND} = V _{STAT} = 24 V T _J = -25 °C < T _J < 100 °C | - | - | 2 | mA |
| V _{OL} | Low state output voltage | V _{IN} = V _{IL} ; R _{LOAD} ≥ 10 MΩ | - | - | 1.5 | V |
| V _{demag} | Output voltage at turn-off | I _{OUT} = 2.8 A; L _{LOAD} ≥ 1 mH | V _{CC} - 65 | V _{CC} - 55 | V _{CC} - 45 | V |

Table 4. Switching

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|------------------------|---------------------------------------|--|------|------|----------|------|
| t _{d(ON)} | Turn-on delay on output current | I _{OUT} = 2.8 A, resistive load input rise time < 0.1 s, V _{CC} = 24 V; T _J = 25 °C | - | 40 | - | μs |
| t _r | Rise time of output current | I _{OUT} = 2.8 A, resistive load input rise time < 0.1 s, V _{CC} = 24 V; T _J = 25 °C | - | 60 | - | μs |
| t _{d(OFF)} | Turn-off delay time of output current | I _{OUT} = 2.8 A, resistive load input rise time < 0.1 s, V _{CC} = 24 V; T _J = 25 °C | - | 60 | - | μs |
| t _f | Fall time of output current | I _{OUT} = 2.8 A, resistive load input rise time < 0.1 s, V _{CC} = 24 V; T _J = 25 °C | - | 25 | - | μs |
| dI/dt _(on) | Turn-on current average slope | I _{OUT} = 2.8 A, I _{OUT} = I _{LIM} ; 25 °C < T _J < 140 °C | - | - | 0.5 2 | A/μs |
| dI/dt _(off) | Turn-off current average slope | I _{OUT} = 2.8 A, I _{OUT} = I _{LIM} ; 25 °C < T _J < 140 °C | - | - | 2 4 | A/μs |

Table 5. Logical input

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---------------|--|---|---------|------------|----------|--------------------------------|
| V_{IL} | Input low level voltage | - | - | - | 2.0 | V |
| V_{IH} | Input high level voltage | - | 3.5 | - | - | V |
| $V_{I(HYST)}$ | Input hysteresis voltage | - | - | 0.5 | - | V |
| I_{IN} | Input current | $V_{IN} = 30\text{ V}$ $V_{IN} = 2.0\text{ V}$ | - 25 | - - | 300 - | μA μA |
| V_{ICL} | I/O input clamp voltage ⁽¹⁾ | $I_{IN} = 1\text{ mA}$ $I_{IN} = -1\text{ mA}$ | 32 - | 36 -0.7 | - - | V V |

1. The input voltage is internally clamped at 32 V minimum, it is possible to connect the input pins to a higher voltage via an external resistor calculate to not exceed 10 mA.

