CAT7105

2.0A 410kHz 23V High Efficiency Step-Down DC/DC Converter

Preliminary Specification V0.3.6

ITE TECH. INC.

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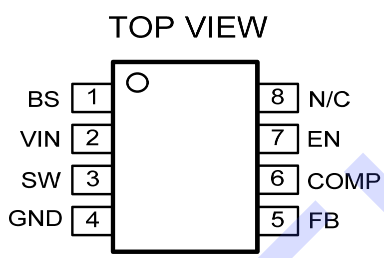
General Description

The CAT7105 is a high efficiency step-down DC/DC converter series with the output current up to 2A and integrates a low on resistance NMOS at the high side. Included on the substrate with the features listed is a high performance trans-conductance error amplifier that provides tight voltage regulation and accuracy under transient conditions. An under voltage lockout circuit is built in to prevent start-up until the input voltage reaches to 4.75V. In addition, it features an over-current protection and thermal shutdown. The CAT7105 is available in the SOP8 package.

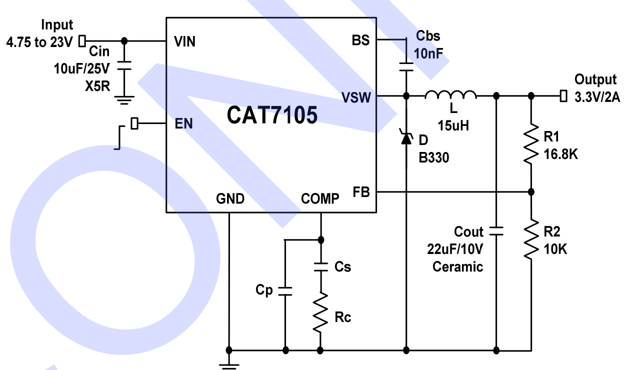
Application

- Set-Top-Box, DVD, LCD Display
- High Power LED Power Supply
- Distributed Power System
- Data comm. xDSL CPE

Pin Configuration



Typical Application



Features

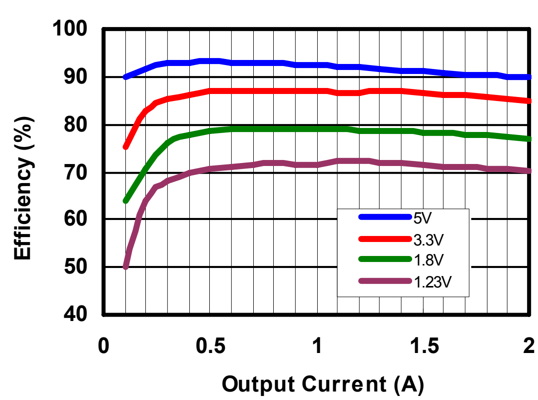
- High Efficiency up to 92%
- Wide Input Voltage Range from 4.75V to 23V
- Adjustable Output from 1.23 to 21V
- 2.0A Output Current
- 410kHz constant Frequency Operation
- Current Mode Control
- Over-temperature Protection
- Over-current Protection
- Under Voltage Lockout
- 25μA Shutdown Current
- Internal Soft-start
- SOP8 Package
- RoHS Compliant (100% Green available)

