



# TC1014/TC1015/TC1185

## 50mA, 100mA and 150mA CMOS LDOs with Shutdown and Reference Bypass

### Features

- Extremely Low Supply Current (50 $\mu$ A, Typ.)
- Very Low Dropout Voltage
- Choice of 50mA (TC1014), 100mA (TC1015) and 150mA (TC1016) Output
- High Output Voltage Accuracy
- Standard or Custom Output Voltages
- Power Saving Shutdown Mode
- Reference Bypass Input for Ultra Low-Noise Operation
- Over Current and Over Temperature Protection
- Space-Saving 5-Pin SOT-23A Package
- Pin Compatible Upgrades for Bipolar Regulators

### Applications

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

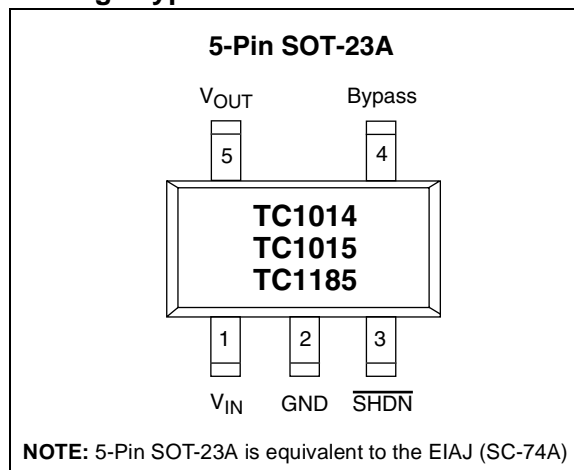
### Device Selection Table

Part Number	Package	Junction Temp. Range
TC1014-xxVCT	5-Pin SOT-23A	-40°C to +125°C
TC1015-xxVCT	5-Pin SOT-23A	-40°C to +125°C
TC1185-xxVCT	5-Pin SOT-23A	-40°C to +125°C

**NOTE:** xx indicates output voltages. Available output voltages: 1.8, 2.5, 2.6, 2.7, 2.8, 2.85, 3.0, 3.3, 3.6, 4.0, 5.0.

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

### Package Type



# TC1014/TC1015/TC1185

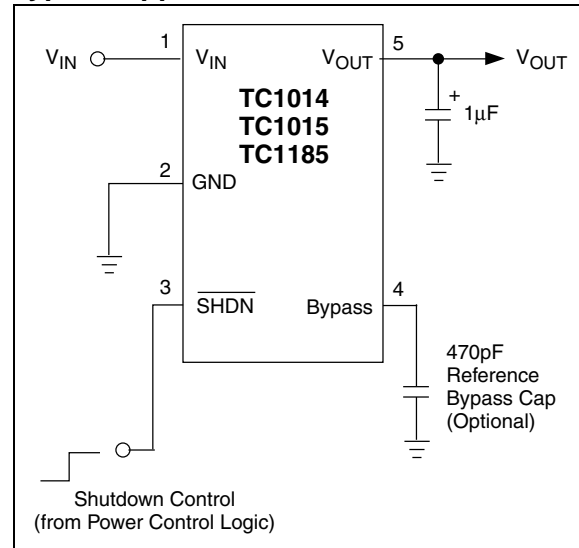
## General Description

The TC1014/TC1015/TC1185 are high accuracy (typically  $\pm 0.5\%$ ) CMOS upgrades for older (bipolar) low dropout regulators such as the LP2980. Designed specifically for battery-operated systems, the devices' CMOS construction eliminates wasted ground current, significantly extending battery life. Total supply current is typically  $50\mu\text{A}$  at full load (20 to 60 times lower than in bipolar regulators).

The devices' key features include ultra low noise operation (plus optional Bypass input), fast response to step changes in load, and very low dropout voltage – typically  $85\text{mV}$  (TC1014);  $180\text{mV}$  (TC1015); and  $270\text{mV}$  (TC1185) at full load. Supply current is reduced to  $0.5\mu\text{A}$  (max) and  $V_{\text{OUT}}$  falls to zero when the shutdown input is low. The devices incorporate both over-temperature and over-current protection.

The TC1014/TC1015/TC1185 are stable with an output capacitor of only  $1\mu\text{F}$  and have a maximum output current of  $50\text{mA}$ ,  $100\text{mA}$  and  $150\text{mA}$ , respectively. For higher output current regulators, please see the TC1107/TC1108/TC1173 ( $I_{\text{OUT}} = 300\text{mA}$ ) data sheets.