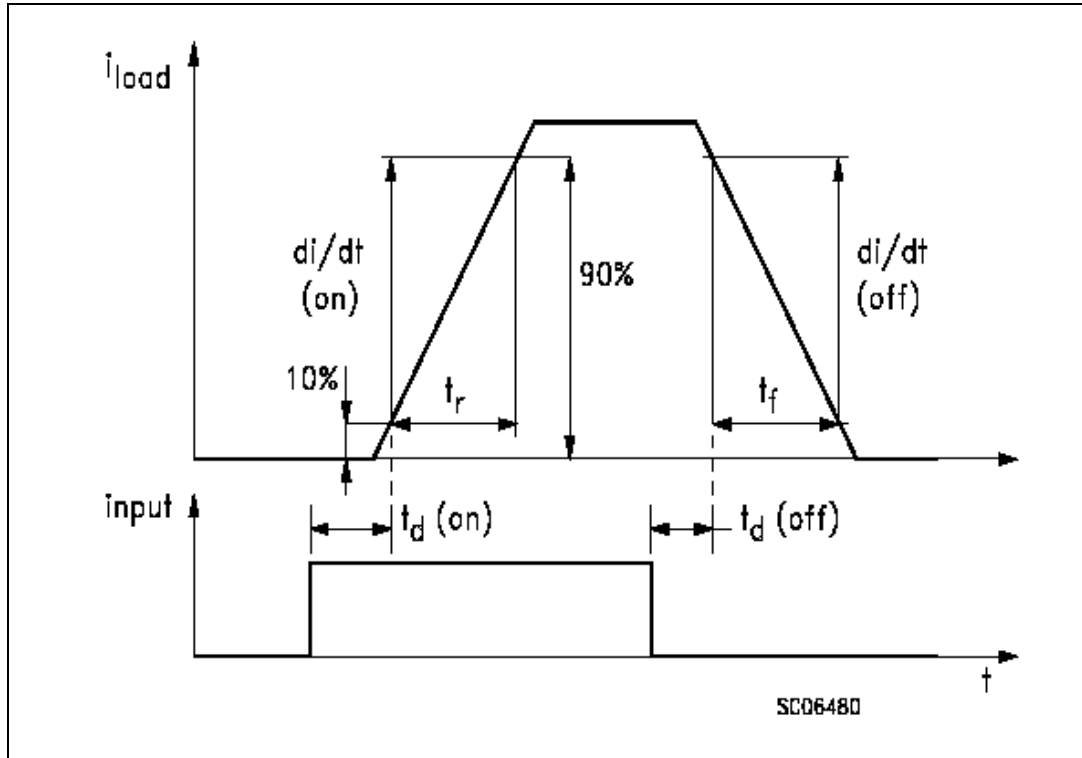
Table 6. Protection and diagnostic

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|-----------------|---|---|------|------------|--------|--------------------|
| V_{STAT} | Status output voltage | $I_{STAT} = 5\text{ mA}$ (fault condition) | - | - | 1 | V |
| $V_{SCL}^{(1)}$ | Status clamp voltage | $I_{STAT} = 1\text{ mA}$ $I_{STAT} = -1\text{ mA}$ | 32 | 36 -0.7 | - - | V V |
| I_{STAT} | Leakage on diagnostic pin in high state | $V_{STAT} = 5\text{ V}$ | - | - | - | μA |
| V_{USD} | Undervoltage shutdown | - | 5.0 | - | 8.0 | V |
| I_{LIM} | DC short-circuit current | $V_{CC} = 24\text{ V}$; $R_{LOAD} < 10\text{ m}\Omega$ | 2.8 | 5.0 | 8.0 | A |
| I_{OVPK} | Peak short-circuit current | $V_{CC} = 24\text{ V}$; $V_{IN} = 30$; $R_{LOAD} < 10\text{ m}\Omega$ | - | - | 4 | A |
| t_{SC} | Delay time of current limiter | - | - | - | 100 | μs |
| T_{TSD} | Thermal shutdown temperature | - | 150 | 170 | - | $^{\circ}\text{C}$ |
| T_R | Thermal reset temperature | - | 135 | 155 | - | $^{\circ}\text{C}$ |

1. Status determination > 100 ms after the switching edge.

5 Switching characteristics

Figure 4. Switching characteristics



6 Truth table

Table 7. Truth table

| Conditions | INPUT | OUTPUT | STATUS |
|--------------------------------------|-------|--------|--------|
| Normal operation | L | L | H |
| | H | H | H |
| Overtemperature | L | L | H |
| | H | L | L |
| Undervoltage | L | L | H |
| | H | L | H |
| Shorted load (current limitation) | L | L | H |
| | H | H | H |