Ordering Information

Part No.	Package	Shipment
CAT7105CA	SOP8	2500/Tape & Reel

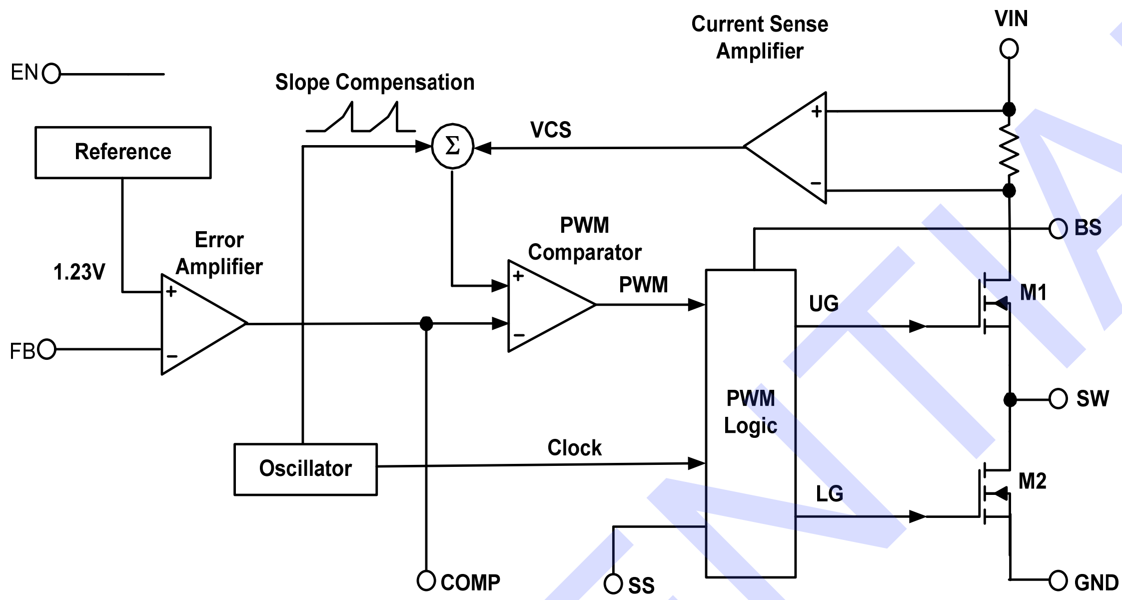
Efficiency Table

Efficiency VS Output Current at V_{IN}=12V



Specifications subject to Change without Notice

Block Diagram



Pin Description

Pin(s) No.	Symbol	Description
1	BS	***High Side Gate Drive Boost Input*** It is required to connect SW and BS by a capacitor, which is able to boost the gate drive to the internal NMOS above VIN to fully turn it ON.
2	VIN	***Power Supply*** The input voltage for the power supply is connected to this pin.
3	SW	***Power Switch Output*** This is the output of a power MOSFET switch connected directly to the input voltage.
4	GND	***Ground*** This is the reference of the ground connection for all components in the power supply.
5	FB	***Voltage Feedback*** This is the input to an error amplifier, which drives the PWM controller. It is necessary to connect this pin to the actual output of power supply to set the DC output voltage.
6	COMP	***Compensation*** This pin is to compensate the regulation control loop by connecting a series of RC network from COMP pin to GND pin.
7	EN	***Enable*** This input provides an electrical ON/OFF control of the power supply.
8	N/C	***No Connection***

Absolute Maximum Ratings

Input Supply Voltage…………..GND - 0.3V to +25V
SW Voltage……………………………- 1 to VIN+0.3V
EN Voltage……………………………- 1 to VIN+0.3V
Other Pins………………………………- 0.3V to +6V
Boost Voltage ………………………….Vsw+6V (<30V)
SW Peak Current…………………………………4.5 A
ESD Classification……………………………..Class 2
Junction Temperature Range…………………...150°C
Storage Temperature Range…………-65°C to 150°C
Lead Temperature (Soldering 10s)…………….260°C

Recommended Operating Conditions

Supply Voltage (VIN)……………………4.75V to 23V
Operating Temperature……………..–40°C to +85°C

Thermal Resistance	θJA	θJC	
SOP8 (3.90*4.85*1.45mm)	91	43	°C/W

Note 1: Stresses beyond above listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.
Note 2: Guaranteed by design, not production tested.

DC Electrical Characteristics

(Recommended Operating Conditions, Unless Otherwise Noted; VIN = 12V; TA = 25 °C)

Parameter	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage		4.75		23	V
Shutdown Supply Current	VEN = 0V		25	50	μA
Regulated Feedback Voltage	4.75V≦VIN≦23V	1.17	1.23	1.27	V
Error Amplifier Transconductance	△ICOMP = ±10μA	500	800	1120	μA/V
Current Sense to COMP Transconductance			3.8		A/V
Current Limit			3		A
SW Leakage Current	VEN = 0V, VSW = 0V			10	μA
High Side On Resistance			0.25		Ω
Low Side On Resistance	l		10		Ω
Oscillation Frequency			410		kHz
Short Circuit Oscillation Frequency	VFB=0V		40		kHz
Maximum Duty Cycle	VFB=1.0V		90		%
Minimum Duty Cycle	VFB=1.5V			0	%
Under Voltage Lockout Threshold	VIN Rising	3.9	4.1	4.3	V
Under Voltage Lockout Threshold Hysteresis			200		mV
Thermal Shutdown Threshold			160		℃
EN High Level		3			V
EN Low Level				0.9	V
EN Input Current	VEN = 0V	1.1	1.8	2.5	μA

Note: Fully production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization

Function Description

The CAT7105 is a current mode PWM step-down converter with a constant switching frequency. It regulates the input voltage from 4.75V to 23V and a low output voltage of 1.23V.The supplied load current is up to 2A.

Oscillator Frequency

Slope compensated current mode PWM control provides not only stable switching and cycle-by-cycle current limit for superior load and line response but also protection of the internal main switch and synchronous rectifier. The CAT7105 switches at a constant frequency (410 kHz) and regulates the output voltage. During each cycle, the PWM comparator modulates the power transferred to the load by changing the inductor's peak current based on the feedback error voltage. During normal operation, the main switch is turned on for a certain period to ramp the inductor's current at each rising edge of the internal oscillator, and switched off when the inductor's peak current is above the error voltage. After the main switch is turned off, the low side MOS will be turned on immediately and stay on until the next cycle starts.

