

## Dual 150mA CMOS LDO With Select Mode™ Operation, Shutdown and RESET Output

### Features

- Extremely Low Supply Current for Longer Battery Life
- Select Mode™ Operation: Selectable Output Voltages for High Design Flexibility
- Very Low Dropout Voltage
- 10µsec (Typ.) Wake-Up Time from  $\overline{\text{SHDN}}$
- Maximum 150mA Output Current per Output
- High Output Voltage Accuracy
- Power-Saving Shutdown Mode
- $\overline{\text{RESET}}$  Output Can Be Used as a Low Battery Detector or Processor Reset Generator
- Over Current Protection and Over Temperature Shutdown
- Space Saving 8-Pin MSOP Package

### Applications

- Load Partitioning
- Battery Operated Systems
- Portable Computers
- Medical Instruments
- Instrumentation
- Pagers and Cellular/GSM/PHS Phones
- Linear Post-Regulator for SMPS

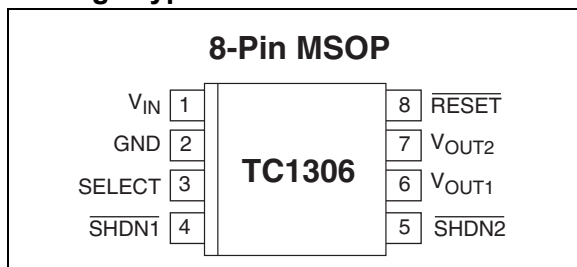
### Device Selection Table

Part Number	Package	Junction Temperature Range
TC1306R-BDVUA	8-Pin MSOP	-40°C to +125°C

**NOTE:** "R" denotes the suffix for the 2.63V RESET threshold.  
 "B" indicates  $V_{\text{OUT1}} = 1.8\text{V}$  (fixed).  
 "D" indicates  $V_{\text{OUT2}} = 2.8\text{V}, 3.0\text{V}$  (selectable).

Other output voltages are available. Please contact Microchip Technology Inc. for details.

### Package Type



### General Description

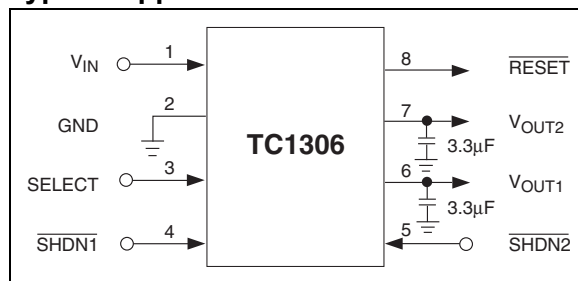
The TC1306 combines two CMOS Low Dropout Regulators and a Microprocessor Monitor in a space saving 8-Pin MSOP package. Designed specifically for battery operated systems, total supply current is typically 120µA at full load, 20 to 60 times lower than in bipolar regulators.

The TC1306 features selectable output voltages for higher design flexibility. The dual-state SELECT input pin allows the user to select  $V_{\text{OUT2}}$  from 2 different values (2.8V and 3.0V).  $V_{\text{OUT1}}$  supplies a fixed 1.8V voltage.

An active low  $\overline{\text{RESET}}$  is asserted when the output voltage  $V_{\text{OUT2}}$  falls below the 2.63V reset voltage threshold. The RESET output remains low for 300msec (typical) after  $V_{\text{OUT2}}$  rises above reset threshold. When the shutdown control ( $\overline{\text{SHDN1}}$ ) is low, the regulator output voltage  $V_{\text{OUT1}}$  falls to zero and  $\overline{\text{RESET}}$  output remains valid. When the shutdown control ( $\overline{\text{SHDN2}}$ ) is low, the regulator output voltage  $V_{\text{OUT2}}$  falls to zero and RESET output is low.

Other key features for the device include ultra low noise operation, fast response to step changes in load and very low dropout voltage (typically 125mV at full load). The device also incorporates both over temperature and over current protection. Each regulator is stable with an output capacitor of only 1µF and has a maximum output current of 150mA.

### Typical Application



# TC1306

## 1.0 ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS\*

Input Voltage .....	6.5V
Output Voltage.....	(-0.3V) to (V <sub>IN</sub> + 0.3V)
Power Dissipation.....	Internally Limited ( <b>Note 7</b> )
Maximum Voltage on Any Pin .....	V <sub>IN</sub> + 0.3V to -0.3V
Operating Temperature Range....	-40°C < T <sub>J</sub> < +125°C
Storage Temperature Range .....	-65°C to +150°C

\*Stresses above those 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 above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

