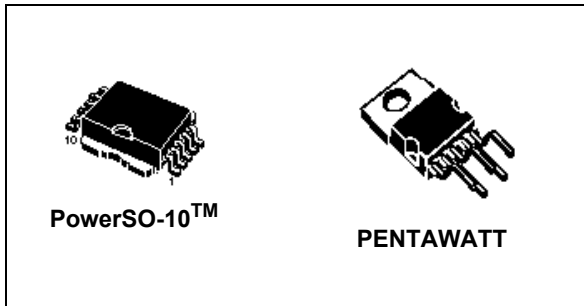


## Single high-side smart power solid state relay

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

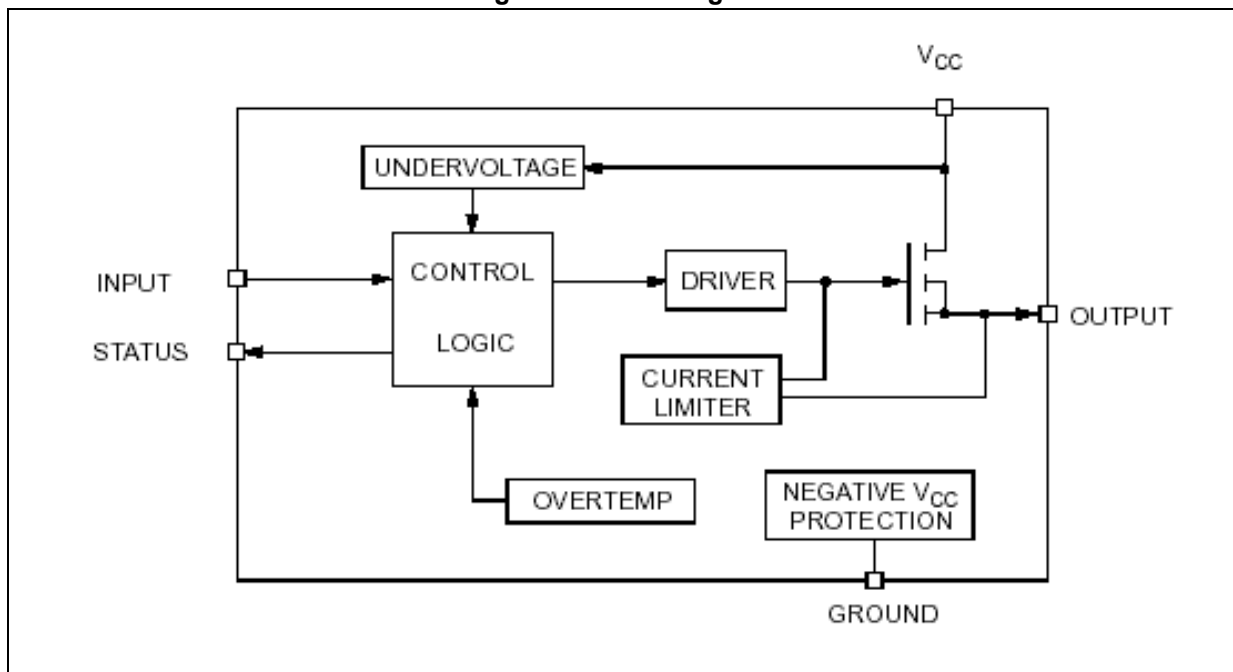
### Features

- 10 V to 36 V supply voltage range
- Up to  $I_{OUT} = 2.8$  A operating current
- $R_{DS(on)}$ : 50 m $\Omega$
- $V_{demag} = V_{CC} - 55$  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	$\pm 10$	mA
$I_{STAT}$	Status pin current	$\pm 10$	mA
$V_{ESD}$	Electrostatic discharge (R = 1.5 KW; C = 100 pF)	2000	V
$P_{TOT}$	Power dissipation (see thermal thresholds in <a href="#">Table 6 on page 7</a> )	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)