## Typical Application



# TC1014/TC1015/TC1185

## 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.....	-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.

### TC1014/TC1015/TC1185 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V <sub>IN</sub> = V <sub>R</sub> + 1V, I <sub>L</sub> = 100μA, C <sub>L</sub> = 3.3μF, $\overline{\text{SHDN}} > V_{IH}$ , T <sub>A</sub> = 25°C, unless otherwise noted. <b>Boldface</b> type specifications apply for junction temperatures of -40°C to +125°C.							
Symbol	Parameter	Min	Typ	Max	Units	Device	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>50</b> <b>100</b> <b>150</b>	—	—	mA	TC1014 TC1015 TC1185	
V <sub>OUT</sub>	Output Voltage	<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	—	0.5 0.5	<b>2</b> <b>3</b>	%	TC1014; TC1015 TC1185	I <sub>L</sub> = 0.1mA to I <sub>OUTMAX</sub> 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 65 85 180 270	— — <b>120</b> <b>250</b> <b>400</b>	mV	TC1015; TC1185 TC1185	I <sub>L</sub> = 100μA I <sub>L</sub> = 20mA 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 (Note 8)	—	50	<b>80</b>	μA		$\overline{\text{SHDN}} = V_{IH}$ , I <sub>L</sub> = 0
I <sub>INSD</sub>	Shutdown Supply Current	—	0.05	0.5	μA		$\overline{\text{SHDN}} = 0V$
PSRR	Power Supply Rejection Ratio	—	64	—	dB		F <sub>RE</sub> ≤ 1kHz
I <sub>OUTsc</sub>	Output Short Circuit Current	—	300	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>SD</sub>	Thermal Shutdown Die Temperature	—	160	—	°C		
ΔT <sub>SD</sub>	Thermal Shutdown Hysteresis	—	10	—	°C		
eN	Output Noise	—	600	—	nV/√Hz		I <sub>L</sub> = I <sub>OUTMAX</sub> , F = 10kHz 470pF from Bypass to GND

- Note**
- 1: The minimum V<sub>IN</sub> has to meet two conditions: V<sub>IN</sub> ≥ 2.7V and V<sub>IN</sub> ≥ V<sub>R</sub> + V<sub>DROPOUT</sub>.
  - 2: V<sub>R</sub> is the regulator output voltage setting. For example: V<sub>R</sub> = 1.8V, 2.5V, 2.6V, 2.7V, 2.8V, 2.85V, 3.0V, 3.3V, 3.6V, 4.0V, 5.0V.
  - 3:  $TC V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$
  - 4: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 1.0mA 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 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<sub>LMAX</sub> at V<sub>IN</sub> = 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<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 4.0 Thermal Considerations for more details.
  - 8: Apply for Junction Temperatures of -40°C to +85°C.

# TC1014/TC1015/TC1185

## TC1014/TC1015/TC1185 ELECTRICAL SPECIFICATIONS (CONTINUED)

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

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
<b>SHDN Input</b>						
$V_{IH}$	$\overline{SHDN}$ Input High Threshold	45	—	—	% $V_{IN}$	$V_{IN} = 2.5V$ to $6.5V$
$V_{IL}$	$\overline{SHDN}$ Input Low Threshold	—	—	15	% $V_{IN}$	$V_{IN} = 2.5V$ to $6.5V$

- Note**
- 1: The minimum  $V_{IN}$  has to meet two conditions:  $V_{IN} \geq 2.7V$  and  $V_{IN} \geq V_R + V_{DROPOUT}$ .
  - 2:  $V_R$  is the regulator output voltage setting. For example:  $V_R = 1.8V, 2.5V, 2.6V, 2.7V, 2.8V, 2.85V, 3.0V, 3.3V, 3.6V, 4.0V, 5.0V$ .
  - 3:  $TC V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$
  - 4: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 1.0mA 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 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 4.0 Thermal Considerations for more details.
  - 8: Apply for Junction Temperatures of  $-40^\circ C$  to  $+85^\circ C$ .

## 2.0 PIN DESCRIPTIONS

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

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

Pin No. (5-Pin SOT-23A)	Symbol	Description
1	$V_{IN}$	Unregulated supply input.
2	GND	Ground terminal.
3	$\overline{\text{SHDN}}$	Shutdown control input. The regulator is fully enabled when a logic high is applied to this input. The regulator enters shutdown when a logic low is applied to this input. During shutdown, output voltage falls to zero, $\overline{\text{ERROR}}$ is open circuited and supply current is reduced to 0.5 $\mu\text{A}$ (max).
4	Bypass	Reference bypass input. Connecting a 470pF to this input further reduces output noise.
5	$V_{OUT}$	Regulated voltage output.

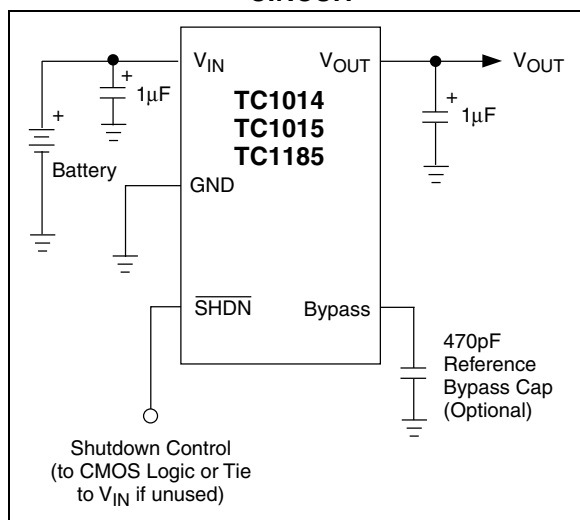
# TC1014/TC1015/TC1185

## 3.0 DETAILED DESCRIPTION

The TC1014/TC1015/TC1185 are precision fixed output voltage regulators. (If an adjustable version is desired, please see the TC1070/TC1071/TC1187 data sheet.) Unlike bipolar regulators, the TC1014/TC1015/TC1185 supply current does not increase with load current. In addition,  $V_{OUT}$  remains stable and within regulation over the entire 0mA to  $I_{OUTMAX}$  operating load current ranges (an important consideration in RTC and CMOS RAM battery back-up applications).