### TC1306 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V <sub>IN</sub> = V <sub>R</sub> + 1V, I <sub>L</sub> = 100μA, C <sub>L</sub> = 3.3μF, SHDN1 > V <sub>IH</sub> , SHDN2 > V <sub>IH</sub> , T <sub>A</sub> = 25°C, unless otherwise noted. <b>Boldface</b> type specifications apply for junction temperature of -40°C to +125°C. Applies to both V <sub>OUT1</sub> and V <sub>OUT2</sub> .						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
V <sub>IN</sub>	Input Operating Voltage	<b>2.7</b>	—	<b>6.0</b>	V	<b>Note 1</b>
I <sub>OUTMAX</sub>	Maximum Output Current	<b>150</b>	—	—	mA	Per Channel
V <sub>OUT</sub>	Output Voltage (V <sub>OUT1</sub> and V <sub>OUT2</sub> )	<b>V<sub>R</sub> - 2.5%</b>	V <sub>R</sub> ± 0.5%	<b>V<sub>R</sub> + 2.5%</b>	V	<b>Note 2</b>
TCV <sub>OUT</sub>	V <sub>OUT</sub> Temperature Coefficient	—	20 <b>40</b>	—	ppm/°C	<b>Note 3</b>
ΔV <sub>OUT</sub> /ΔV <sub>IN</sub>	Line Regulation	—	0.05	<b>0.35</b>	%	(V <sub>R</sub> + 1V) ≤ V <sub>IN</sub> ≤ 6V
ΔV <sub>OUT</sub> /V <sub>OUT</sub>	Load Regulation	—	0.3	<b>2</b>	%	I <sub>L</sub> = 0.1mA to I <sub>OUTMAX</sub> <b>(Note 4)</b>
V <sub>IN</sub> - V <sub>OUT</sub>	Dropout Voltage	—	2 45 85 125	— <b>120</b> <b>240</b> <b>360</b>	mV	I <sub>L</sub> = 100μA I <sub>L</sub> = 50mA I <sub>L</sub> = 100mA I <sub>L</sub> = 150mA, ( <b>Note 5</b> )
I <sub>IN</sub>	Supply Current	—	120	<b>200</b>	μA	SHDN1, SHDN2 = V <sub>IH</sub> , I <sub>L</sub> = 0
I <sub>INSD</sub>	Shutdown Supply Current	—	0.05	0.5	μA	SHDN1, SHDN2 = 0V
PSRR	Power Supply Rejection Ratio	—	55	—	dB	F <sub>RE</sub> ≤ 120Hz
I <sub>OUTSC</sub>	Output Short Circuit Current	—	450	—	mA	V <sub>OUT</sub> = 0V
ΔV <sub>OUT</sub> /ΔP <sub>D</sub>	Thermal Regulation	—	0.04	—	V/W	<b>Notes 6, 7</b>
t <sub>WK</sub>	Wake Up Time (from Shutdown Mode)	—	10	—	μsec	V <sub>IN</sub> = 5V C <sub>IN</sub> = 1μF, C <sub>OUT</sub> = 4.7μF I <sub>L</sub> = 30mA, (See Figure 4-1)
ts	Settling Time (from Shutdown Mode)	—	40	—	μsec	V <sub>IN</sub> = 5V C <sub>IN</sub> = 1μF, C <sub>OUT</sub> = 4.7μF I <sub>L</sub> = 30mA, (See Figure 4-1)

**Note 1:** The minimum V<sub>IN</sub> has to meet two conditions: V<sub>IN</sub> ≥ 2.7 and V<sub>IN</sub> = V<sub>R</sub> + V<sub>DROPOUT</sub>.

**Note 2:** V<sub>R</sub> is the regulator output voltage setting. For example: V<sub>R</sub> = 2.8V, 3.0V.

**Note 3:**  $T_C V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$

**Note 4:** Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

**Note 5:** Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value measured at a 1V differential.

**Note 6:** Thermal Regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a current pulse equal to I<sub>LMAX</sub> at V<sub>IN</sub> = 6V for T = 10 msec.

**Note 7:** The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction-to-air (i.e., T<sub>A</sub>, T<sub>J</sub>, θ<sub>JA</sub>). Exceeding the maximum allowable power dissipation causes the device to initiate thermal shutdown. Please see Section 5.0 Thermal Considerations section of this data sheet for more details.

## TC1306 ELECTRICAL SPECIFICATIONS (CONTINUED)

**Electrical Characteristics:**  $V_{IN} = V_R + 1V$ ,  $I_L = 100\mu A$ ,  $C_L = 3.3\mu F$ ,  $\overline{SHDN1} > V_{IH}$ ,  $\overline{SHDN2} > V_{IH}$ ,  $T_A = 25^\circ C$ , unless otherwise noted. **Boldface** type specifications apply for junction temperature of  $-40^\circ C$  to  $+125^\circ C$ . Applies to both  $V_{OUT1}$  and  $V_{OUT2}$ .

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$T_{SD}$	Thermal Shutdown Die Temperature	—	160	—	$^\circ C$	
$\Delta T_{SD}$	Thermal Shutdown Hysteresis	—	15	—	$^\circ C$	
eN	Output Noise	—	200	—	$nV\sqrt{Hz}$	F = 10kHz
<b>SHDN Input</b>						
$V_{IH}$	$\overline{SHDN}$ Input High Threshold	<b>65</b>	—	—	% $V_{IN}$	$V_{IN} = 2.7V$ to $6.0V$
$V_{IL}$	$\overline{SHDN}$ Input Low Threshold	—	—	<b>15</b>	% $V_{IN}$	$V_{IN} = 2.7V$ to $6.0V$
<b>SELECT Input</b>						
$V_{SELH}$	SELECT Input High Threshold	<b>65</b>	—	—	% $V_{IN}$	$V_{IN} = 2.7V$ to $6.0V$
$V_{SELL}$	SELECT Input Low Threshold	—	—	<b>15</b>	% $V_{IN}$	$V_{IN} = 2.7V$ to $6.0V$
<b>RESET Output</b>						
$V_{INMIN}$	Minimum $V_{IN}$ Operating Voltage	1.0 <b>1.2</b>	—	6.0 <b>6.0</b>	V	$T_A = 0^\circ C$ to $+70^\circ C$ $T_A = -40^\circ C$ to $+125^\circ C$
$V_{TH}$	Reset Threshold	2.59 <b>2.55</b>	2.63 —	2.66 <b>2.70</b>	V	$T_A = +25^\circ C$ $T_A = -40^\circ C$ to $+125^\circ C$
	Reset Threshold Tempco	—	30	—	ppm/ $^\circ C$	
	$V_{OUT2}$ to Reset Delay	—	100	—	$\mu sec$	$V_{OUT2} = V_{TH}$ to $(V_{TH} - 100mV)$
	Reset Active Time-out Period	<b>140</b>	300	<b>560</b>	msec	
$V_{OL}$	$\overline{RESET}$ Output Voltage Low	—	—	<b>0.3</b>	V	$V_{OUT2} = V_{THMIN}$ , $I_{SINK} = 1.2mA$ $V_{OUT2} = V_{THMIN}$ , $I_{SINK} = 3.2mA$ $V_{OUT2} > 1.0V$ , $I_{SINK} = 50\mu A$
		—	—	<b>0.4</b>		
		—	—	<b>0.3</b>		
$V_{OH}$	$\overline{RESET}$ Output Voltage High	$0.8 V_{OUT2}$	—	—	V	$V_{OUT2} > V_{THMAX}$ , $I_{SOURCE} = 500\mu A$ $V_{OUT2} > V_{THMAX}$ , $I_{SOURCE} = 800\mu A$
		$V_{OUT2} - 1.5$	—	—		

- Note** 1: The minimum  $V_{IN}$  has to meet two conditions:  $V_{IN} \geq 2.7$  and  $V_{IN} = V_R + V_{DROPOUT}$ .  
 2:  $V_R$  is the regulator output voltage setting. For example:  $V_R = 2.8V, 3.0V$ .  
 3:  $T_C V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$   
 4: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.  
 5: Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value measured at a 1V differential.  
 6: Thermal Regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a current pulse equal to  $I_{LMAX}$  at  $V_{IN} = 6V$  for T = 10 msec.  
 7: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction-to-air (i.e.,  $T_A, T_J, \theta_{JA}$ ). Exceeding the maximum allowable power dissipation causes the device to initiate thermal shutdown. Please see Section 5.0 Thermal Considerations section of this data sheet for more details.