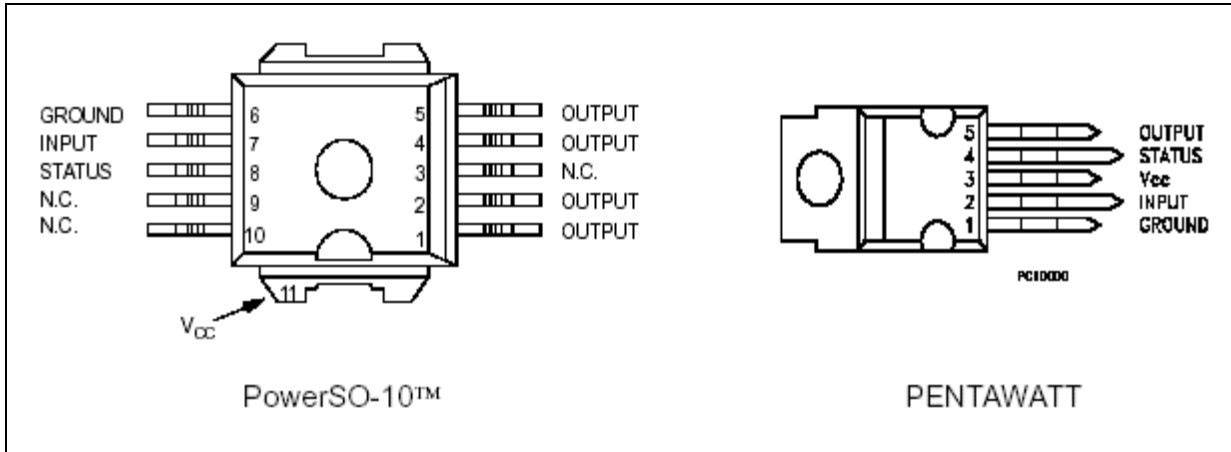
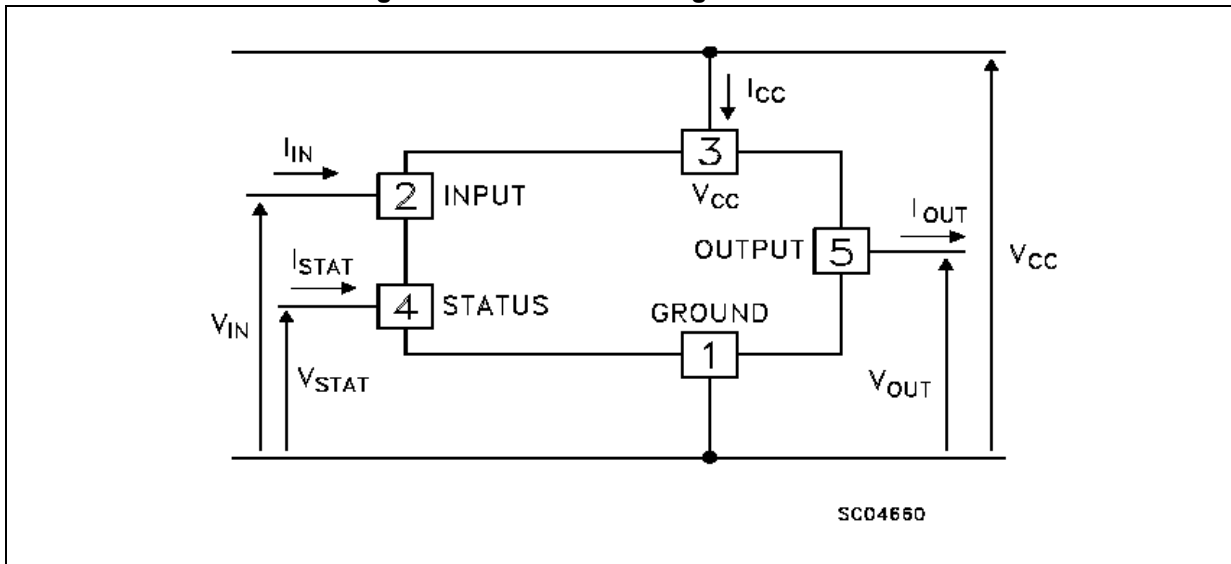


Figure 3. Current and voltage conventions



### 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<sub>CC</sub> < 36 V; -25 °C < T<sub>J</sub> < 85 °C; unless otherwise specified).