Figure 3-1 shows a typical application circuit. The regulator is enabled any time the shutdown input ( $\overline{SHDN}$ ) is at or above  $V_{IH}$ , and shutdown (disabled) when  $\overline{SHDN}$  is at or below  $V_{IL}$ .  $\overline{SHDN}$  may be controlled by a CMOS logic gate, or I/O port of a microcontroller. If the  $\overline{SHDN}$  input is not required, it should be connected directly to the input supply. While in shutdown, supply current decreases to 0.05 $\mu$ A (typical),  $V_{OUT}$  falls to zero volts.

**FIGURE 3-1: TYPICAL APPLICATION CIRCUIT**



## 3.1 Bypass Input

A 470pF capacitor connected from the Bypass input to ground reduces noise present on the internal reference, which in turn significantly reduces output noise. If output noise is not a concern, this input may be left unconnected. Larger capacitor values may be used, but results in a longer time period to rated output voltage when power is initially applied.

## 3.2 Output Capacitor

A 1 $\mu$ F (min) capacitor from  $V_{OUT}$  to ground is required. The output capacitor should have an effective series resistance greater than 0.1 $\Omega$  and less than 5 $\Omega$ . A 1 $\mu$ F capacitor should be connected from  $V_{IN}$  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 $^{\circ}$ C, solid tantalums are recommended for applications operating below -25 $^{\circ}$ 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.

## 4.0 THERMAL CONSIDERATIONS

### 4.1 Thermal Shutdown

Integrated thermal protection circuitry shuts the regulator off when die temperature exceeds 160°C. The regulator remains off until the die temperature drops to approximately 150°C.

### 4.2 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 4-1:

$$P_D \approx (V_{INMAX} - V_{OUTMIN})I_{LOADMAX}$$

Where:

- $P_D$  = Worst case actual power dissipation
- $V_{INMAX}$  = Maximum voltage on  $V_{IN}$
- $V_{OUTMIN}$  = Minimum regulator output voltage
- $I_{LOADMAX}$  = Maximum output (load) current

The maximum allowable power dissipation (Equation 4-2) is a function of the maximum ambient temperature ( $T_{AMAX}$ ), the maximum allowable die temperature ( $T_{JMAX}$ ) and the thermal resistance from junction-to-air ( $\theta_{JA}$ ). The 5-Pin SOT-23A package has a  $\theta_{JA}$  of approximately 220°C/Watt.

#### EQUATION 4-2:

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

Where all terms are previously defined.

Equation 4-1 can be used in conjunction with Equation 4-2 to ensure regulator thermal operation is within limits. For example:

Given:

$$\begin{aligned} V_{INMAX} &= 3.0V + 10\% \\ V_{OUTMIN} &= 2.7V - 2.5\% \\ I_{LOADMAX} &= 40mA \\ T_{JMAX} &= 125^\circ C \\ T_{AMAX} &= 55^\circ C \end{aligned}$$

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

Actual power dissipation:

$$\begin{aligned} P_D &\approx (V_{INMAX} - V_{OUTMIN})I_{LOADMAX} \\ &= [(3.0 \times 1.1) - (2.7 \times .975)]40 \times 10^{-3} \\ &= 26.7mW \end{aligned}$$

Maximum allowable power dissipation:

$$\begin{aligned} P_{DMAX} &= \frac{(T_{JMAX} - T_{AMAX})}{\theta_{JA}} \\ &= \frac{(125 - 55)}{220} \\ &= 318mW \end{aligned}$$

In this example, the TC1014 dissipates a maximum of 26.7mW; below the allowable limit of 318mW. In a similar manner, Equation 4-1 and Equation 4-2 can be used to calculate maximum current and/or input voltage limits.