# TC1306

## 2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

**TABLE 2-1: PIN FUNCTION TABLE**

Pin No. (8-Pin MSOP)	Symbol	Description
1	$V_{IN}$	Power supply input.
2	GND	Ground terminal.
3	SELECT	SELECT control for setting $V_{OUT2}$ . SELECT = Low for $V_{OUT2} = 2.8V$ , SELECT = High for $V_{OUT2} = 3.0V$ .
4	$\overline{SHDN1}$	Shutdown control input for $V_{OUT1}$ . Regulator 1 is fully enabled when a logic high is applied to this input. Regulator 1 enters shutdown when a logic low is applied to this input. During shutdown, regulator output voltage falls to zero, $\overline{RESET}$ output remains valid.
5	$\overline{SHDN2}$	Shutdown control input for $V_{OUT2}$ . Regulator 2 is fully enabled when a logic high is applied to this input. Regulator 2 enters shutdown when a logic low is applied to this input. During shutdown, regulator output voltage falls to zero, $\overline{RESET}$ output is low.
6	$V_{OUT1}$	Regulated voltage output 1.
7	$V_{OUT2}$	Regulated voltage output 2.
8	$\overline{RESET}$	$\overline{RESET}$ Output. $\overline{RESET} = \text{Low}$ when $V_{OUT2}$ is below the Reset Threshold Voltage. $\overline{RESET} = \text{High}$ when $V_{OUT2}$ is above the Reset Threshold Voltage.

## 3.0 DETAILED DESCRIPTION

The TC1306 is a precision fixed output voltage regulator that contains two fully independent 150mA outputs. The device also features separate shutdown modes for low-power operation. The Select Mode™ operation allows the user to select  $V_{OUT2}$  from two different values (2.8V, 3.0V), therefore providing high design flexibility.  $V_{OUT1}$  supplies a fixed 1.8V output voltage. The CMOS construction of the TC1306 results in a very low supply current, which does not increase with load changes. In addition,  $V_{OUT}$  remains stable and within regulation at no load currents.

The TC1306 also features an integrated microprocessor supervisor that monitors the  $V_{OUT2}$  output. The active low  $\overline{RESET}$  signal is asserted when the voltage of  $V_{OUT2}$  falls below the reset voltage threshold (2.63V). The  $\overline{RESET}$  output remains low for 300msec (typical) after  $V_{OUT2}$  rises above the reset threshold. The  $\overline{RESET}$  output of the TC1306 is optimized to reject fast transient glitches on the monitored output line.

## 4.0 TYPICAL APPLICATIONS

### 4.1 Input and Output Capacitor

The TC1306 is stable with a wide range of capacitor values and types. A capacitor with a minimum value of  $1\mu\text{F}$  from  $V_{\text{OUT}}$  to Ground is required. The output capacitor should have an effective series resistance (ESR) of  $0.1\Omega$  to  $10\Omega$  for a  $1\mu\text{F}$  capacitor and  $0.01\Omega$  to  $10\Omega$  for a  $10\mu\text{F}$  capacitor. A  $1\mu\text{F}$  capacitor should be connected from the  $V_{\text{IN}}$  to GND if there is more than 10 inches of wire between the regulator and the AC filter capacitor, or if a battery is used as the power source. Aluminum electrolytic or tantalum capacitor types can be used. (Since many aluminum electrolytic capacitors freeze at approximately  $-30^\circ\text{C}$ , solid tantalums are recommended for applications operating below  $-20^\circ\text{C}$ ). When operating from sources other than batteries, supply-noise rejection and transient response can be improved by increasing the value of the input and output capacitors and employing passive filtering techniques.

### 4.2 Shutdown Mode

Applying a logic high to each of the shutdown pins turns on the corresponding output. Each regulator enters shutdown mode when a logic low is applied to the corresponding input. During shutdown mode, output voltage falls to zero, and regulator supply current is reduced to  $0.5\mu\text{A}$  (max). If shutdown mode is not necessary, the pins should be connected to  $V_{\text{IN}}$ .

### 4.3 Select Mode™ Operation

The Select Mode™ operation is a dual-state input that allows the user to select  $V_{\text{OUT}2}$  from two different values. By applying a logic low to the SELECT pin,  $V_{\text{OUT}2}$  is set to supply a 2.8V output voltage. A logic high signal at the SELECT pin sets  $V_{\text{OUT}2}$  to 3.0V. This output voltage functionality provides high design flexibility and minimizes cost associated with inventory, time-to-market and new device qualifications.

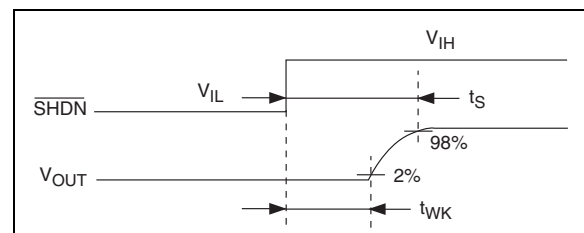
### 4.4 Turn On Response

The turn on response is defined as two separate response categories, Wake Up Time ( $t_{\text{WK}}$ ) and Settling Time ( $t_{\text{S}}$ ).

The TC1306 has a fast Wake Up Time ( $10\mu\text{sec}$  typical) when released from shutdown. See Figure 4-1 for the Wake Up Time designated as  $t_{\text{WK}}$ . The Wake Up Time is defined as the time it takes for the output to rise to 2% of the  $V_{\text{OUT}}$  value after being released from shutdown.