**Table 3. Power section**

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

**Table 4. Switching**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
t <sub>d(ON)</sub>	Turn-on delay on output current	I <sub>OUT</sub> = 2.8 A, resistive load input rise time < 0.1 s, V <sub>CC</sub> = 24 V; T <sub>J</sub> = 25 °C	-	40	-	μs
t <sub>r</sub>	Rise time of output current	I <sub>OUT</sub> = 2.8 A, resistive load input rise time < 0.1 s, V <sub>CC</sub> = 24 V; T <sub>J</sub> = 25 °C	-	60	-	μs
t <sub>d(OFF)</sub>	Turn-off delay time of output current	I <sub>OUT</sub> = 2.8 A, resistive load input rise time < 0.1 s, V <sub>CC</sub> = 24 V; T <sub>J</sub> = 25 °C	-	60	-	μs
t <sub>f</sub>	Fall time of output current	I <sub>OUT</sub> = 2.8 A, resistive load input rise time < 0.1 s, V <sub>CC</sub> = 24 V; T <sub>J</sub> = 25 °C	-	25	-	μs
dI/dt <sub>(on)</sub>	Turn-on current average slope	I <sub>OUT</sub> = 2.8 A, I <sub>OUT</sub> = I <sub>LIM</sub> ; 25 °C < T <sub>J</sub> < 140 °C	-	-	0.5 2	A/μs
dI/dt <sub>(off)</sub>	Turn-off current average slope	I <sub>OUT</sub> = 2.8 A, I <sub>OUT</sub> = I <sub>LIM</sub> ; 25 °C < T <sub>J</sub> < 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 -	$\mu\text{A}$ $\mu\text{A}$
$V_{ICL}$	I/O input clamp voltage <sup>(1)</sup>	$I_{IN} = 1\text{ mA}$ $I_{IN} = -1\text{ mA}$	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.

