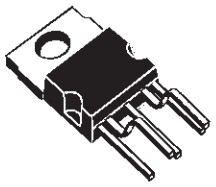
VB409
VB409SP

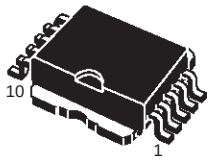
HIGH VOLTAGE REGULATOR POWER I.C.

PRELIMINARY DATA

TYPE	$I_{CL(in)}$	$I_{CL(out)}$	V_{OUT}
VB409 VB409SP	0.8 A	70 mA	5V ± 5%

- NO HIGH VOLTAGE EXTERNAL CAPACITOR
- 5 V DC REGULATED OUTPUT VOLTAGE
- OUTPUT CURRENT LIMITED TO 70 mA
- THERMAL SHUT-DOWN PROTECTION
- INPUT OVERCURRENT PROTECTION
- POWER DISSIPATION INTERNALLY LIMITED





PENTAWATT HV(022Y) **PowerSO-10™**

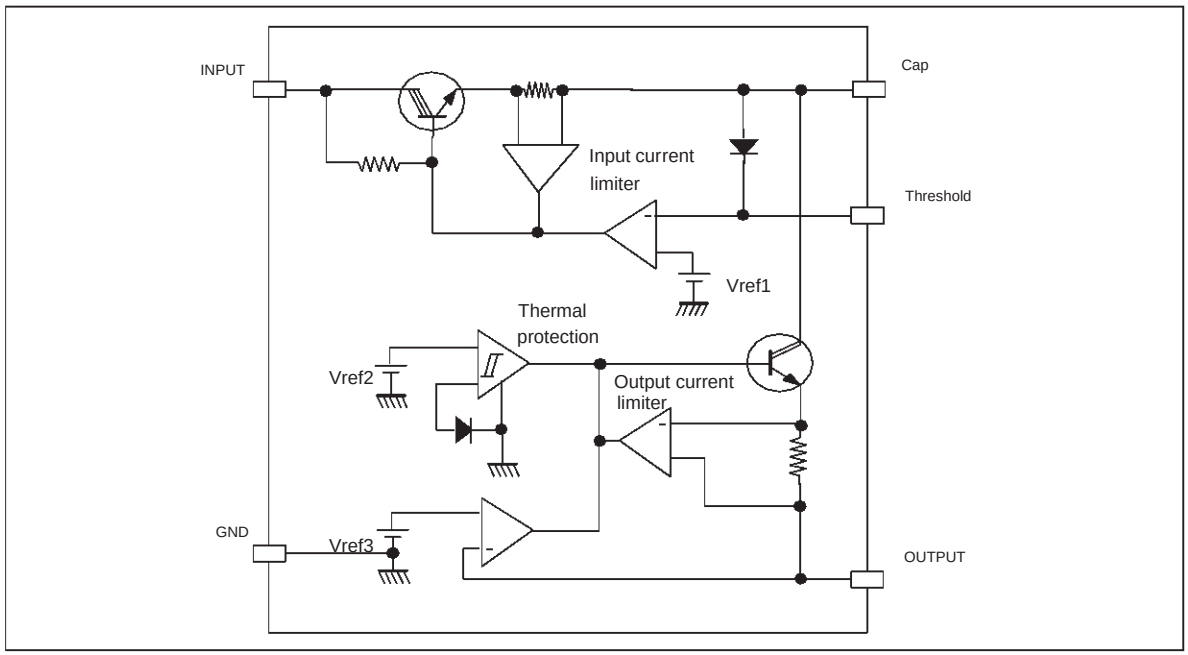
ORDER CODES:

PENTAWATT HV(022Y) VB409
PowerSO-10™ VB409SP

DESCRIPTION

The VB409 VB409SP are fully protected positive voltage regulator designed in STMicroelectronics High Voltage VIPower™ technology. The devices can be connected directly to the rectified mains (110V/230V). The devices are well suited for applications powered from the AC mains and requiring a 5V DC regulated output voltage without galvanic insulation. VB409, VB409SP provides up to 70 mA output current (internally limited) at 5V. The included over current and thermal shutdown provide protection for the device.