### 4.3 Layout Considerations

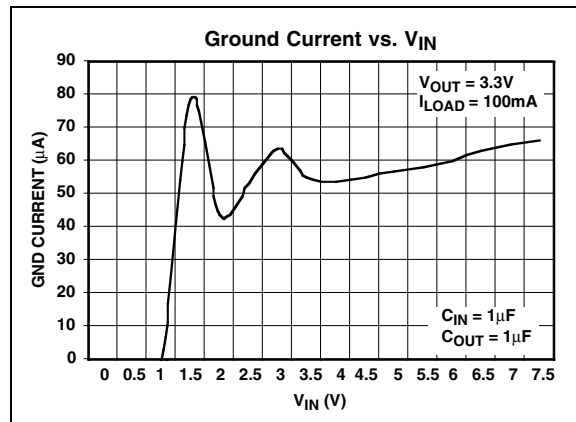
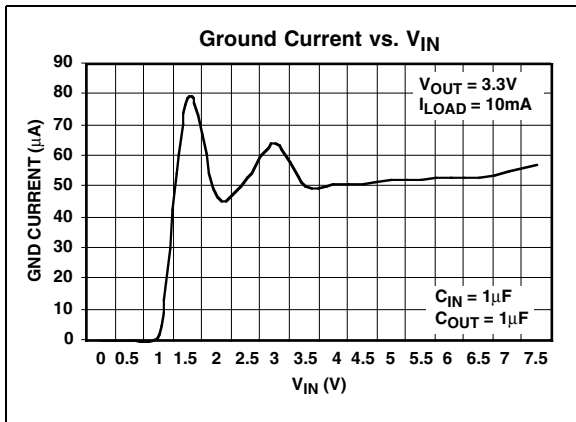
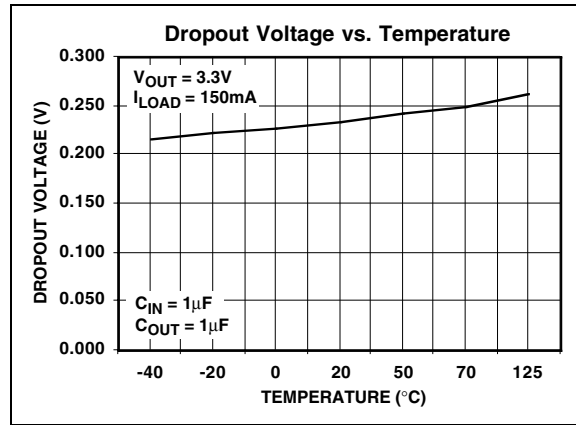
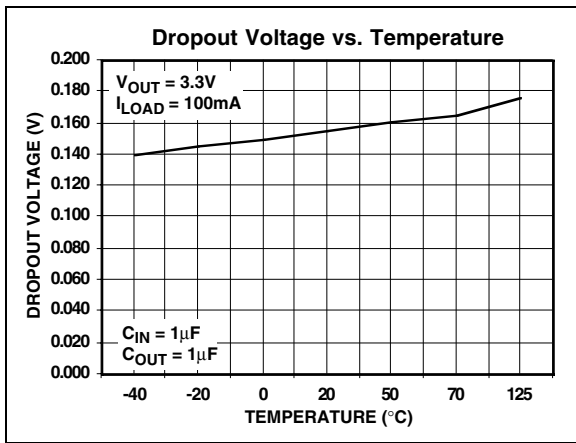
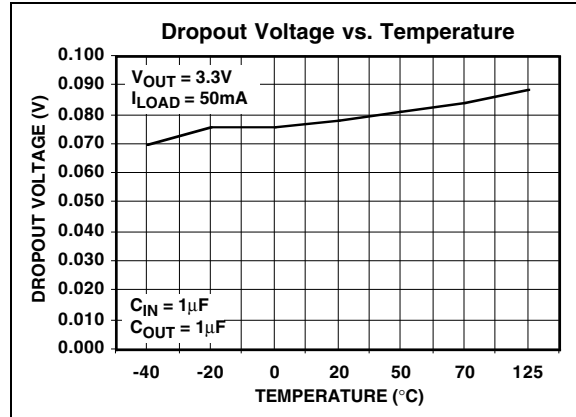
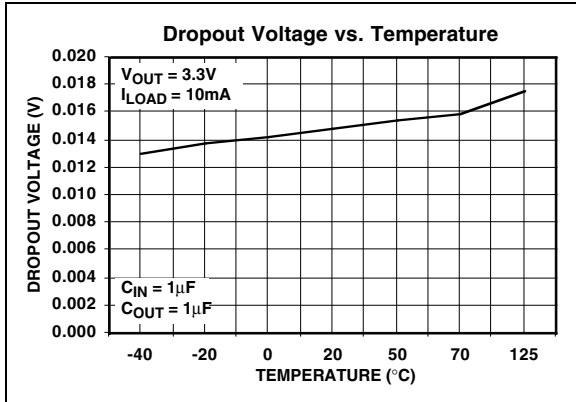
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower  $\theta_{JA}$  and therefore increase the maximum allowable power dissipation limit.

# TC1014/TC1015/TC1185

## 5.0 TYPICAL CHARACTERISTICS

(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)

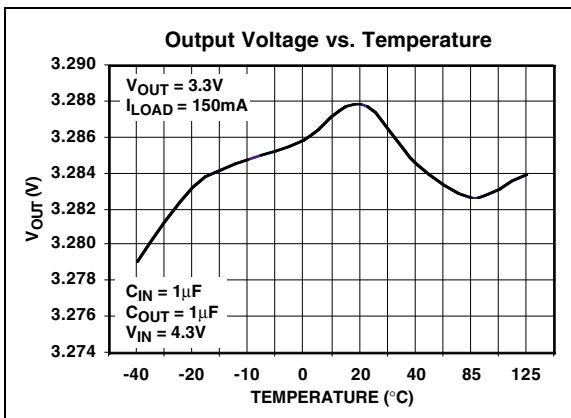
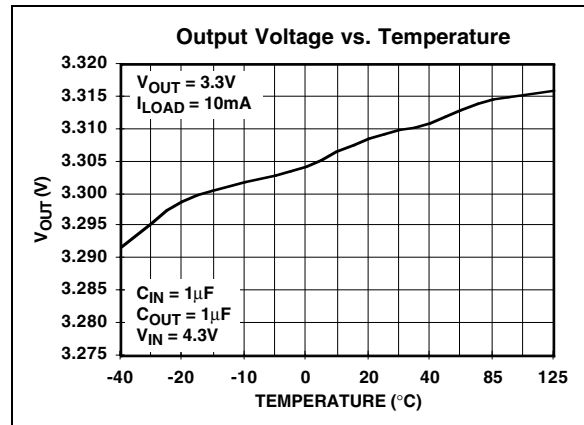
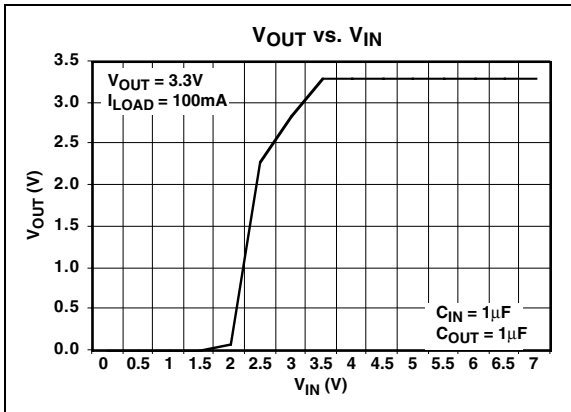
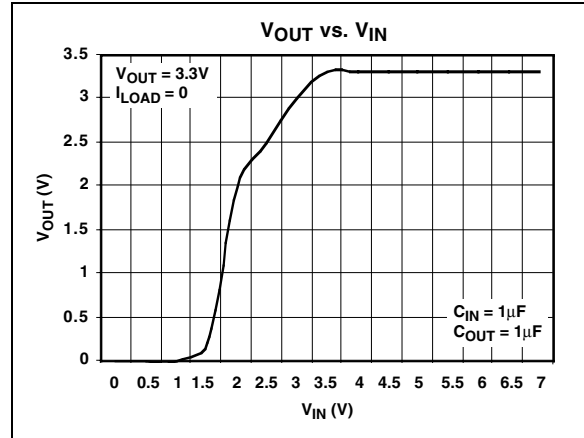
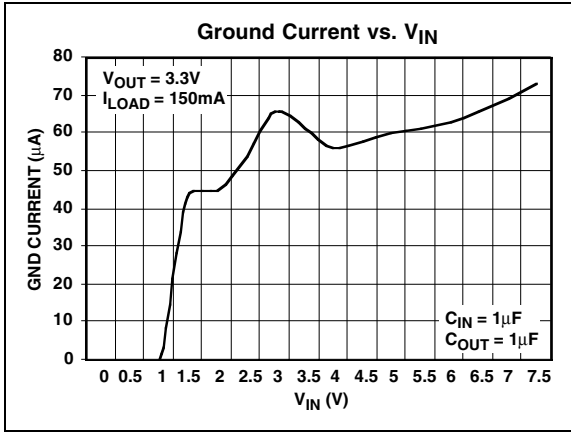
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be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





## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

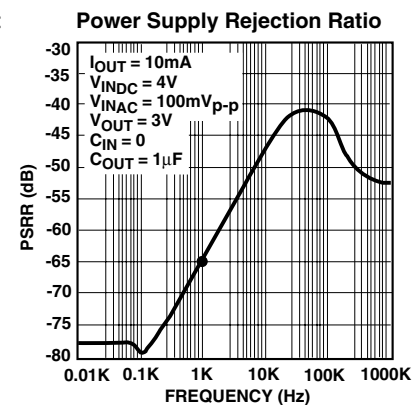
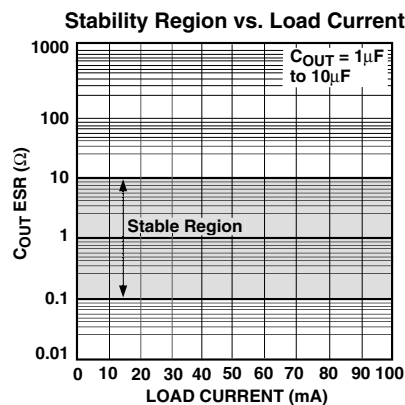
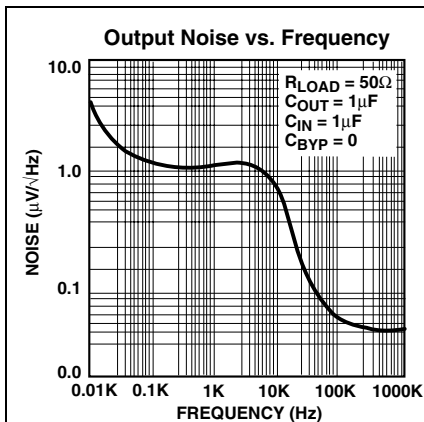
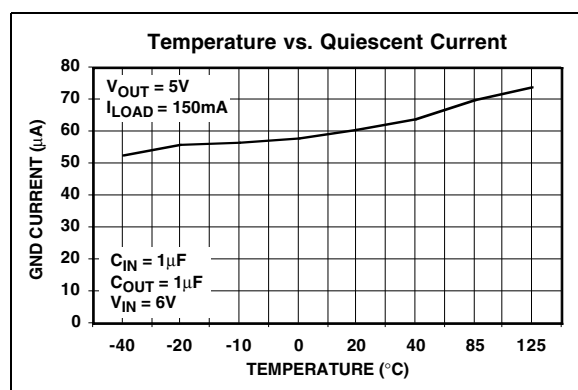
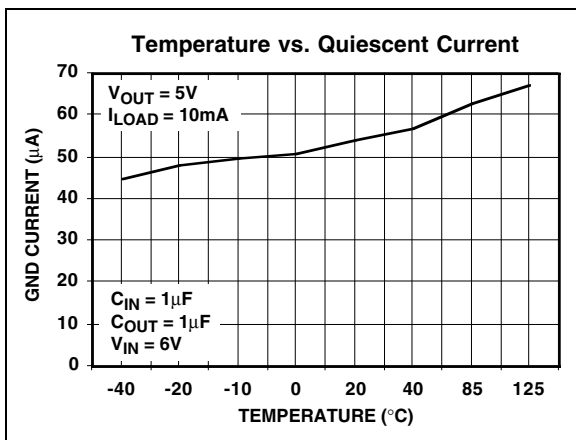
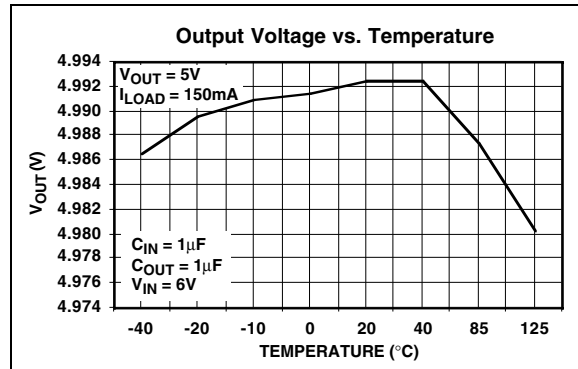
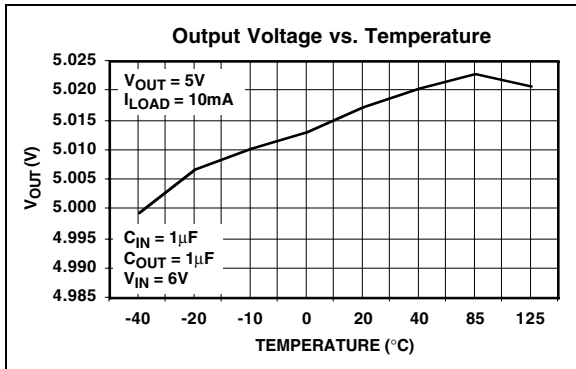
(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)