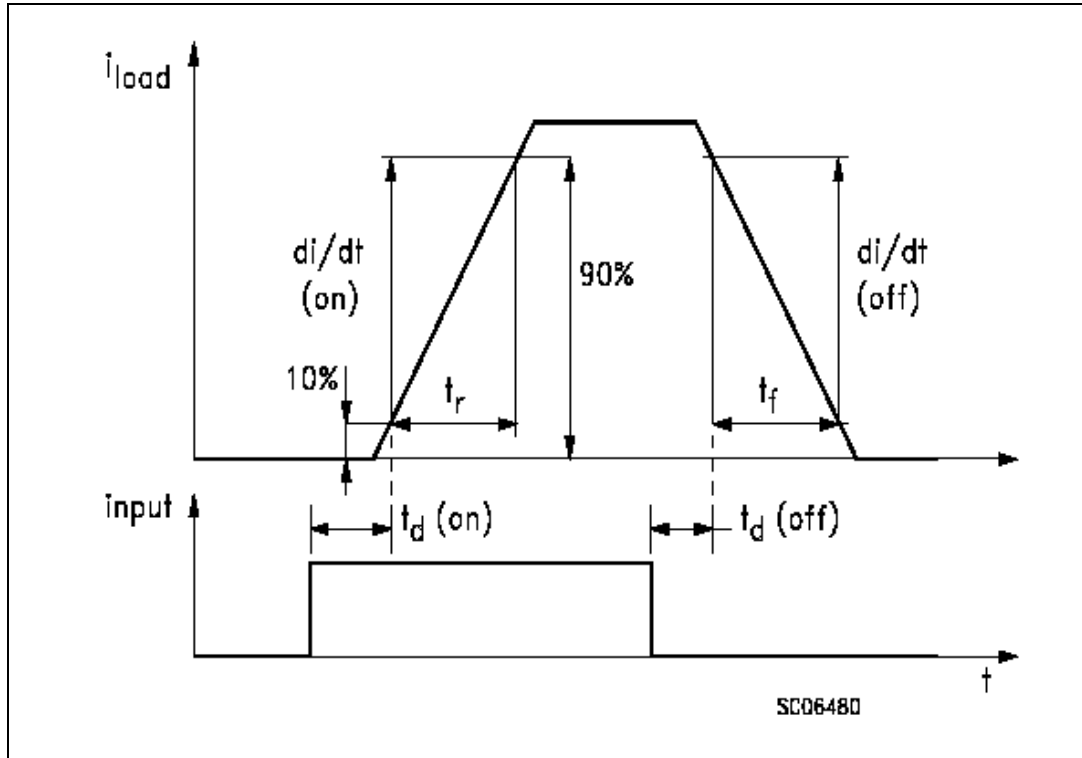
Table 6. Protection and diagnostic

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	$V_{STAT} = 5\text{ V}$	-	-	-	$\mu\text{A}$
$V_{USD}$	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	$\mu\text{s}$
$T_{TSD}$	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