7 Test circuits and waveforms

Figure 5. Peak short test circuit

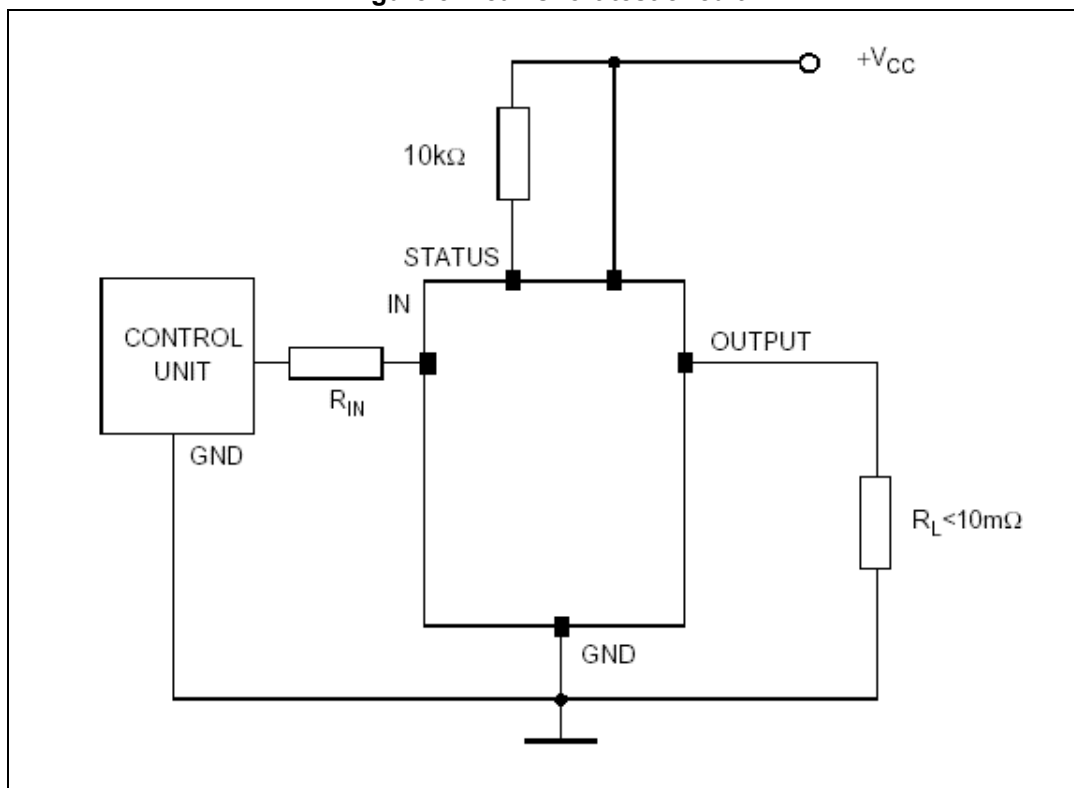