The total turn on response is defined as the Settling Time ( $t_{\text{S}}$ ), see Figure 4-1. Settling Time (inclusive with  $t_{\text{WK}}$ ) is defined as the condition when the output is within 2% of its fully enabled value ( $40\mu\text{sec}$  typical) when released from shutdown. The settling time of the output voltage is dependent on load conditions, output voltage and  $V_{\text{OUT}}$  (RC response).

**FIGURE 4-1: WAKE-UP RESPONSE TIME**



## 5.0 THERMAL CONSIDERATIONS

### 5.1 Thermal Shutdown

Integrated thermal protection circuitry shuts the regulator off when die exceeds approximately 160°C. The regulator remains off until the die temperature drops to approximately 145°C.

Thermal shutdown is intended to protect the device under transient accidental (fault) overload conditions. Thermal Shutdown may not protect the LDO while operating above junction temperatures of 125°C continuously. Sufficient thermal evaluation of the design needs to be conducted to ensure that the junction temperature does not exceed 125°C.

### 5.2 Power Dissipation

The amount of power the regulator dissipates is primarily a function of input and output voltage, and output current. The following equation is used to calculate worst case *actual* power dissipation.

#### EQUATION 5-1:

$$P_D \approx (V_{INMAX} - V_{OUT1MIN})I_{LOAD1MAX} + (V_{INMAX} - V_{OUT2MIN})I_{LOAD2MAX}$$

Where:

$P_D$  = Worst case actual power dissipation  
 $V_{INMAX}$  = Maximum voltage on  $V_{IN}$   
 $V_{OUT1MIN}$  = Minimum regulator output voltage1  
 $I_{LOAD1MAX}$  = Maximum output (load) current1  
 $V_{OUT2MIN}$  = Minimum regulator output voltage2  
 $I_{LOAD2MAX}$  = Maximum output (load) current2

The maximum *allowable* power dissipation (Equation 5-2) is a function of the maximum ambient temperature ( $T_{AMAX}$ ), the maximum allowable die temperature (125°C), and the thermal resistance from junction-to-air ( $\theta_{JA}$ ). The MSOP-8 package has a  $\theta_{JA}$  of approximately 200°C/W when mounted on a four layer FR4 dielectric copper clad PC board.

#### EQUATION 5-2:

$$P_{DMAX} = \frac{(T_{JMAX} - T_{AMAX})}{\theta_{JA}}$$

Where all terms are previously defined.

Equation 5-1 can be used in conjunction with Equation 5-2 to ensure regulator thermal operation is within limits. For example:

Given:

$$\begin{aligned} V_{INMAX} &= 3.8V \pm 5\% \\ V_{OUT1MIN} &= 1.8V \pm 2.5\% \\ V_{OUT2MIN} &= 3.0V \pm 2.5\% \\ I_{LOAD1MAX} &= 60mA \\ I_{LOAD2MAX} &= 120mA \\ T_{JMAX} &= 125^\circ C \\ T_{AMAX} &= 55^\circ C \\ \theta_{JA} &= 200^\circ C/W \end{aligned}$$

Find: 1. Actual power dissipation  
 2. Maximum allowable dissipation

Actual power dissipation:

$$\begin{aligned} P_D &\approx [(V_{INMAX} - V_{OUT1MIN}) \times I_{LOAD1MAX} \\ &+ [(V_{INMAX} - V_{OUT2MIN}) \times I_{LOAD2MAX} \\ &[(3.8 \times 1.05) - (1.8 \times .975)] \times 60 \times 10^{-3} \\ &+ [(3.8 \times 1.05) - (3.0 \times .975)] \times 120 \times 10^{-3} \\ &= 256mW \end{aligned}$$

Maximum allowable power dissipation:

$$\begin{aligned} P_D &= \frac{(T_{JMAX} - T_{AMAX})}{\theta_{JA}} \\ &= \frac{(125 - 55)}{200} \\ &= 350mW \end{aligned}$$