BLOCK DIAGRAM



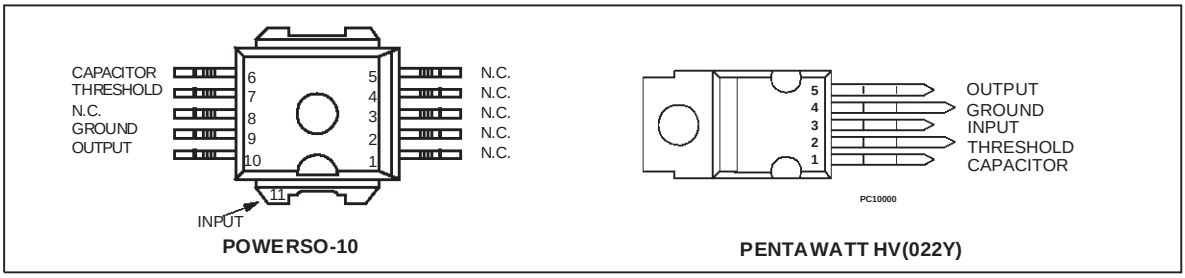
ABSOLUTE MAXIMUM RATING

Symbol	Parameter	Value	Unit
$\Delta V_{IN,OUT}$	Input to output voltage	- 0.2 to 420	V
I_{OUT}	Output current	Internally limited	mA
P_{TOT}	Power dissipation at T_C=25°C	Internally limited	W
I_{IN}	Input current	Internally limited	mA
T_j	Junction operating temperature	- 40 to 125	°C
T_{STG}	Storage temperature	- 55 to 150	°C

THERMAL DATA

Symbol	Parameter		Value		Unit
			PENTAWATT	POWERSO-10	Unit
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient	(MAX)	60	50	°C/W
$R_{thj\text{-}case}$	Thermal resistance junction-case	(MAX)	1.1		°C/W

CONNECTION DIAGRAM (TOP VIEW)



ELECTRICAL CHARACTERISTICS (V_{IN}=230Vr.m.s.; 50Hz; C_1=100µF; V_1=50V (See Fig. 2); I_{OUT} =25mA; V_{OUT}=5V; -25°C<T_j<125°C) (unless otherwise specified)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
$V_{IN(ac)}$	Input voltage a.c.		15		230	Vr.m.s.
$BV_{IN\text{-}GND}$	Breakdown voltage input-ground in off state		650			V
f_{IN}	Input frequency		0		1	kHz
V_{OUT}	Output voltage		4.75	5	5.25	V
$\Delta V_{OUT}/\Delta V_{cap}$	Cap regulation	V_{cap}=8 to 12V; V_{IN}=0V; T_j=25°C			7	mV/V
$\Delta V_{OUT}/\Delta I_{OUT}$	Load regulation	I_{OUT}=1 to 40mA; V_{cap}=10V; T_j=25°C			500	µV/mA
$I_{CL(out)}$	Output current limit	T_j=25°C	70		90	mA
T_{jsh}	Junction temperature shutdown limit			140	150	°C
ΔT_{jsh}	Junction temperature shutdown hysteresis			35		°C
I_d	Quiescent current	T_j=25°C; I_{OUT}=0A			2	mA
V_d	Dropout voltage (V_{cap} to V_{OUT})	T_j=25°C			3	V
$I_{CL(in)}$	Input clamp current		0.8		2	A
$\Delta V_{cap}/\Delta T$	Drift of capacitor pin voltage in temperature			-15		mV/°C
$V_{cap(max)}$	Max clamped voltage on cap pin		12		14.5	V
V_{ref1}	Reference threshold Voltage		10	10.5	11	V
I_{th}	Current on threshold pin			100		µA