Figure 6. Switching waveforms

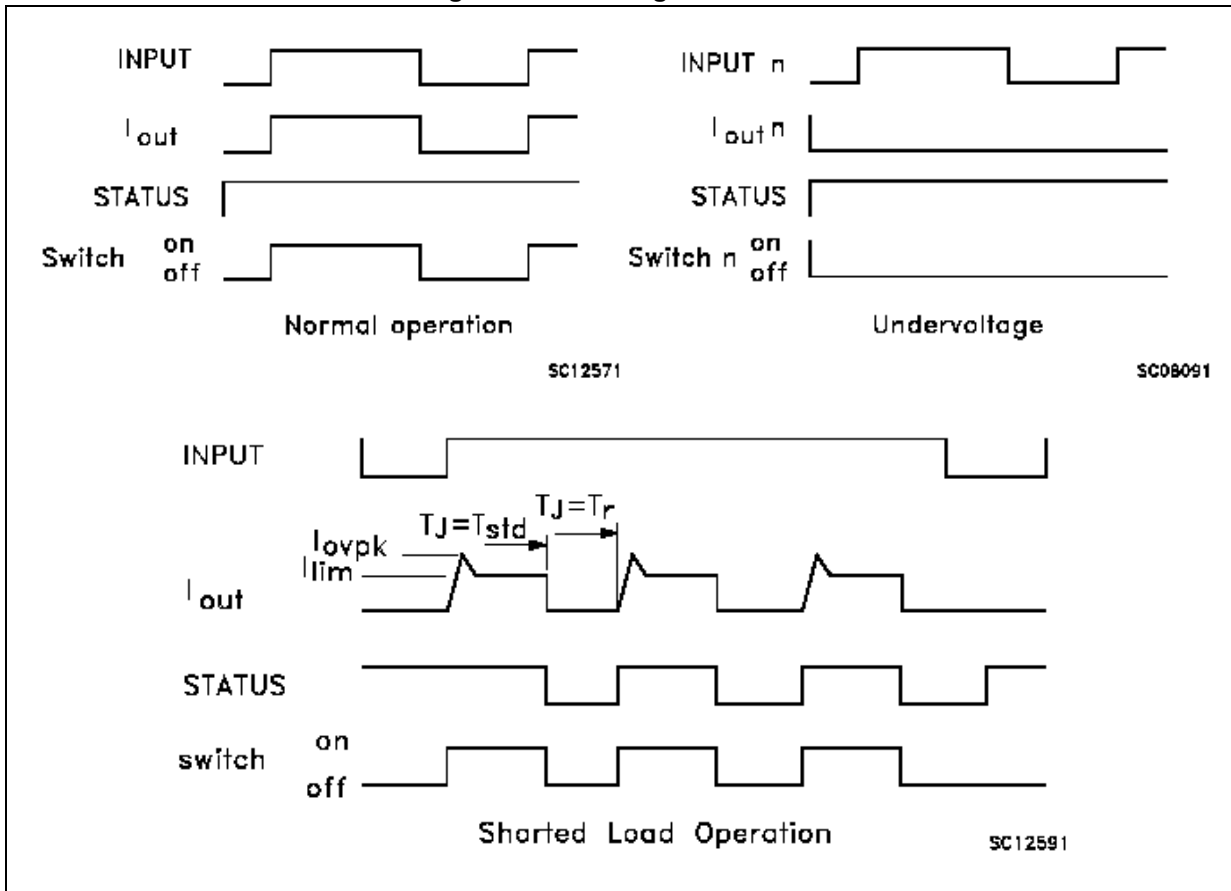


Figure 7. I_{LGND} test