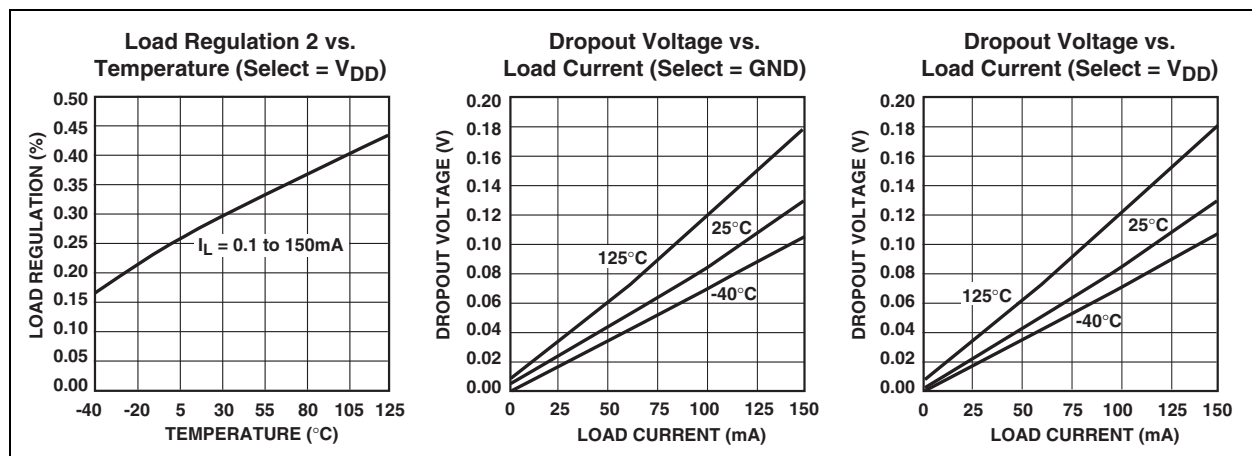
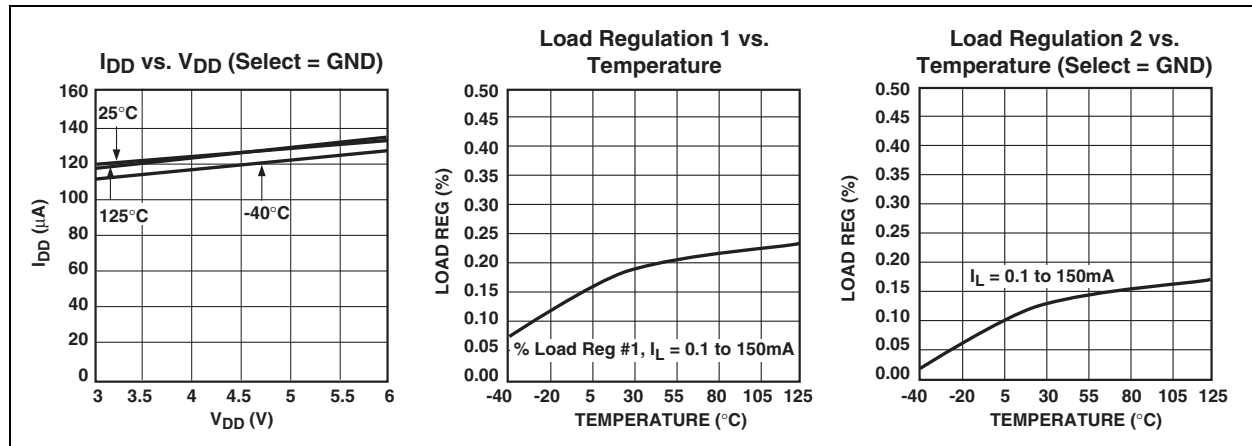
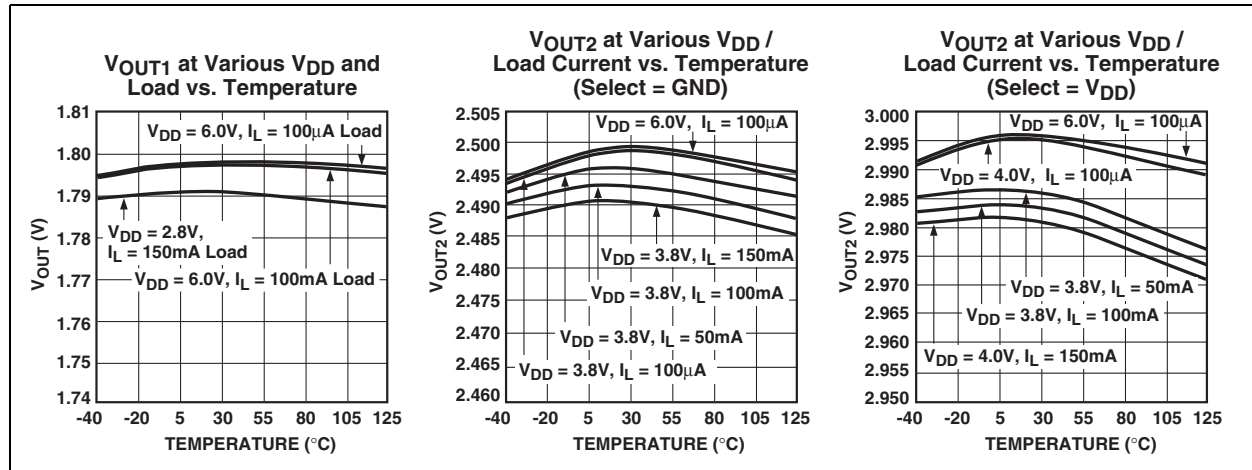
In this example, the TC1306 dissipates a maximum of 262mW; below the allowable limit of 350mW. In a similar manner, Equation 5-1 and Equation 5-2 can be used to calculate maximum current and/or input voltage limits. For example, the maximum allowable  $V_{IN}$  is found by substituting the maximum allowable power dissipation of 350mW into Equation 5-1, from which  $V_{INMAX} = 4.5V$ .

### 5.3 Layout Considerations

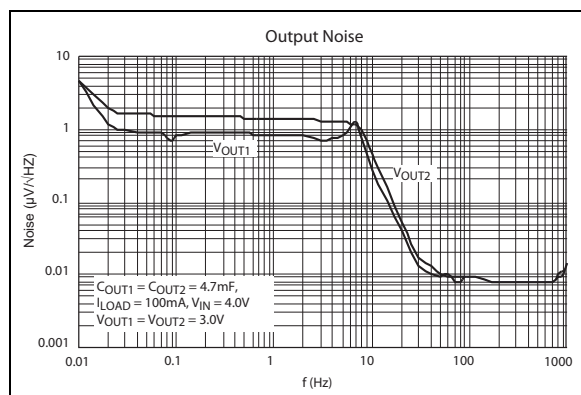
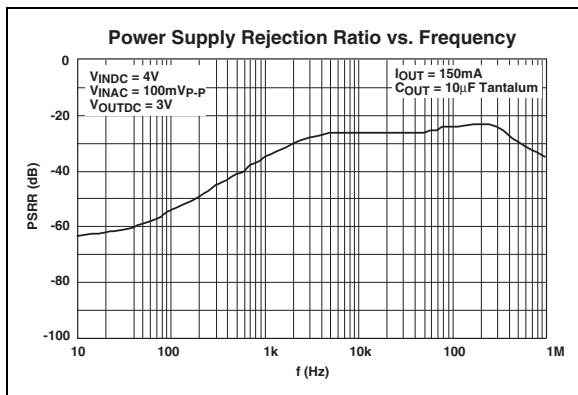
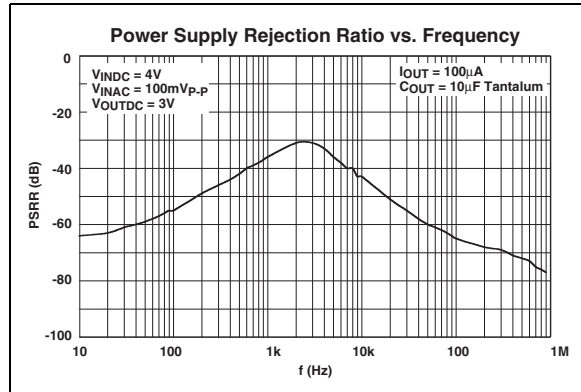
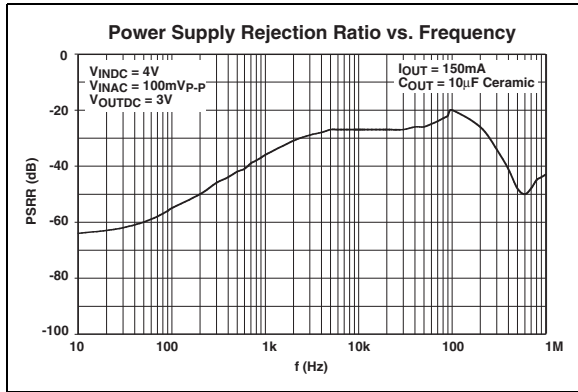
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower  $\theta_{JA}$  and therefore increase the maximum allowable power dissipation limit.