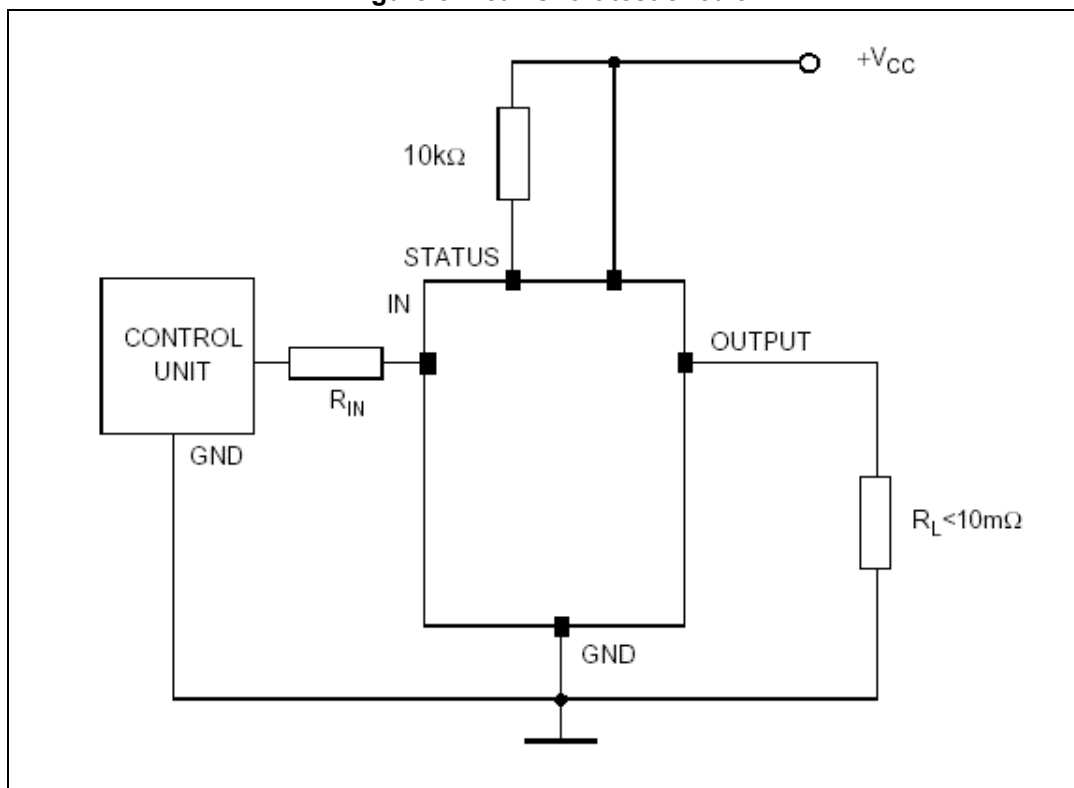


Figure 6. Switching waveforms

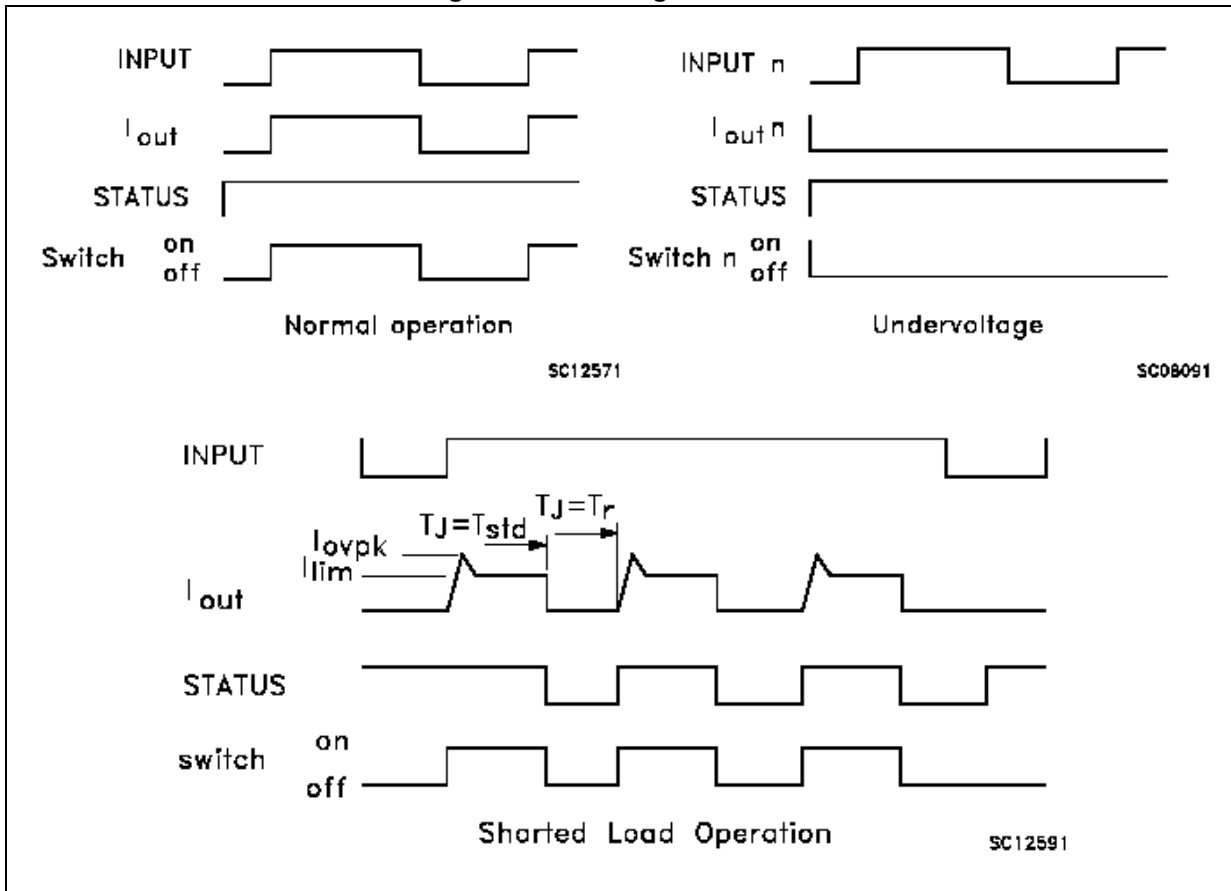