configuration

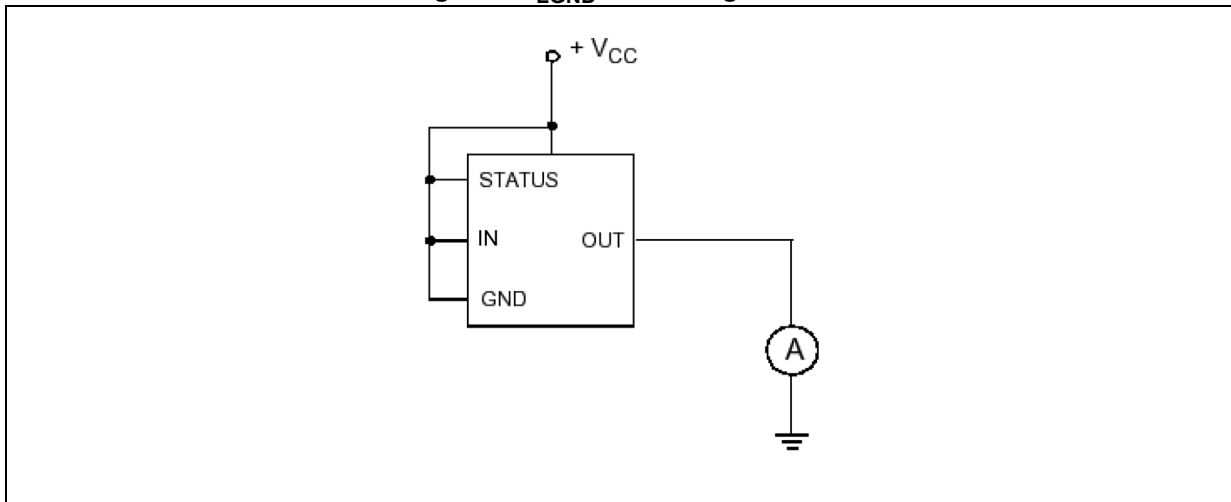
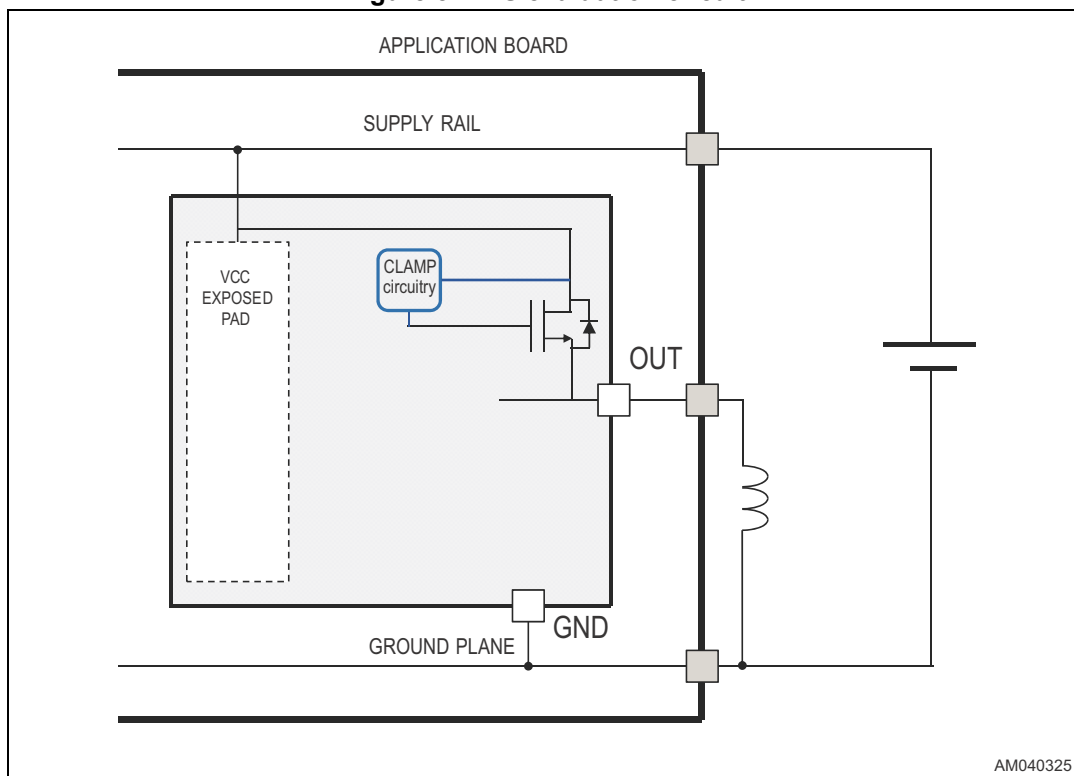