## 6.0 TYPICAL CHARACTERISTICS

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

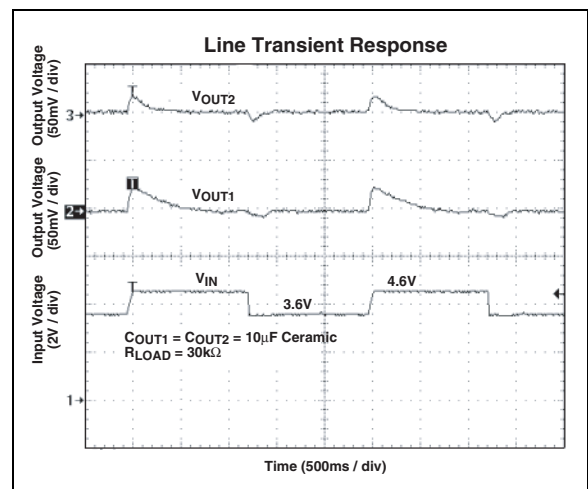
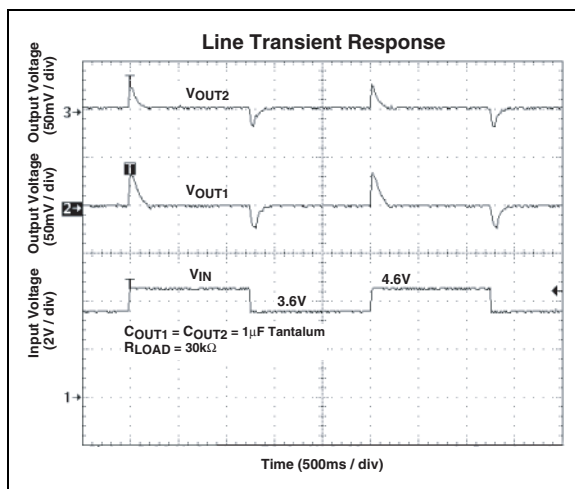
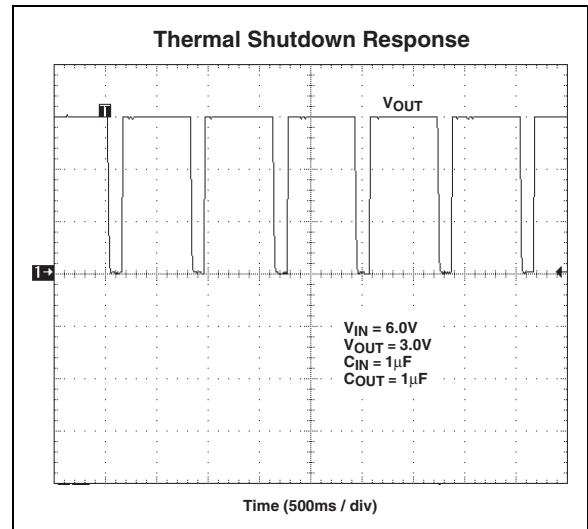
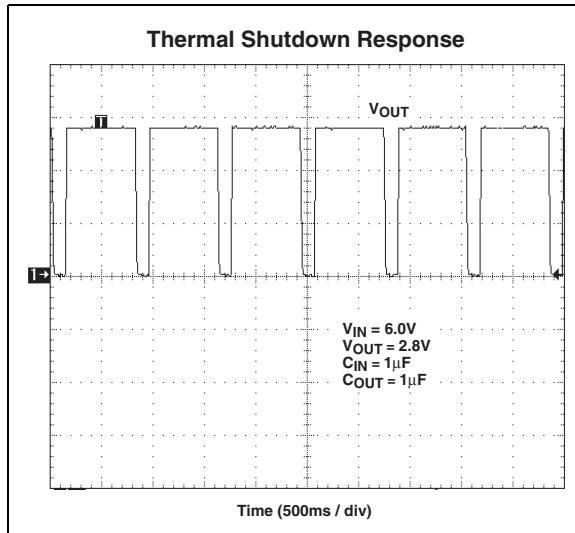
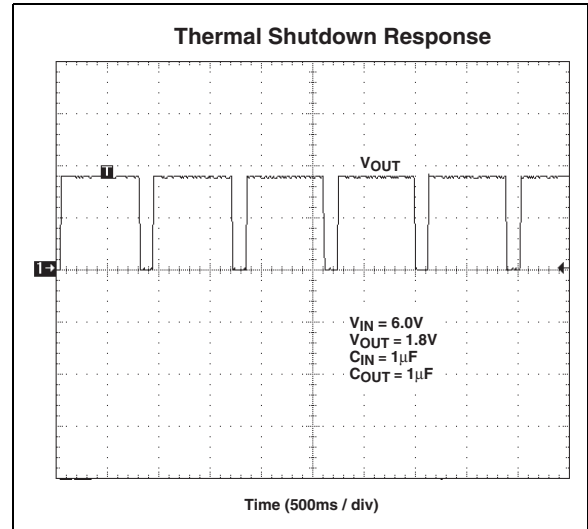
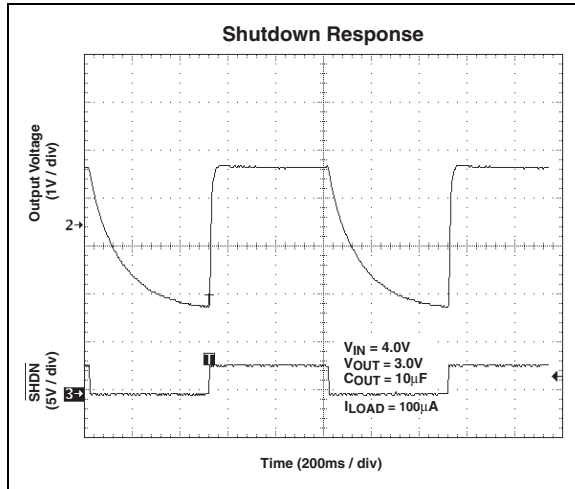