Short Circuit Protection

The CAT7105 provides short circuit protection. When the output is shorted to ground, the oscillator's frequency is reduced to prevent the inductor's current from increasing beyond the NMOS current limit. The NMOS current limit is also reduced to lower the short circuit current. The frequency and current limit will return to the normal values once the short circuit condition is removed and the feedback voltage reaches 1.23V.

Maximum Load current

The CAT7105 can operate down to 4.75V input voltage; however the maximum load current decreases at lower input due to large IR voltage drop on the main switch and low side switch. The slope compensation signal reduces the inductor's peak current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%.

Enable

The EN pin provides electrical on/off control of the regulator. Once the voltage of the EN pin exceeds the threshold voltage, the regulator starts operation and the internal slow start begins to ramp. If the voltage of the EN pin is pulled below the threshold, the regulator will stop switching and the internal slow start reset. Connecting the pin to ground or to any voltage less than 0.9V will disable the regulator and activate the shutdown mode.

Under Voltage Lockout

The CAT7105 incorporates an under voltage lockout circuit to keep the device disabled when VIN is below the UVLO start threshold. During power-up, the internal circuit is held inactive until VIN exceeds the UVLO start threshold voltage. Once this threshold voltage is reached, device start-up begins. The device operates until VIN falls below the UVLO stop threshold voltage. The typical hysteretic in the UVLO comparator is 200mV.

Soft Start

There is a built-in soft start function provided by CAT7105 to reduce the input inrush current after power-on. If this pin is activated, it will provide about 160μS timing to make the duty transferred from small to specific duty during power-on period. Thus this function can lower the current stress on input power, MOSFET, and freewheeling diode. The soft start time can be programmed by connecting this pin with a capacitor, which is defined as the following.

tss=τ*Css ----- To be defined from RD.

Boost Capacitor

The BS pin and SW pin and be connected by a 10nF low ESR ceramic capacitor, which provides the gate drive voltage for the high side MOSFET.

Thermal Shutdown

The CAT7105 protects itself from overheating with an internal thermal shutdown circuit. If the junction temperature exceeds the thermal shutdown threshold, the voltage reference is grounded and high side MOSFET is turned off.

Compensation

The system stability is controlled through COMP pin. It will present a general design procedure to ensure a stable and operational circuit. The design in this data sheet is optimized for particular requirements. If there are different requirements, some components may need to be changed to ensure stability. The power components and their effects will be determined first, and then the compensation components will be chosen to produce stability.

The compensation steps for the converter are listed below:

(1).Choose reasonable inductor and output capacitance according to the allowed output voltage ripple and load transient.

(2). Place F_C sufficiently below F_S. Typically, F_C is approximately below 1/4 ~ 1/10 of F_S.

(3). Set the compensation R_C to zero to cancel the R_{LOAD} C_{OUT} pole.

$$R_C = \frac{2\pi \times F_C \times C_{OUT} \times V_{OUT}}{G_M \times G_{CS} \times V_{REF}}$$

$$C_C = \frac{C_{OUT} \times R_{LOAD}}{R_C}$$

G_M: error amp transconductance

G_{CS}: current sense transconductance

(4). Determine C_P if is required.

If Z_{ESR} (zero occurs by output capacitor ESR) is less than F_C, it should be cancelled with a pole set by capacitor C_P connected from C_C to GND.

$$C_P = C_{OUT} \times \frac{R_{ESR}}{R_C}$$

Input Capacitor Selection

It is necessary for the input capacitor to sustain the ripple current produced during the period of “on” state of the upper MOSFET, so a low ESR is required to minimize the loss. The RMS value of this ripple can be obtained by the following:

$$I_{IN}RMS = I_{OUT}\sqrt{D \times (1-D)}$$

where D is the duty cycle, I_{inRMS} is the input RMS current, and I_{OUT} is the load current. The equation reaches its maximum value with D = 0.5. The loss of the input capacitor can be calculated by the following equation:

$$P_{CIN} = ESR_{CIN} \times I_{IN}RMS^2$$

where P_{CIN} is the power loss of the input capacitor and ESR_{CIN} is the effective series resistance of the input capacitance. Due to large dI/dt through the input capacitor, electrolytic or ceramics should be used. If a tantalum must be used, it must be surge-protected. Otherwise, capacitor failure could occur.

Application Information

Output Inductor Selection

The output inductor selection is to meet the requirements of the output voltage ripple and affects the load transient response. The higher inductance can reduce the inductor's ripple current and induce the lower output ripple voltage. The ripple voltage and current are approximated by the following equations:

$$\Delta I = \frac{V_{in} - V_{out}}{F_S \times L} \bullet \frac{V_{out}}{Vin}$$

$$\Delta V_{out} = \Delta I \times ESR$$

Although the increase of the inductance reduces the ripple current and voltage, it contributes to the decrease of the response time for the regulator to load transient as well. Increasing the switching frequency (Fs) for a given inductor also can reduce the ripple current and voltage but it will increase the switching loss of the power MOS.