Figure 8. EAS evaluation circuit



8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK® is an ST trademark.

8.1 PowerSO-10 package information

Figure 9. PowerSO-10 package outline

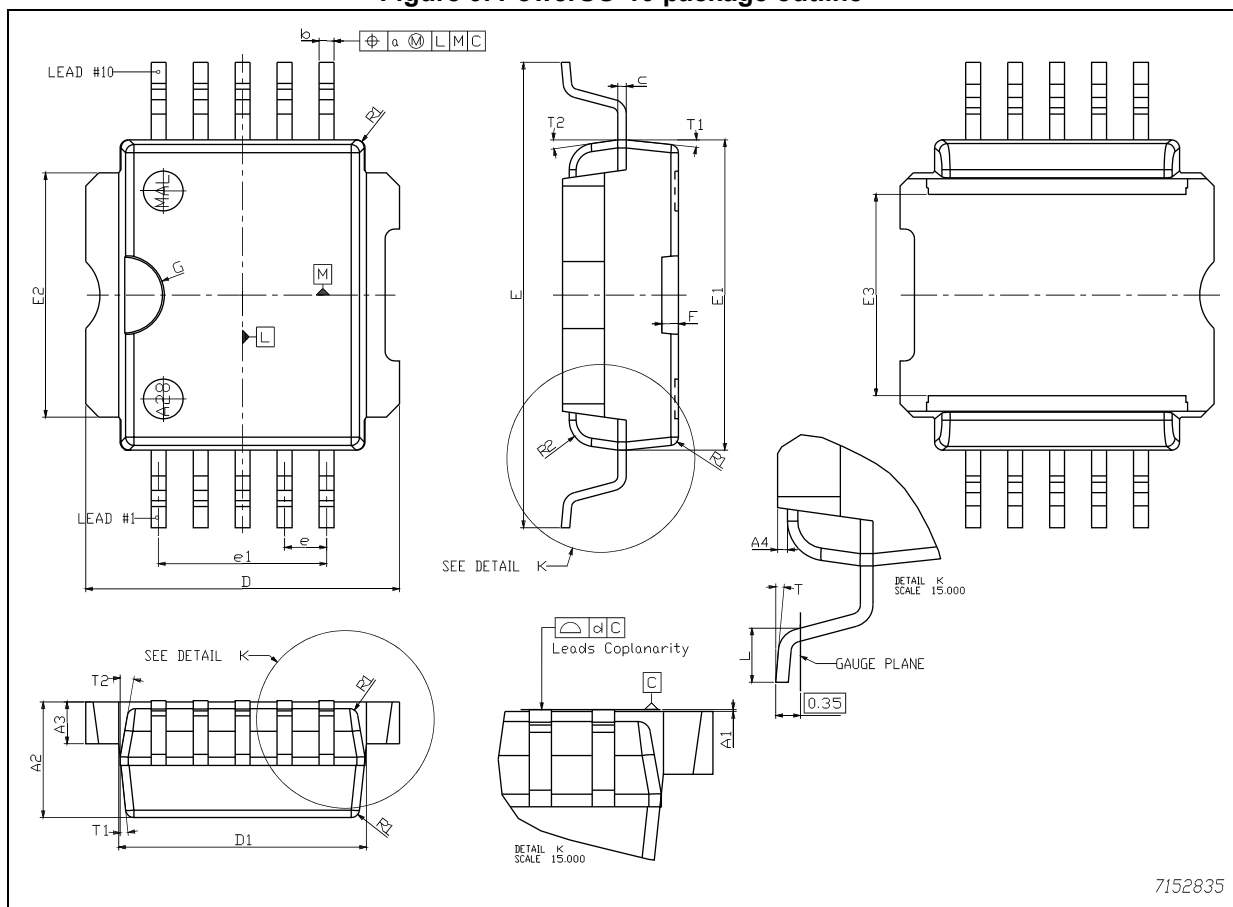


Table 8. PowerSO-10 package mechanical data

| Symbol | Dimensions (mm) | | | Dimensions (inch) | | | Note |
|--------|------------------|--------|--------|--------------------|--------|--------|------|
| | Typ. | Min. | Max. | Typ. | Min. | Max. | |
| A1 | 0.05 | 0 | 0.1 | 0.0019 | 0.0004 | 0.003 | - |
| A2 | 3.5 | 3.4 | 3.6 | 0.137 | 0.135 | 0.139 | - |
| A3 | 1.3 | 1.2 | 1.4 | 0.05 | 0.048 | 0.052 | - |
| A4 | 0.2 | 0.15 | 0.25 | 0.007 | 0.006 | 0.01 | - |
| a | 0.2 | - | - | 0.007 | - | - | - |
| b | 0.45 | 0.37 | 0.53 | 0.017 | 0.015 | 0.019 | - |
| c | 0.27 | 0.23 | 0.32 | 0.01 | 0.009 | 0.011 | - |
| D | 9.5 | 9.4 | 9.6 | 0.374 | 0.372 | 0.377 | - |
| D1 | 7.5 | 7.4 | 7.6 | 0.295 | 0.292 | 0.298 | - |
| d | 0.05 | 0 | 0.1 | 0.0015 | 0 | 0.0035 | - |
| E | 14.1 | 13.85 | 14.35 | 0.555 | 0.547 | 0.562 | - |
| E1 | 9.4 | 9.3 | 9.5 | 0.37 | 0.367 | 0.372 | (1) |
| E2 | 7.4 | 7.3 | 7.5 | 0.292 | 0.291 | 0.295 | - |
| E3 | 6.1 | 5.9 | 6.3 | 0.24 | 0.234 | 0.246 | - |
| e | 1.27 | - | - | 0.05 | 0.048 | 0.051 | - |
| e1 | 5.08 | - | - | 0.2 | - | - | - |
| F | 0.5 | - | - | 0.019 | - | - | - |
| G | 1.2 | - | - | 0.047 | - | - | - |
| L | 1 | 0.8 | 1.1 | 0.039 | 0.033 | 0.043 | - |
| R1 | - | - | 0.25 | - | - | 0.01 | - |
| R2 | 0.8 | - | - | 0.031 | - | - | - |
| T | 5 deg. | 2 deg. | 8 deg. | 5 deg. | 3 deg. | 7 deg. | - |
| T1 | 6 deg. | - | - | 6 deg. | - | - | - |
| T2 | 10 deg. | - | - | 10 deg. | - | - | - |