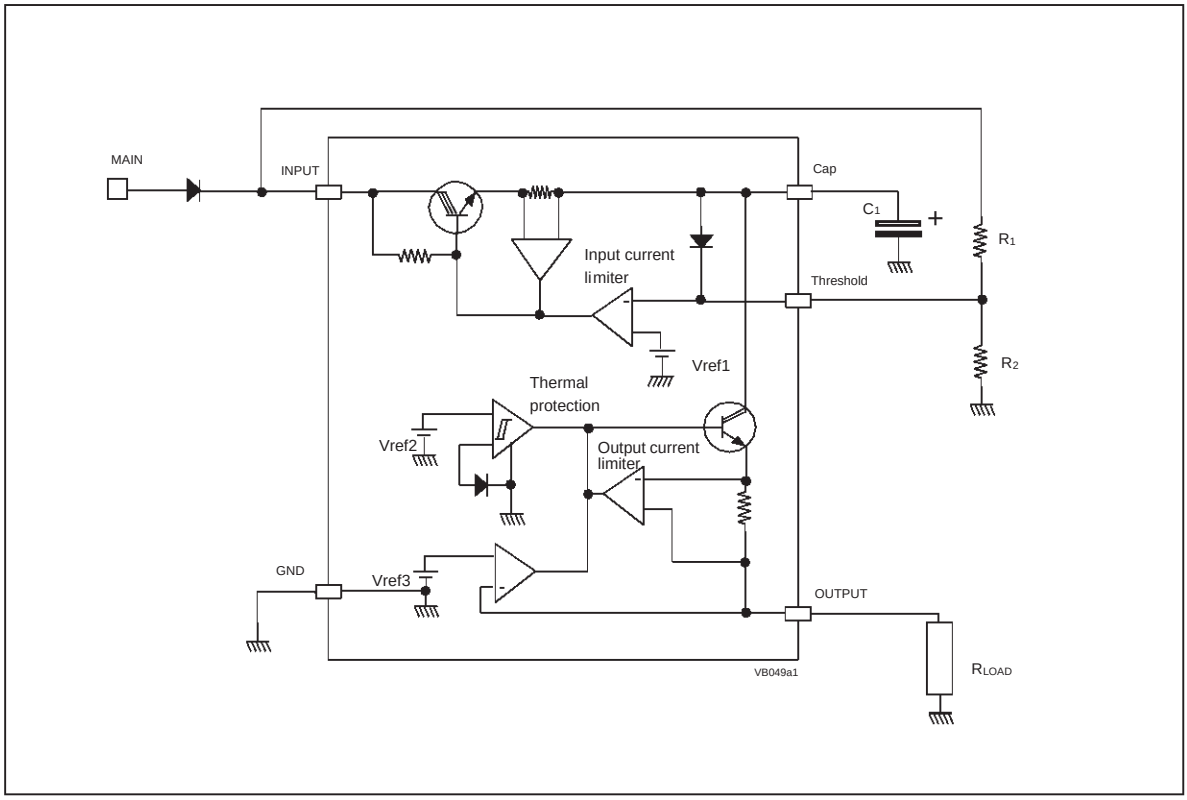
OPERATION DESCRIPTION

The VB409, VB409SP contain two separate stages, as shown in the block diagram. The first stage is a preregulator that translates the high rectified mains voltage to a low voltage and charges an external electrolytic capacitor. The second stage is a simple 5V regulator. The typical operating waveforms are shown in Figure 2. The device may be driven by a half wave (110 or 230 Vr.m.s.) or by a full wave using a bridge rectifier. Current flow through the preregulator stage is provided by the trilinton only during a conduction angle, at both the start and the end of each half cycle. This angle is set by adjusting the external resistor divider (R1 and R2), in order to set the time t_1 at which voltage at the threshold pin reaches the internal threshold V_{ref1} (see Figure 2a). When the threshold pin voltage gets over V_{ref1}, the series trilinton is switched off and remains off until voltage at the threshold pin again drops below the internal threshold. Using this technique, energy is drawn from the AC mains only during the low voltage portions of each positive half cycle, thus reducing the dissipation in the first stage. During the conduction angle, current provided by the trilinton is used to supply the load and to charge the capacitor C1. In such a way, when the trilinton switches off, the load receives the required current by the capacitor discharge. For this reason it is important to set properly the conduction angle: during this period C1 has to reach a sufficient charge to guarantee that, at the end of discharging, the voltage drop between the capacitor and the output pin is over 2V. Assuming that conduction angle has been set, two different possibilities can occur:

1) C1 value is such to reach $V_{cap(max)}$ within the conduction angle. As the comparator also senses C1 voltage, when V_{cap} gets over V_{ref1}, the trilinton would switch off. But doing this, the capacitor would discharge through the load so reducing its voltage. As soon as V_{cap} drops below V_{ref1}, the trilinton switches on. As consequence the trilinton reaches a stable condition limiting the current to a value sufficient to supply the load and hold the capacitor voltage just below $V_{cap(max)}$ (see figures 2b and 2c).
2) C1 value is such to reach $V_{cap(max)}$ outside the conduction angle. In this case the trilinton doesn't reduce the current, but hold it to a constant value ($I_{CL(in)}$) during the whole conduction angle (see figures 3a and 3b).

As there are two conduction angles for each half cycle, the capacitor is recharged twice during each period. In such a way the capacitor voltage has a small ripple and, consequently, it needs a small current to regenerate its charge. The device has integrated current limit and thermal shutdown protections. The thermal shutdown turns the low voltage stage off, if the die temperature exceeds a predetermined value. Hysteresis in the thermal sense circuit holds the device off until the die temperature cools down.