Figure 7.  $I_{LGND}$  test configuration

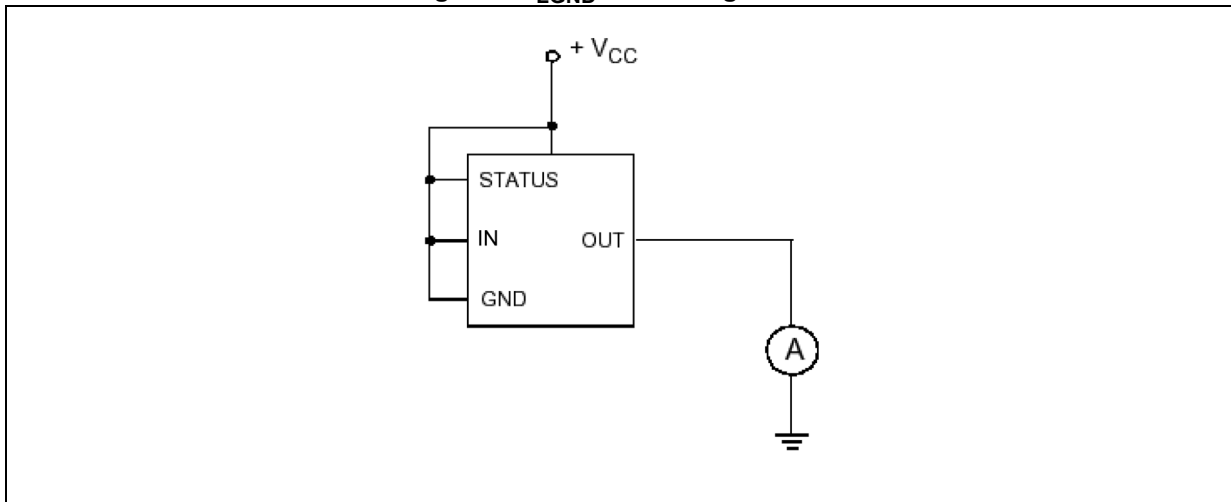
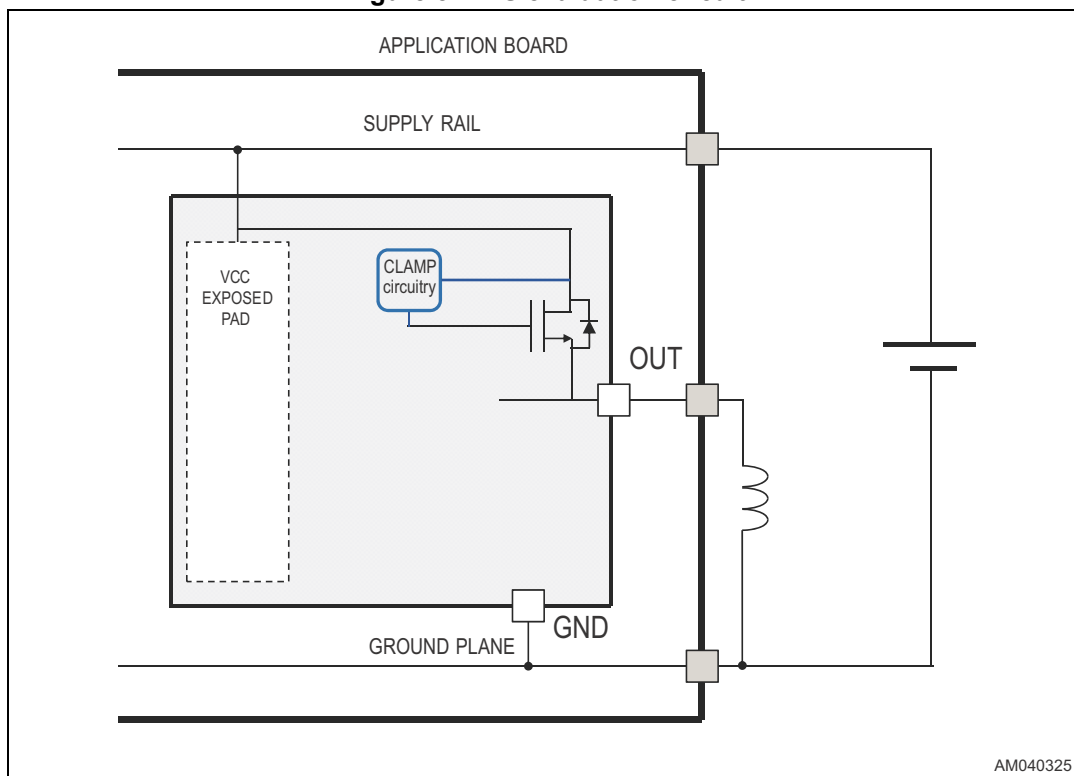