1. Resin protrusions not included (max. value: 0.15 mm per side).

8.2 PENTAWATT vertical package information

Figure 10. PENTAWATT vertical package outline

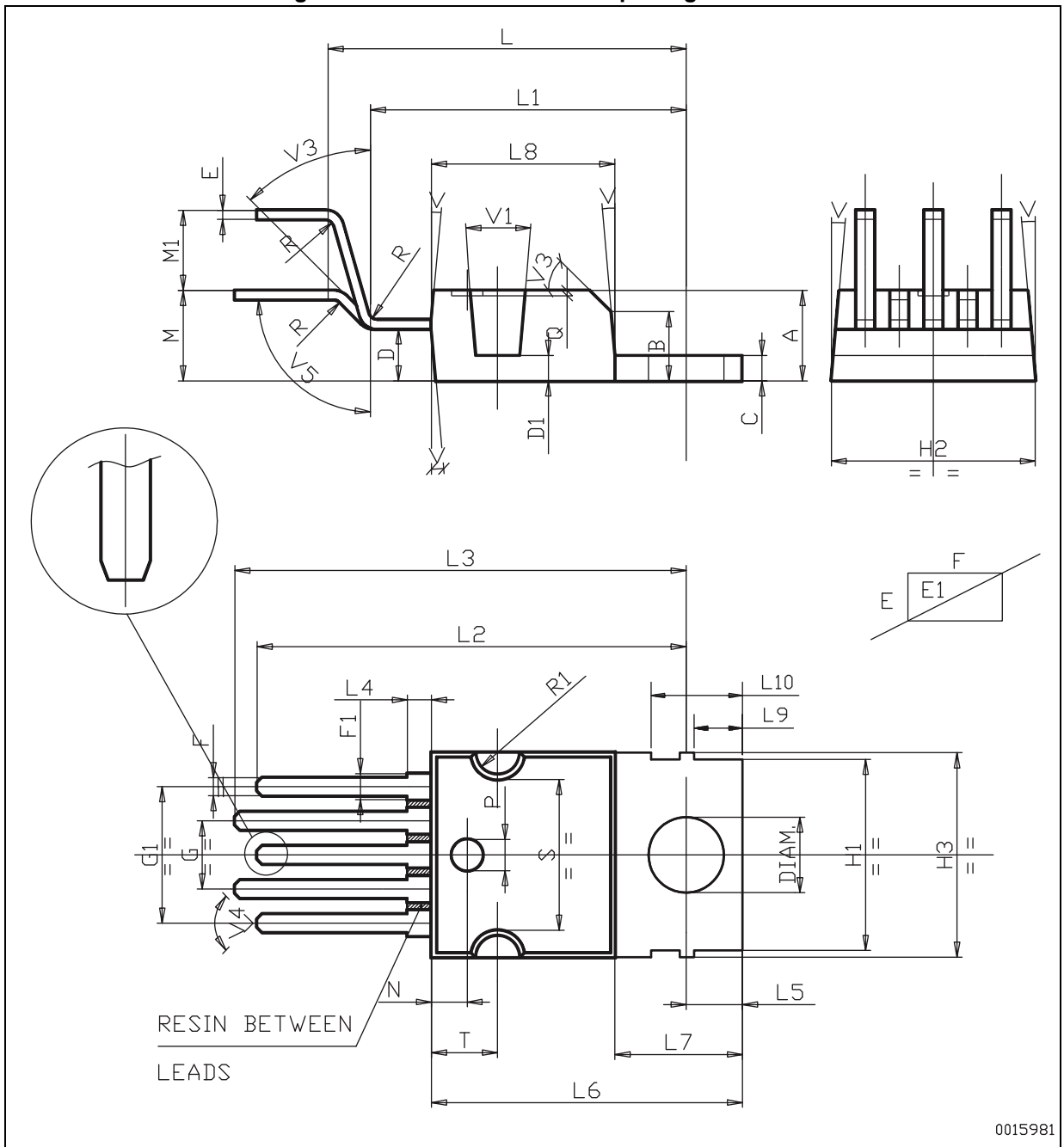


Table 9. PENTAWATT vertical package mechanical data

| Symbol | Dimensions (mm) | | | Dimensions (inch) | | |
|--------|------------------|-------|-------|--------------------|-------|-------|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | - | - | 4.80 | 0.178 | 0.174 | 0.182 |
| B | - | - | - | 0.136 | 0.132 | 0.140 |
| C | - | - | 1.37 | 0.050 | 0.047 | 0.053 |
| D | - | 2.40 | 2.80 | 0.102 | 0.098 | 0.106 |
| D1 | - | 1.20 | 1.35 | 0.050 | 0.049 | 0.051 |
| E | - | 0.35 | 0.55 | 0.016 | 0.014 | 0.018 |
| E1 | - | 0.76 | 1.19 | - | 0.029 | 0.044 |
| F | - | 0.80 | 1.05 | 0.036 | 0.033 | 0.039 |
| F1 | - | 1.00 | 1.40 | - | 0.043 | 0.053 |
| G | 3.40 | 3.20 | 3.60 | 0.134 | 0.130 | 0.138 |
| G1 | 6.80 | 6.60 | 7.00 | 0.268 | 0.264 | 0.272 |
| H1 | - | - | - | 0.375 | 0.367 | 0.382 |
| H2 | - | - | 10.4 | - | - | 0.400 |
| H3 | - | - | 10.40 | 0.401 | 0.399 | 0.405 |
| L | 17.85 | 17.55 | 18.15 | 0.703 | 0.693 | 0.713 |
| L1 | 15.75 | 15.55 | 15.95 | 0.620 | 0.614 | 0.626 |
| L2 | 21.40 | 21.20 | 21.60 | 0.842 | 0.836 | 0.848 |
| L3 | 22.50 | 22.30 | 22.70 | 0.886 | 0.881 | 0.889 |
| L4 | - | - | 1.29 | - | - | 0.051 |
| L5 | - | 2.60 | 3.00 | 0.110 | 0.106 | 0.114 |
| L6 | - | 15.10 | 15.80 | 0.610 | 0.604 | 0.615 |
| L7 | - | 6.00 | 6.60 | 0.250 | 0.246 | 0.254 |
| L8 | - | - | - | 0.361 | 0.358 | 0.364 |