The way to set a proper inductor value is to have the ripple current (△I) be approximately 10%~50% of the maximum output current. Once the value has been determined, select an inductor capable of carrying the required peak current without going into saturation. It is also important to have the inductance tolerance specified to keep the accuracy of the system controlled. Using 20% for the inductance (at room temperature) is reasonable tolerance able to be met by most manufacturers. For some types of inductors, especially those with core made of ferrite, the ripple current will increase abruptly when it saturates, which will result in a larger output ripple voltage.

Output Capacitors Selection

An output capacitor is required to filter the output and supply the load transient current. The high capacitor value and low ESR will reduce the output ripple and the load transient drop. These requirements are met by a mix of capacitors and careful layout.

In typical switching regulator design, the ESR of the output capacitor bank dominates the transient response. The number of output capacitors can be determined by the following equations:

$$ESR_{MAX} = \frac{\Delta V_{ESR}}{\Delta I_{OUT}}$$

$$\text{Number Of Capacitors} = \frac{ESR_{CAP}}{ESR_{MAX}}$$

$\triangle V_{ESR}$ = change in output voltage due to ESR (assigned by the designer)

$\triangle$IOUT = load transient.

ESR_{CAP} = maximum ESR per capacitor (specified in manufacturer's data sheet).

ESR_{MAX} = maximum allowable ESR.

High frequency decoupling capacitors should be placed as close to the power pins of the load as physically possible. For the decoupling requirements, please consult the capacitor manufacturers for confirmation.

Output Voltage

The output voltage is set using the FB pin and a resistor divider connected to the output as shown in the following AP Circuit. The output voltage (V_{out}) can be calculated according to the voltage of the FB pin (V_{FB}) and ratio of the feedback resistors by the following equation, where (V_{FB}) is 1.23:

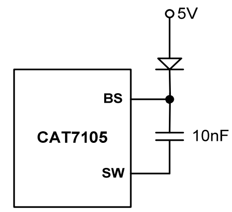
$$V_{FB} = V_{out} \times \frac{R_2}{(R_1 + R_2)}$$

Thus the output voltage is:

$$V_{out} = 1.23 \times \frac{(R_1 + R_2)}{R_2}$$

External Bootstrap Diode

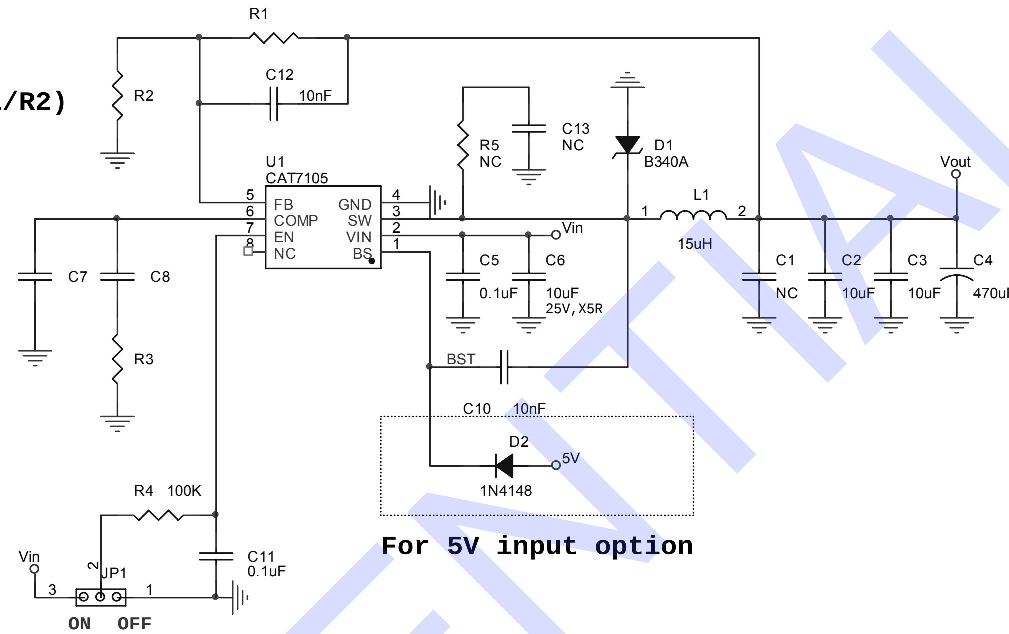
It is strongly recommended that an external bootstrap diode be added when there is a 5V fixed input for the system or the power supply generates a 5V output in order to improve the efficiency of the CAT7105 regulator. The boost diode can be the one with lost cost such as IN4148 or BAT54.



This diode is also recommended for high duty cycle operation when Duty Cycle>65% (Example: VIN=5V & Vout=3.3V; Duty Cycle=66%) and high output voltage (VOUT>12V) applications.