## 6.0 TYPICAL CHARACTERISTICS (CONTINUED)

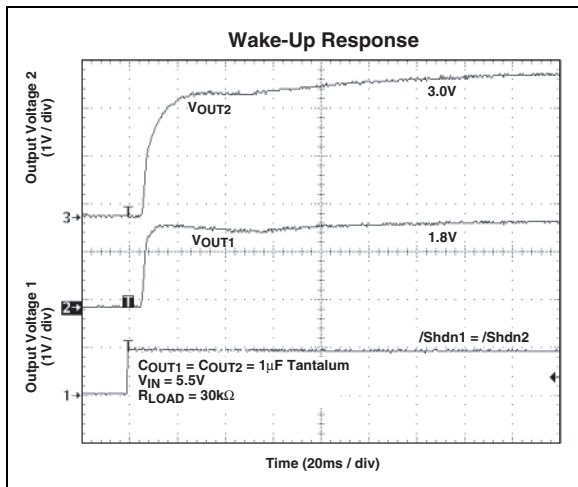
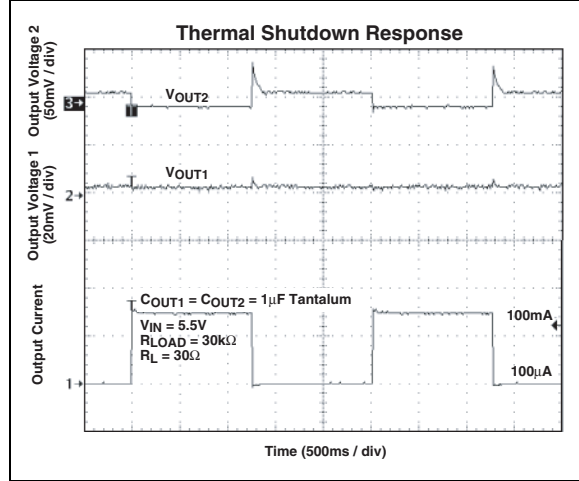
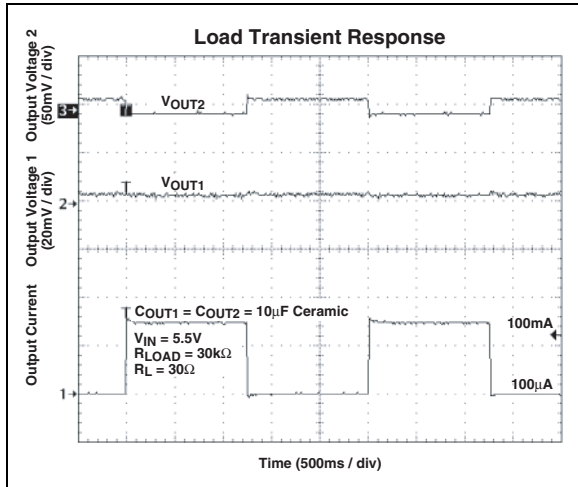
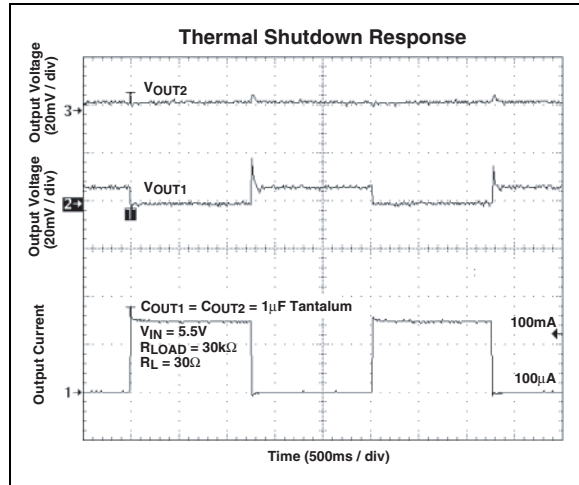
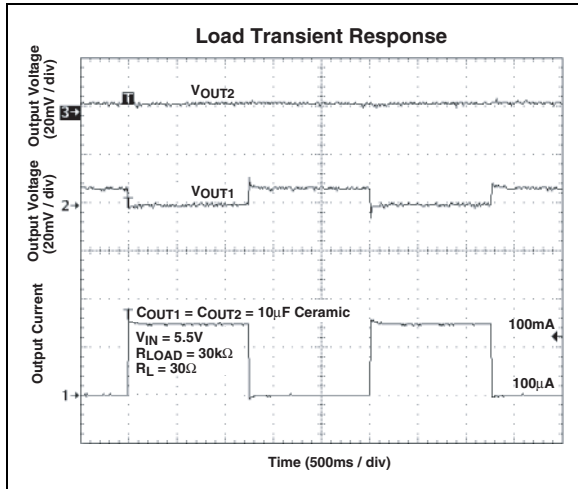