| L9 | - | 2.10 | 2.70 | 0.094 | 0.090 | 0.098 |
| L10 | - | 4.30 | 4.80 | 0.183 | 0.180 | 0.187 |
| M | 4.50 | 4.23 | 4.75 | 0.178 | 0.171 | 0.183 |
| M1 | 4.00 | 3.75 | 4.25 | 0.157 | 0.151 | 0.163 |
| N | - | - | - | 0.070 | - | - |
| P | - | - | - | - | 0.059 | 0.063 |
| Q | - | - | - | - | 0.002 | 0.004 |
| R | - | - | - | - | 0.023 | 0.039 |
| R1 | - | - | - | 0.043 | - | - |
| S | - | - | - | 0.315 | 0.313 | 0.317 |

Table 9. PENTAWATT vertical package mechanical data (continued)

| Symbol | Dimensions (mm) | | | Dimensions (inch) | | |
|--------|------------------|------|------|--------------------|-------|-------|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| T | - | - | - | 0.130 | 0.128 | 0.132 |
| V | - | - | - | 5d | - | - |
| V1 | - | - | - | 10d | - | - |
| V3 | - | - | - | 45d | - | - |
| V4 | 40d | - | - | 40d | - | - |
| V5 | 90d | - | - | 90d | - | - |
| Diam. | - | 3.65 | 3.85 | 0.148 | 0.146 | 0.150 |

9 Ordering information

Table 10. Order codes

| Package | Tube | Tape and reel |
|--------------------|-----------|---------------|
| PowerSO-10 | VN540SP-E | VN540SPTR-E |
| PENTAWATT vertical | VN540-E | - |

10 Revision history

Table 11. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 2-Nov-2005 | 1 | Initial release. |
| 09-May-2018 | 2 | Removed VN540-12-E and PENTAWATT(012Y) from the whole document. Updated P_{TOT} and E_{AS} in Table 1 on page 3 . Added Figure 8 on page 11 . Updated Section 8 on page 12 . Minor modifications throughout document. |

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