CAT7105 EVB Schematic

Fsw=380K Hz
Vin=4.75V~23V
Vout=1.23V*(1+R1/R2)



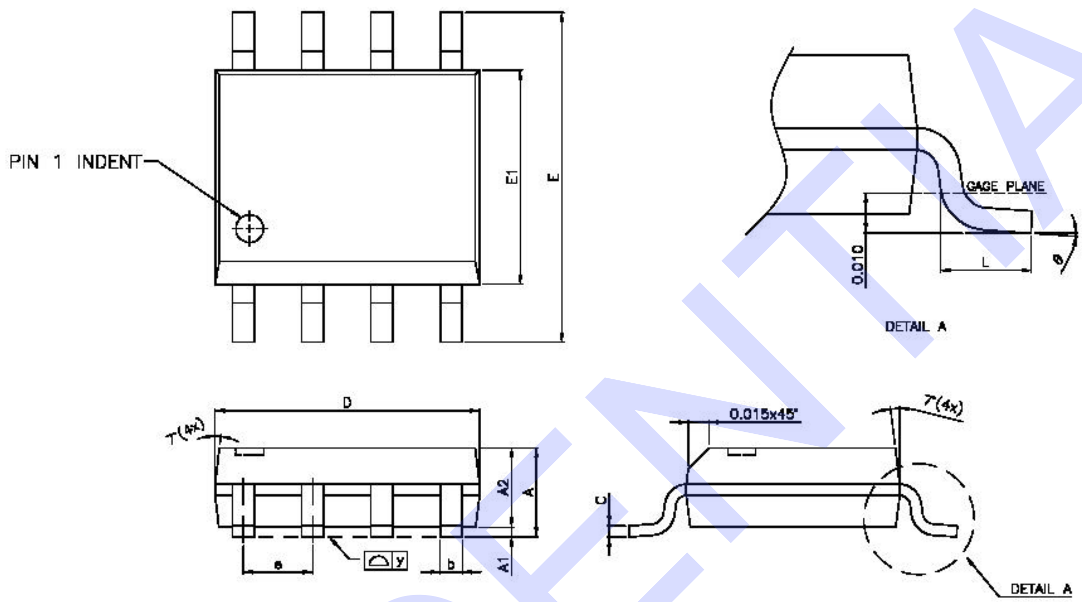
EVB BOM List

Qty	Ref	Value		Description	Package
2	C1, C2,	10µF		Ceramic Capacitor, 6.3V , X5R	1206
1	C6	10µF		Ceramic Capacitor, 25V, X5R	1206
1	C4	470µF		Electrolytic Capacitor, 6.3V	6.3X11
3	C5,C11	0.1uF		Ceramic Capacitor, 50V, X5R	0603
1	L1	15uH		Inductor, Rated Current 3A	SMD
1	R4	100KΩ		Resistor, ±1%	0603
1	R1	Vout=5V	68 K Ω	Resistor, ±1%	0603
		Vout=3.3V	56 K Ω		
		Vout=1.8V	4.7 K Ω		
		Vout=1.23V	4.7 K Ω		
1	R2	Vout=5V	22 K Ω	Resistor, ±1%	0603
		Vout=3.3V	33 K Ω		
		Vout=1.8V	10 K Ω		
		Vout=1.23V	NC		
1	R3	Vout=5V	4.7 K Ω	Resistor, ±1%	0603
		Vout=3.3V	5.6 K Ω		
		Vout=1.8V	5.6 K Ω		
		Vout=1.23V	3 K Ω		
1	C10	0.01uF		Ceramic Capacitor, 50V, X5R	0603
1	C7	33pF		Ceramic Capacitor, 50V, X5R	0603
1	C8	2.2nF		Ceramic Capacitor, 50V, X5R	0603
1	C13,R5	NC			
1	D1	B340A		Diode	1206
1	U1	CAT7105		Step-Down DC/DC Converter	SOP8

Package Information

SOP8 (3.90*4.85*1.45mm) Outline Dimensions

unit: inches/mm



Symbol	Dimension in inches			Dimension in mm		
	Min	Nom	Max	Min	Nom	Max
A	0.058	0.063	0.068	1.47	1.60	1.73
A_1	0.004	—	0.010	0.10	—	0.25
A_2	—	0.057	—	—	1.45	—
b	0.013	0.016	0.020	0.33	0.41	0.51
C	0.0075	0.008	0.0098	0.19	0.20	0.25
D	0.189	0.191	0.195	4.80	4.85	4.95
E	0.228	0.236	0.244	5.80	6.00	6.20
E_1	0.150	0.154	0.157	3.80	3.90	4.00
e	—	0.050	—	—	1.27	—
L	0.015	0.028	0.050	0.38	0.71	1.27
y	—	—	0.004	—	—	0.1
θ	0°	—	8°	0°	—	8°

Notes:

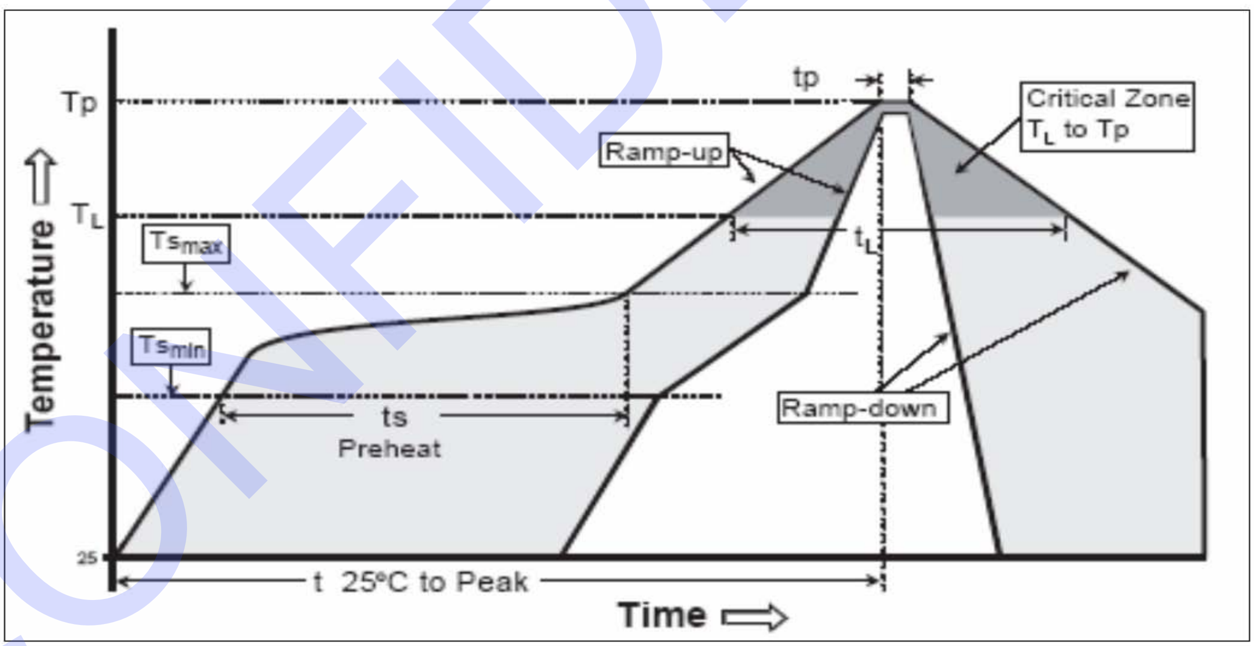
1. Controlling dimension：INCH
2. Dimension 〝D〞 does not include mold flash, Tie bar burrs and gate burrs.
3. Dimension 〝b〞 does not include dambar protrusion.
4. Reference document：JEDEC SPEC MS-012

DI-SOP8(150mil Body)v0

Classification Reflow Profiles

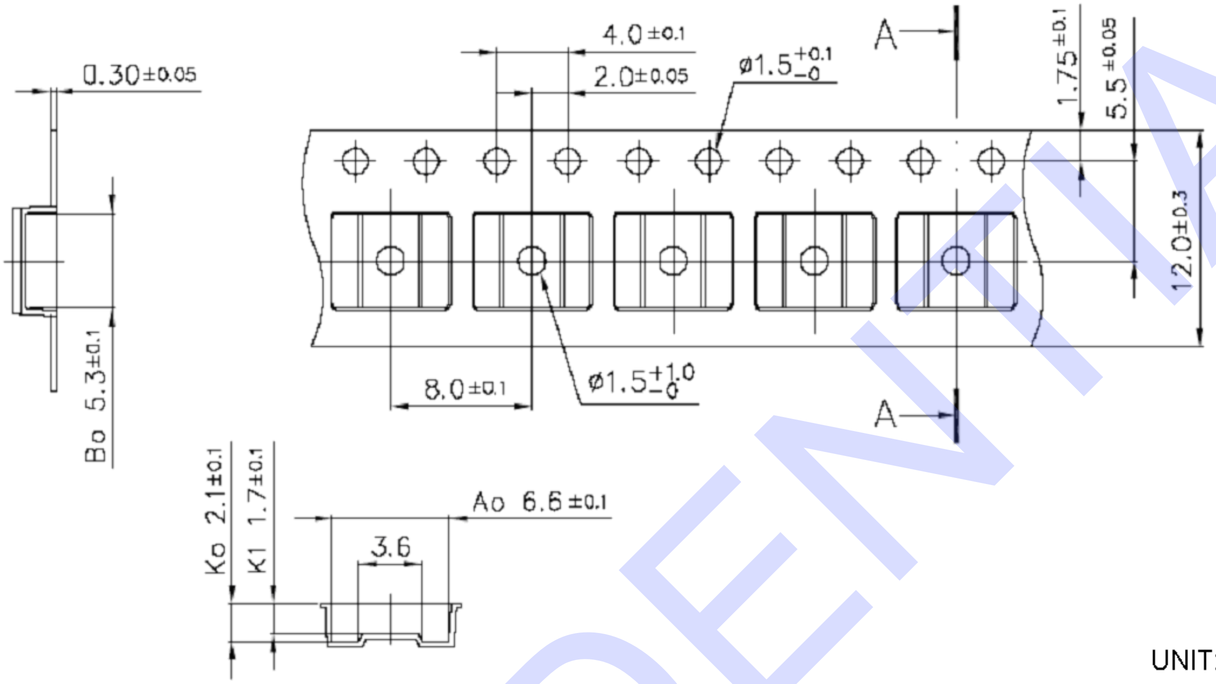
Reflow Profile	Green Assembly
Average Ramp-Up Rate (Ts_{max} to Tp)	3℃/second max.
Preheat -Temperature Min(Ts_{min}) -Temperature Max(Ts_{max}) -Time(ts_{min} to ts ts_{max})	150℃ 200℃ 60-120 seconds
Time maintained above: -Temperature(T_L) -Time(t_L)	217℃ 60-150 seconds
Peak Temperature(Tp)	260 +0/-5 ℃
Time within 5 ℃ of actual Peak Temperature(tp)	10-30 seconds
Ramp-Down Rate	6℃/second max.
Time 25℃ to Peak Temperature	8 minutes max.