## 6.0 TYPICAL CHARACTERISTICS (CONTINUED)



## 6.0 TYPICAL CHARACTERISTICS (CONTINUED)

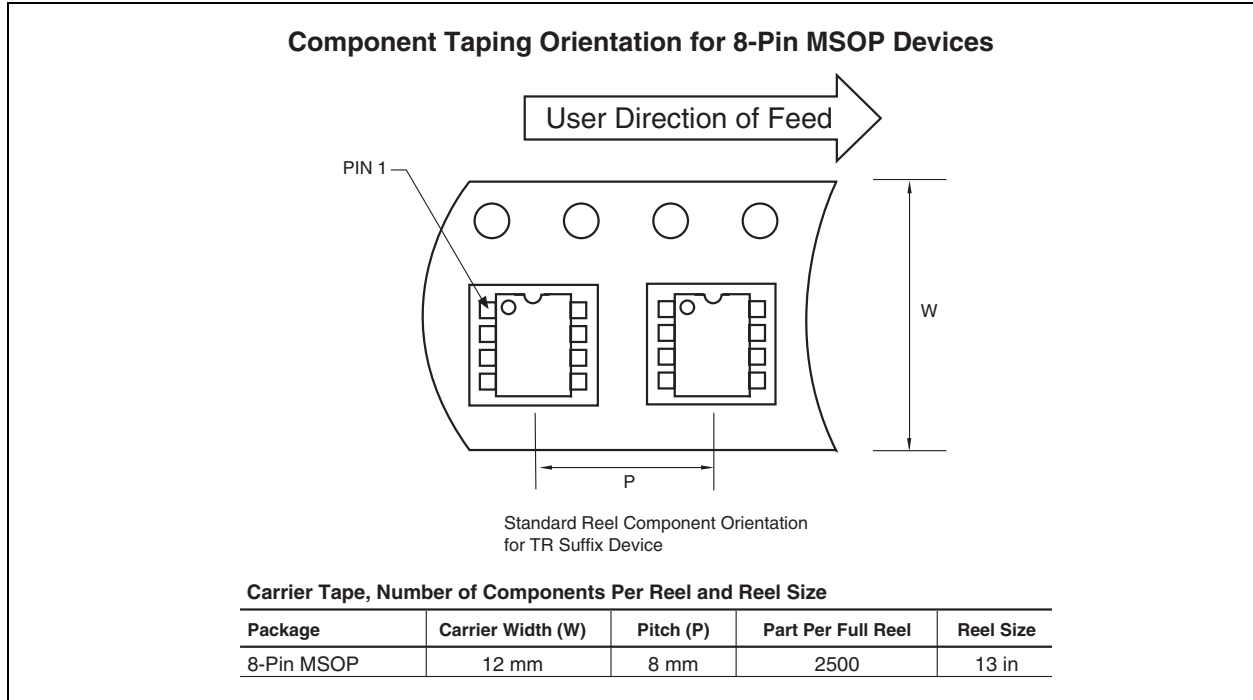


## 7.0 PACKAGING INFORMATION

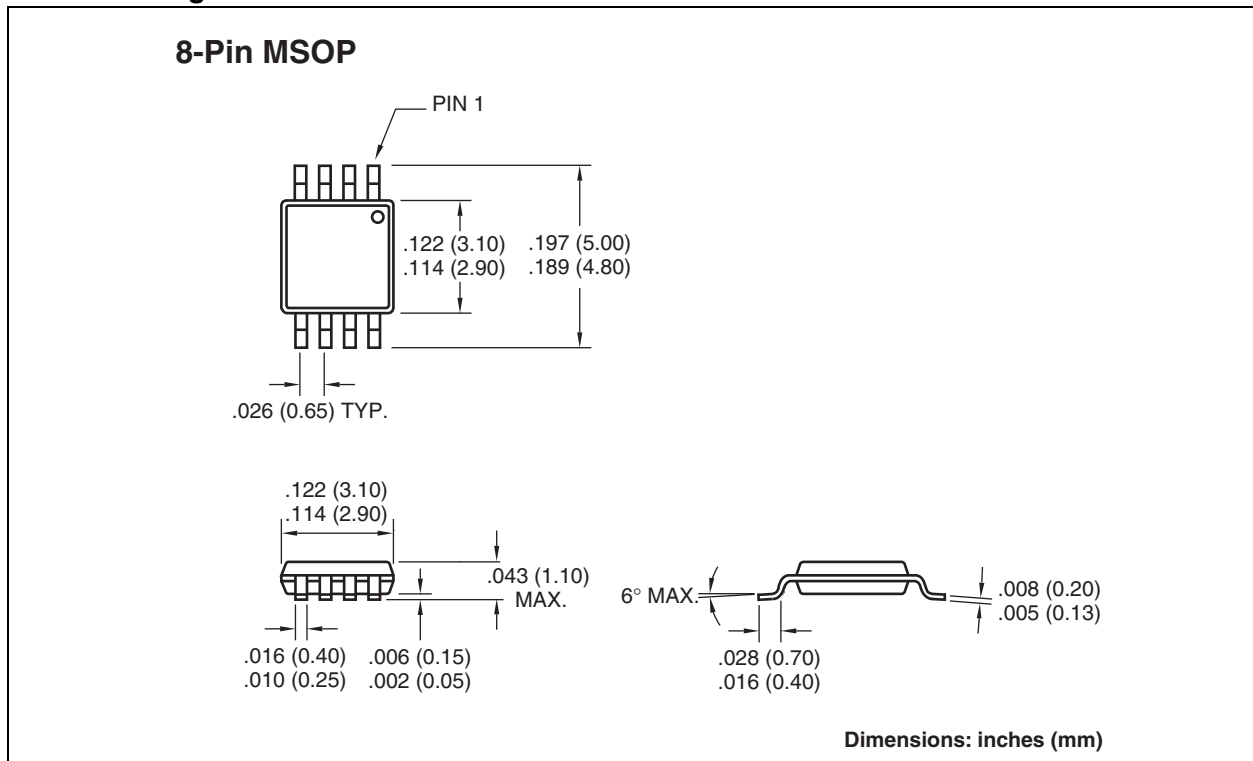
### 7.1 Package Marking Information

Package marking data not available at this time.

### 7.2 Taping Form



### 7.3 Package Dimensions



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NOTES:

## **APPENDIX A: REVISION HISTORY**

### **Revision C (February 2007)**

- Changed device status to “Obsolete” on data sheet
- Corrected Figure 6-4 Output Noise

### **Revision B (May 2002)**

- Undocumented changes

### **Revision A (March 2001)**

- Original Release of this Document.

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NOTES:

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