# TC1014/TC1015/TC1185

## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

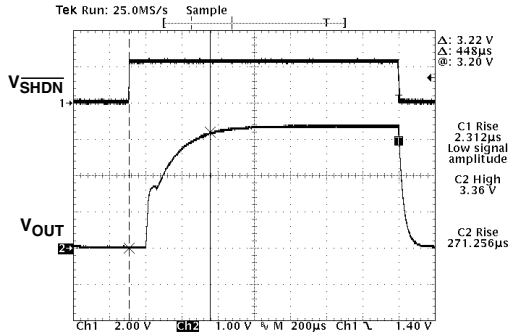
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## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

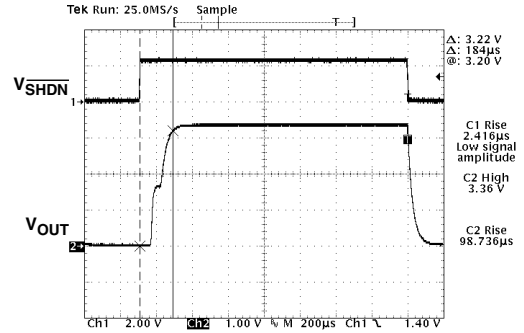
**Measure Rise Time of 3.3V LDO With Bypass Capacitor**

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 470\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 4.3\text{V}$ , Temp = 25°C, Rise Time = 448 $\mu\text{s}$



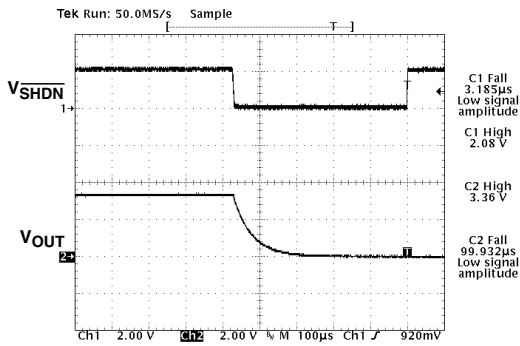
**Measure Rise Time of 3.3V LDO Without Bypass Capacitor**

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 0\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 4.3\text{V}$ , Temp = 25°C, Rise Time = 184 $\mu\text{s}$



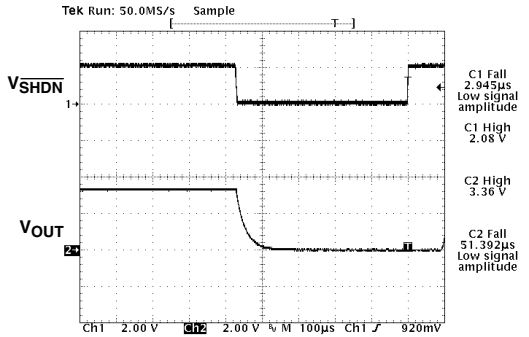
**Measure Fall Time of 3.3V LDO With Bypass Capacitor**

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 470\text{pF}$ ,  $I_{LOAD} = 50\text{mA}$   
 $V_{IN} = 4.3\text{V}$ , Temp = 25°C, Fall Time = 100 $\mu\text{s}$



**Measure Fall Time of 3.3V LDO Without Bypass Capacitor**

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 0\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 4.3\text{V}$ , Temp = 25°C, Fall Time = 52 $\mu\text{s}$

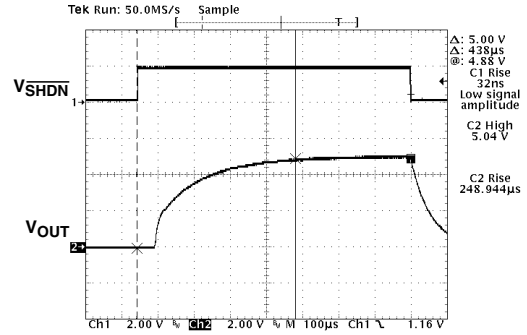


# TC1014/TC1015/TC1185

## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

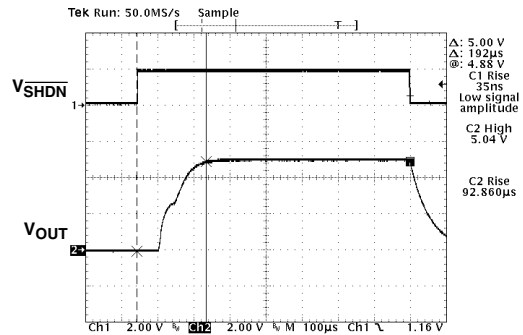
Measure Rise Time of 5.0V LDO With Bypass Capacitor