Note: For all temperature information, please refer to topside of the package, measured on the package body surface.

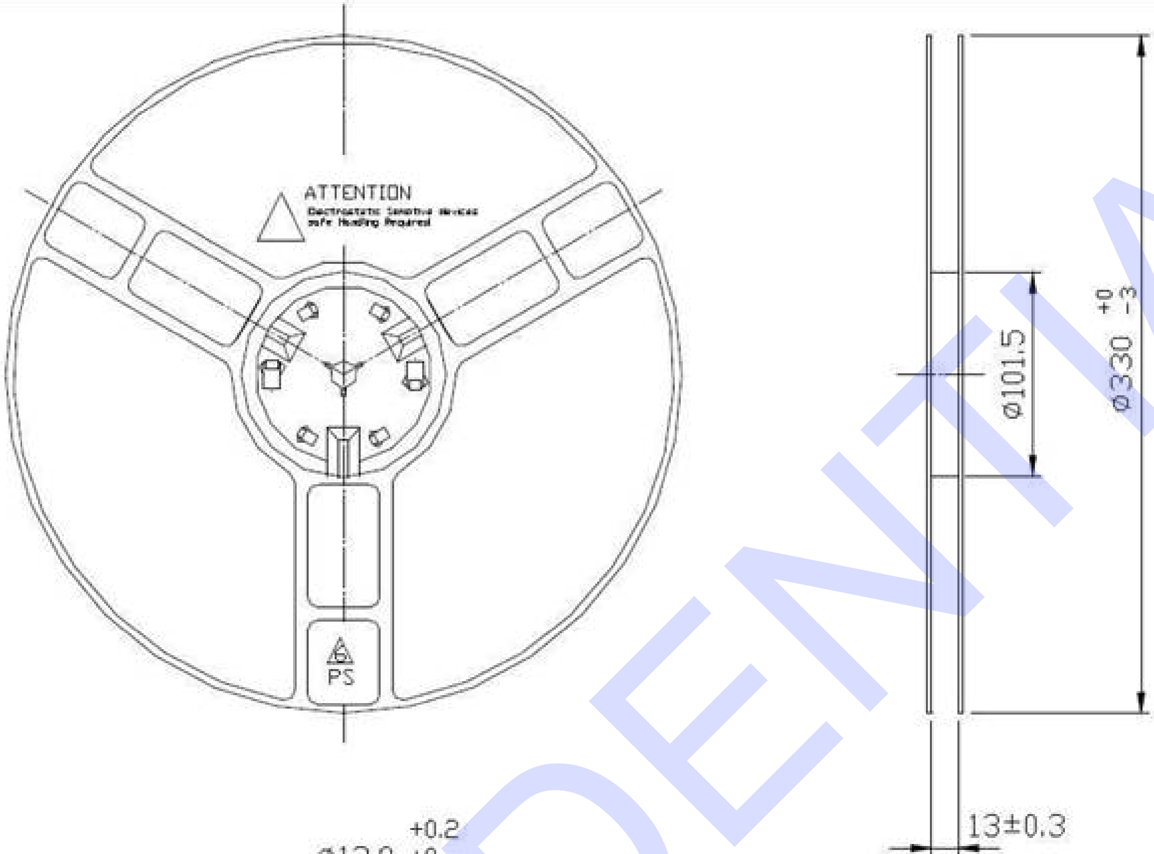


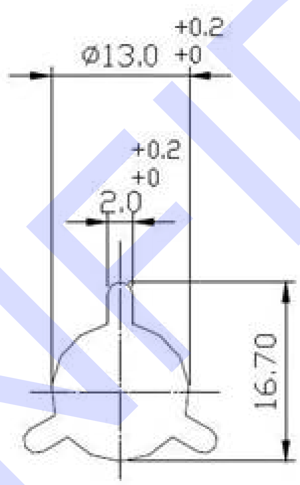
Carrier Tape & Reel Dimensions

Carrier Tape



UNIT: mm.