Figure 8. EAS evaluation circuit



## 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](http://www.st.com). ECOPACK® is an ST trademark.

### 8.1 PowerSO-10 package information

Figure 9. PowerSO-10 package outline

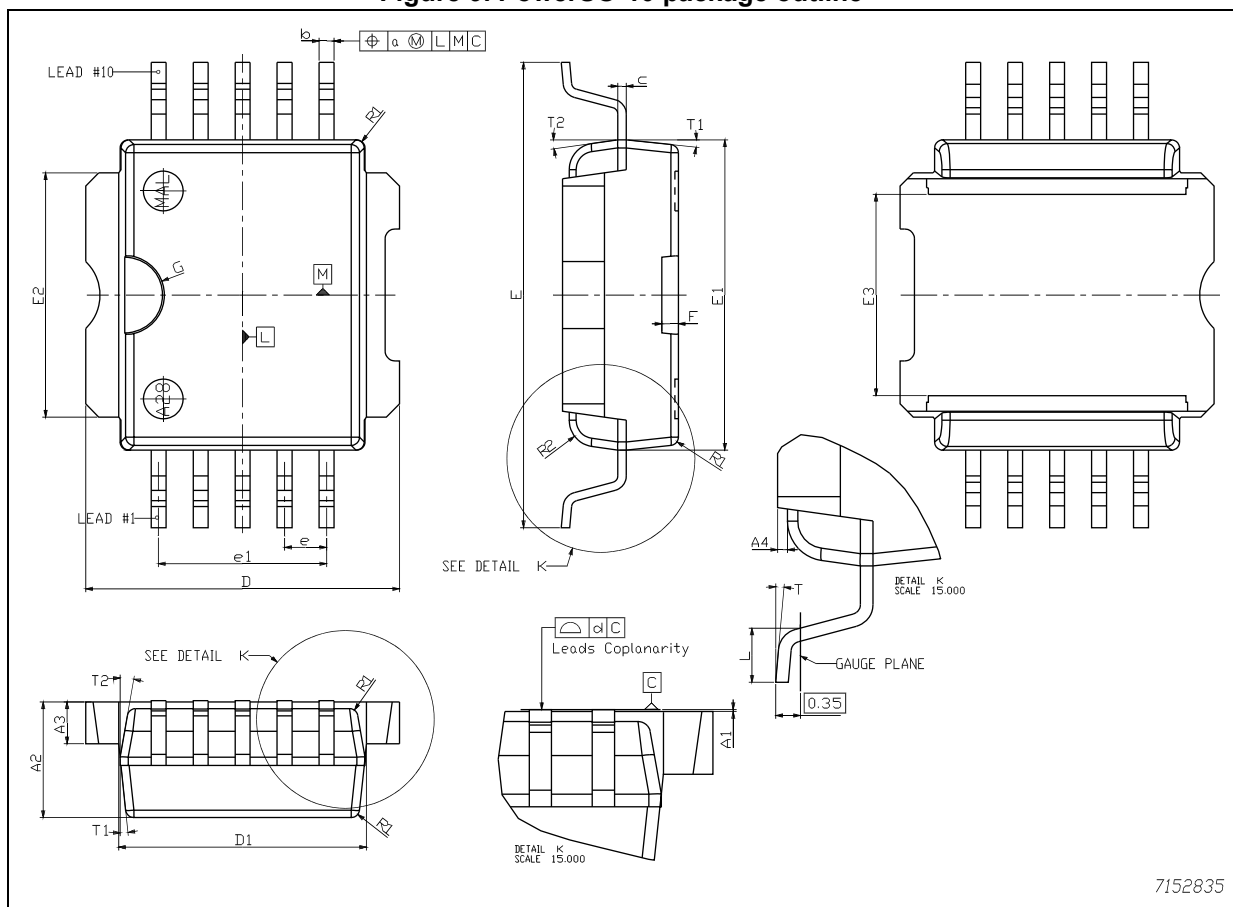


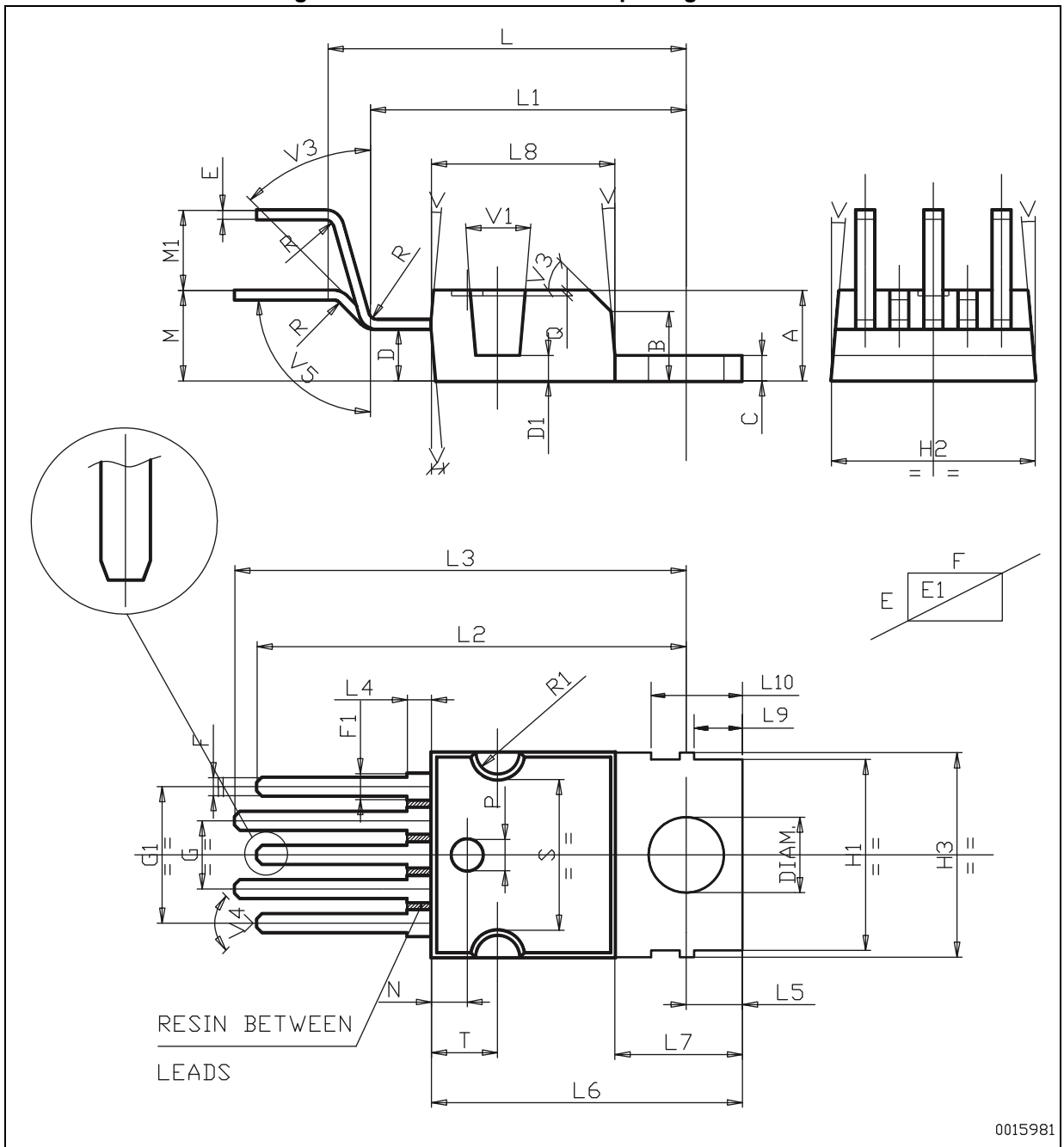
Table 8. PowerSO-10 package mechanical data

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



0015981

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 <a href="#">Table 1 on page 3</a> . Added <a href="#">Figure 8 on page 11</a> . Updated <a href="#">Section 8 on page 12</a> . Minor modifications throughout document.

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