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 470\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 6\text{V}$ , Temp = 25°C, Rise Time = 390 $\mu\text{s}$



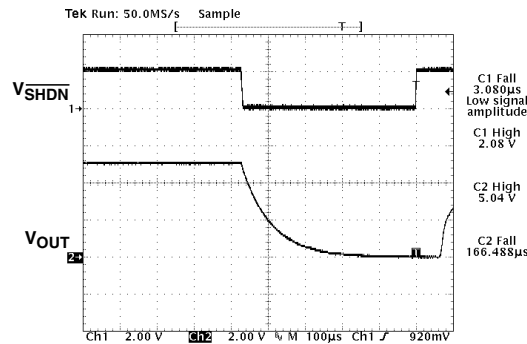
Measure Rise Time of 5.0V LDO Without Bypass Capacitor

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 0\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 6\text{V}$ , Temp = 25°C, Rise Time = 192 $\mu\text{s}$



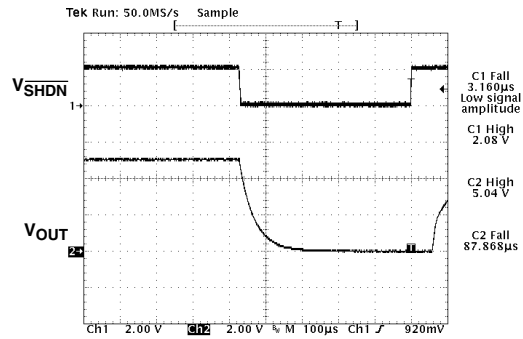
Measure Fall Time of 5.0V LDO With Bypass Capacitor

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 470\text{pF}$ ,  $I_{LOAD} = 50\text{mA}$   
 $V_{IN} = 6\text{V}$ , Temp = 25°C, Fall Time = 167 $\mu\text{s}$

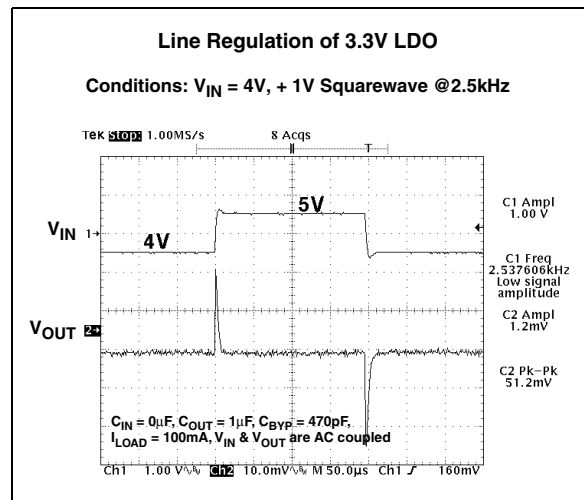
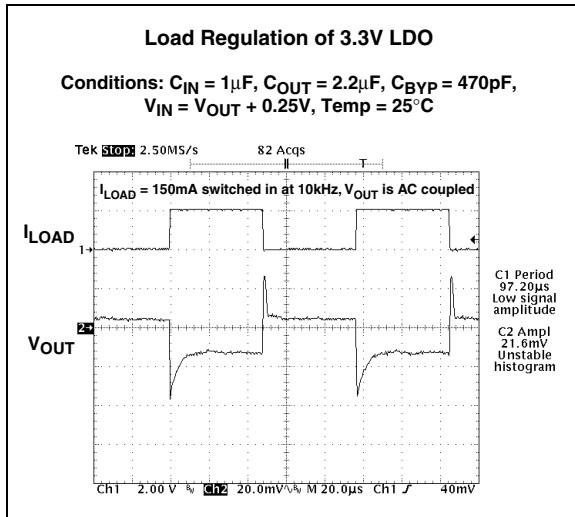
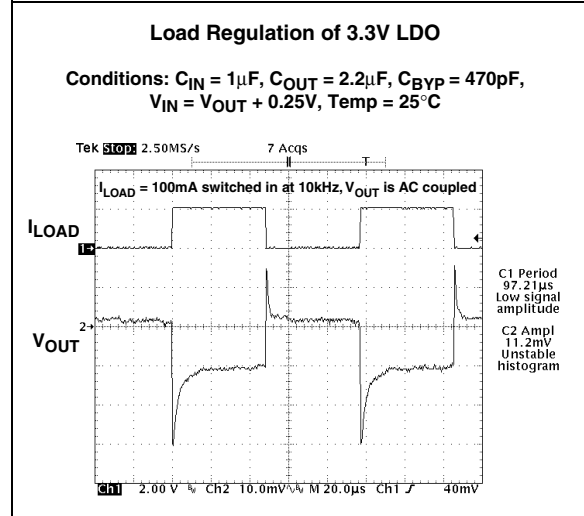
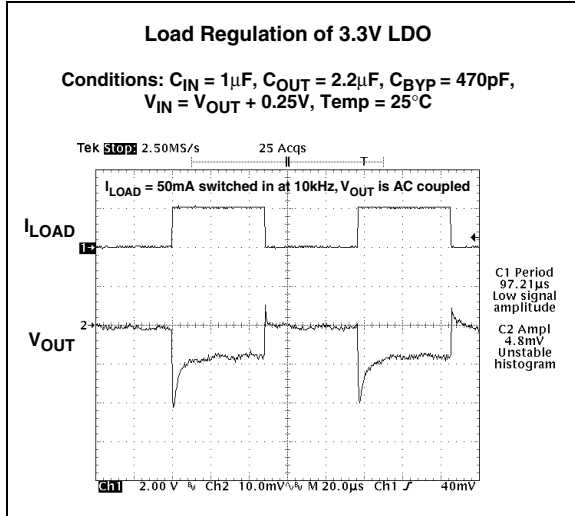