DETAIL "A"
SCALE 2:1

13" Reel

W=12 mm

MATERIAL:

PS

Anti-static

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(a) Delivery will be made Free Carrier (Incoterms), Seller's warehouse, Science-Based Industrial Park, Hsinchu, Taiwan.

(b) Title to the goods and the entire risk will pass to Buyer upon delivery to carrier.

(c) Shipments are subject to availability. Seller shall make every reasonable effort to meet the date(s) quoted or acknowledged; and if Seller makes such effort, Seller will not be liable for any delays.

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(a) Terms are as stated on Seller's quotation, or if none are stated, net thirty (30) days. Accounts past due will incur a monthly charge at the rate of one percent (1%) per month (or, if less, the maximum allowed by applicable law) to cover servicing costs.

(b) Seller reserves the right to change credit terms at any time in its sole discretion.

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(f) BUYER EXPRESSLY AGREES TO THE LIMITATIONS OF THIS PARAGRAPH 5 AND TO THEIR REASONABLENESS.

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Seller may at any time make substitutions for product ordered which do not materially and adversely affect overall performance with the then current specifications in the typical and intended use. Seller reserves the right to halt deliveries and shipments and alter specifications and prices without notice. Buyer shall verify that the literature and information is current before purchasing.

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8. INDEMNIFICATION

Seller will, at its own expense, assist Buyer with technical support and information in connection with any claim that any parts as shipped by Seller under the purchase order infringe any valid and enforceable copyright, or trademark, provided however, that Buyer (i) gives immediate written notice to Seller, (ii) permits Seller to participate and to defend if Seller requests to do so, and (iii) gives Seller all needed information, assistance and authority. However, Seller will not be responsible for infringements resulting from anything not entirely manufactured by Seller, or from any combination with products, equipment, or materials not furnished by Seller. Seller will have no liability with respect to intellectual property matters arising out of products made to Buyer's specifications, code, or designs.

Except as expressly stated in this Paragraph 8 or in another writing signed by an authorized officer, Seller makes no representations and/or warranties with respect to intellectual and/or industrial property and/or with respect to claims of infringement. Except as to claims Seller agrees in writing to defend, BUYER WILL INDEMNIFY, DEFEND AND HOLD HARMLESS SELLER FROM ALL CLAIMS, COSTS, LOSSES AND DAMAGES (INCLUDING ATTORNEYS FEES) AGAINST AND/OR ARISING OUT OF GOODS SOLD AND/OR SHIPPED HEREUNDER.

9. NO CONFIDENTIAL INFORMATION

Seller shall have no obligation to hold any information in confidence except as provided in a separate non-disclosure agreement signed by both parties.

10. ENTIRE AGREEMENT

(a) These terms and conditions are the entire agreement and the only representations and understandings between Seller and Buyer, and no addition, deletion or modification shall be binding on Seller unless expressly agreed to in written and signed by an officer of Seller.

(b) Buyer is not relying upon any warranty or representation except for those specifically stated here.

11. APPLICABLE LAW

The contract and all performance and disputes arising out of or relating to goods involved will be governed by the laws of R.O.C. (Taiwan, Republic of China), without reference to the U.N. Convention on Contracts for the International Sale of Goods or to conflict of laws principles. Buyer agrees at its sole expense to comply with all applicable laws in connection with the purchase, use or sale of the goods provided hereunder and to indemnify Seller from any failure by Buyer to so comply. Without limiting the foregoing, Buyer certifies that no technical data or direct products thereof will be made available or re-exported, directly or indirectly, to any country to which such export or access is prohibited or restricted under R.O.C. laws or U.S. laws or regulations, unless prior authorization is obtained from the appropriate officials and agencies of the government as required under R.O.C. or U.S. laws or regulations.

12. JURISDICTION AND VENUE

The courts located in Hsinchu, Taiwan, Republic of China, will have the sole and exclusive jurisdiction and venue over any dispute arising out of or relating to the contract or any sale of goods hereunder. Buyer hereby consents to the jurisdiction of such courts.

13. ATTORNEYS' FEES

Reasonable attorneys' fees and costs will be awarded to the prevailing party in the event of litigation involving and/or relating to the enforcement or interpretation of the contract and/or any goods sold under it.