Figure 1: Application scheme



APPLICATION EXAMPLE

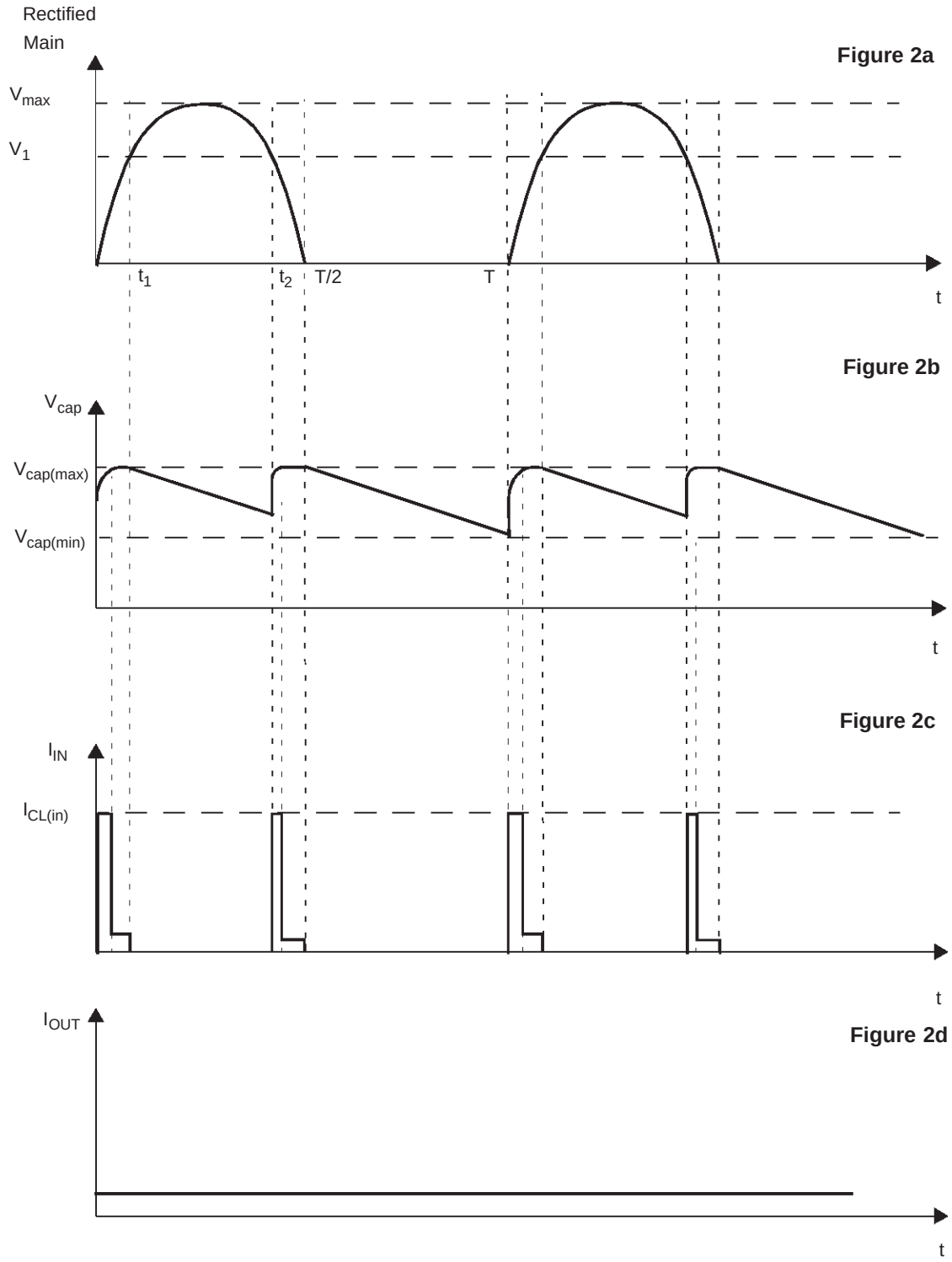
(without heatsink; R1=1MΩ; C1=47µF)

I_{OUT}	R2	P_{AV}
10 mA	560 KΩ	0.32 W
15 mA	470 KΩ	0.49 W
20 mA	390 KΩ	0.67 W

(without heatsink; R1=1MΩ; C1=100µF)

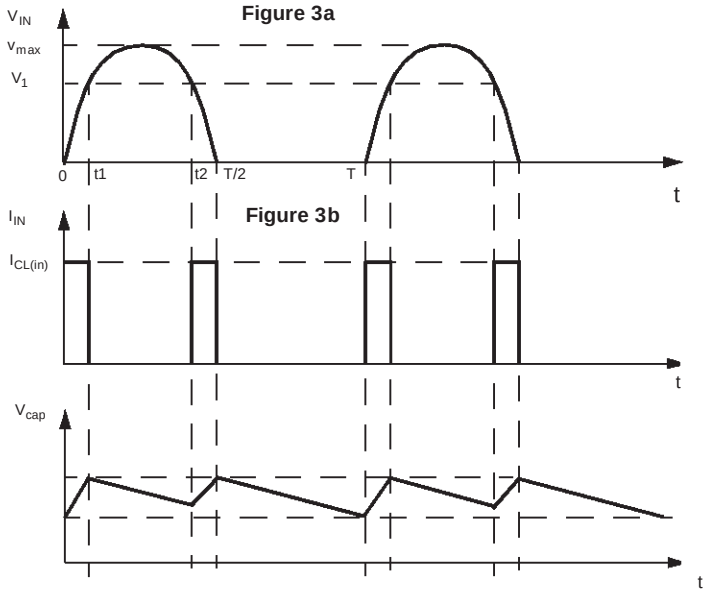
I_{OUT}	R2	P_{AV}
20mA	390 KΩ	0.70 W
25mA	330 KΩ	0.92 W
30mA	270 KΩ	1.20 W
35mA	220 KΩ	1.53 W
40mA	180 KΩ	1.92 W

Figure 2: typical waveforms



AVERAGE POWER CALCULATION IN WORST CASE

As before explained, the device also senses the preregulator voltage (V_{cap}), so that as soon as the capacitor reaches its maximum voltage, the trilinton reduces the current so limiting furtherly power dissipation. On the contrary if the capacitor doesn't reach the maximum value, the trilinton supplies current at a steady value (I_{max}) during the whole conduction angle. This is obviously the worst case, in which the average power dissipation is maximum.



$$V_{IN} = \begin{cases} V_{max} \cdot \sin(\frac{2\pi}{T} \cdot t) & 0 \le t \le \frac{T}{2} \\ 0 & \frac{T}{2} \le t \le T \end{cases}$$

$$I_{IN} = \begin{cases} I_{CL(in)} \cdot & 0 \le t \le t1 \\ & t2 \le t \le \frac{T}{2} \\ 0 & \text{elsewhere} \end{cases}$$

Assuming that

$$[0, t1] = [t2, \frac{T}{2}]$$

are the conduction angles, it results:

$$P_{AV} = \frac{1}{T} \cdot \int_0^T (V_{IN} \cdot I_{IN}) dt = \frac{1}{T} \cdot \left[\int_0^{t1} (V_{IN} \cdot I_{CL(in)}) dt + \int_{t2}^{\frac{T}{2}} (V_{IN} \cdot I_{CL(in)}) dt \right] =$$

$$= \frac{I_{CL(in)} \cdot V_{max}}{T} \cdot \left[\int_0^{t1} \sin(\frac{2\pi}{T} \cdot t) dt + \int_{t2}^{\frac{T}{2}} \sin(\frac{2\pi}{T} \cdot t) dt \right] = \frac{I_{CL(in)} \cdot V_{max}}{T} \cdot \left[2 \int_0^{t1} \sin(\frac{2\pi}{T} \cdot t) dt \right] =$$

$$= 2 \frac{I_{CL(in)} \cdot V_{max}}{T} \cdot \frac{T}{2\pi} \cdot [-\cos(\frac{2\pi}{T} \cdot t1) + \cos 0] = \frac{I_{CL(in)} \cdot V_{max}}{\pi} \left[1 - \sqrt{1 - \sin^2(\frac{2\pi}{T} \cdot t1)} \right] =$$

As for t1:

$$\frac{V_1}{V_{max}} = \sin(\frac{2\pi}{T} \cdot t1)$$

it follows:

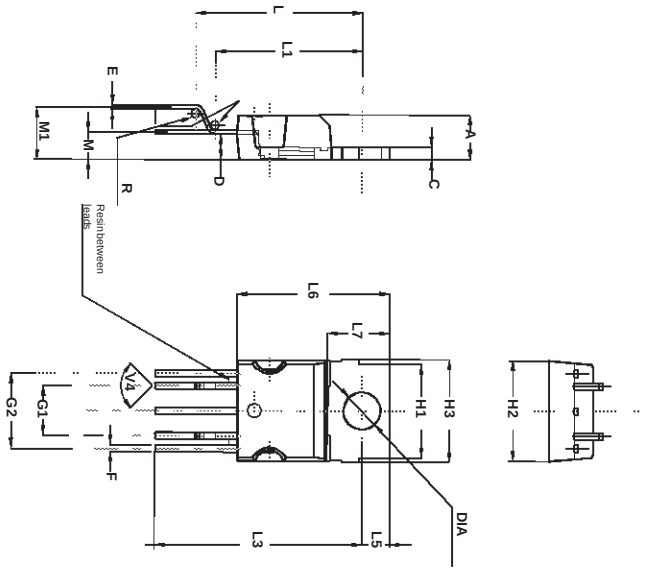
$$P_{AV} = \frac{I_{CL(in)} \cdot V_{max}}{\pi} \cdot \left[1 - \sqrt{1 - \left(\frac{V_1}{V_{max}} \right)^2} \right]$$

Where

$$V_1 = V_{ref1} \cdot (1 + \frac{R1}{R2})$$

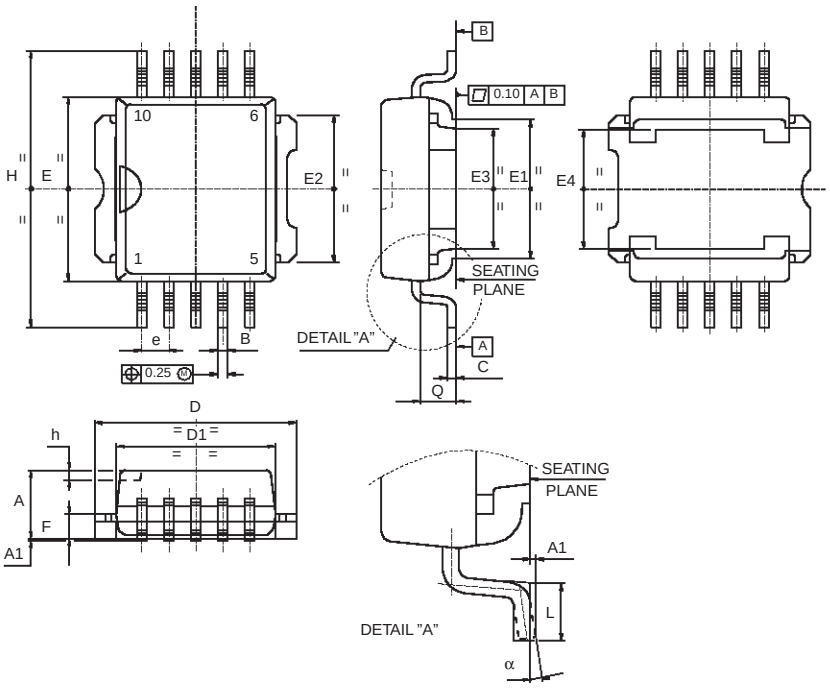
PENTAWATT HV 022Y (VERTICAL HIGH PITCH) MECHANICAL DATA

DIM.	mm.			inch		
	MIN.	TYP	MAX.	MIN.	TYP.	MAX.
A	4.30		4.80	0.169		0.189
C	1.17		1.37	0.046		0.054
D	2.40		2.80	0.094		0.110
E	0.35		0.55	0.014		0.022
F	0.60		0.80	0.024		0.031
G1	4.91		5.21	0.193		0.205
G2	7.49		7.80	0.295		0.307
H1	9.30		9.70	0.366		0.382
H2			10.40			0.409
H3	10.05		10.40	0.396		0.409
L	16.42		17.42	0.646		0.686
L1	14.60		15.22	0.575		0.599
L3	20.52		21.52	0.808		0.847
L5	2.60		3.00	0.102		0.118
L6	15.10		15.80	0.594		0.622
L7	6.00		6.60	0.236		0.260
M	2.50		3.10	0.098		0.122
M1	5.00		5.70	0.197		0.224
R		0.50			0.020	
V4		90°			90°	
Diam.	3.70		3.90	0.146		0.154



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		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		0.070
Q		1.70			0.067	
α	0º		8º			



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