Measure Fall Time of 5.0V LDO Without Bypass Capacitor

Conditions:  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $C_{BYP} = 0\text{pF}$ ,  $I_{LOAD} = 100\text{mA}$   
 $V_{IN} = 6\text{V}$ , Temp = 25°C, Fall Time = 88 $\mu\text{s}$

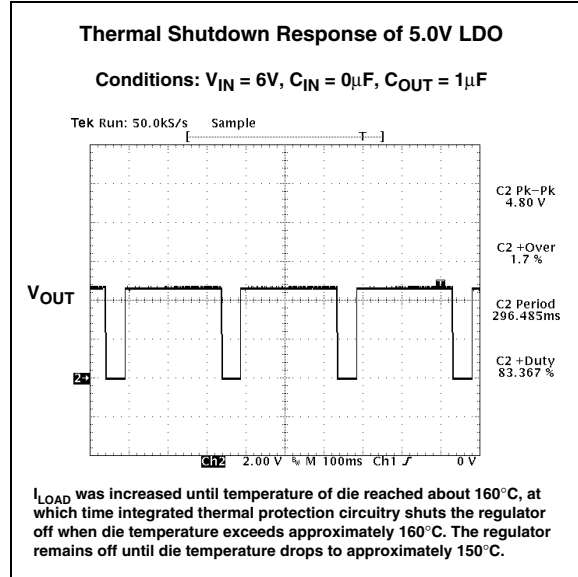
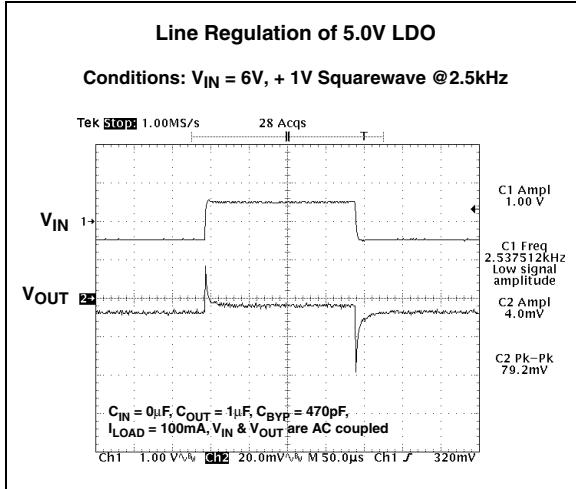


## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



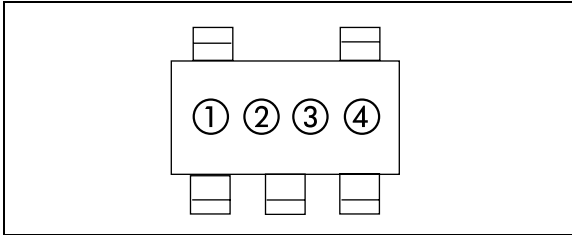
# TC1014/TC1015/TC1185

## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)



## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information



“1” & “2” = part number code + temperature range and voltage

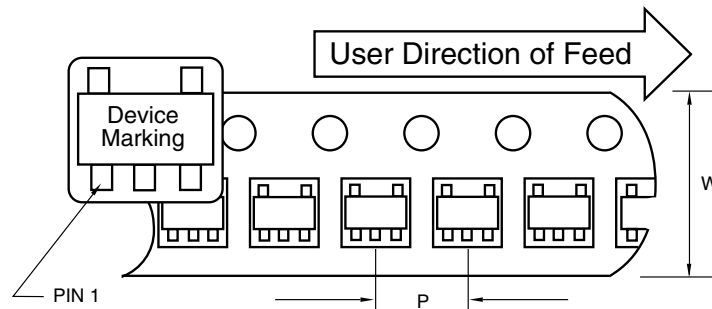
(V)	TC1014 Code	TC1015 Code	TC1185 Code
1.8	AY	BY	NY
2.5	A1	B1	N1
2.6	NB	BT	NT
2.7	A2	B2	N2
2.8	AZ	BZ	NZ
2.85	A8	B8	N8
3.0	A3	B3	N3
3.3	A5	B5	N5
3.6	A9	B9	N9
4.0	A0	B0	N0
5.0	A7	B7	N7

“3” represents date code

“4” represents lot ID number

### 6.2 Taping Form

#### Component Taping Orientation for 5-Pin SOT-23A (EIAJ SC-74A) Devices



Standard Reel Component Orientation  
TR Suffix Device  
(Mark Right Side Up)

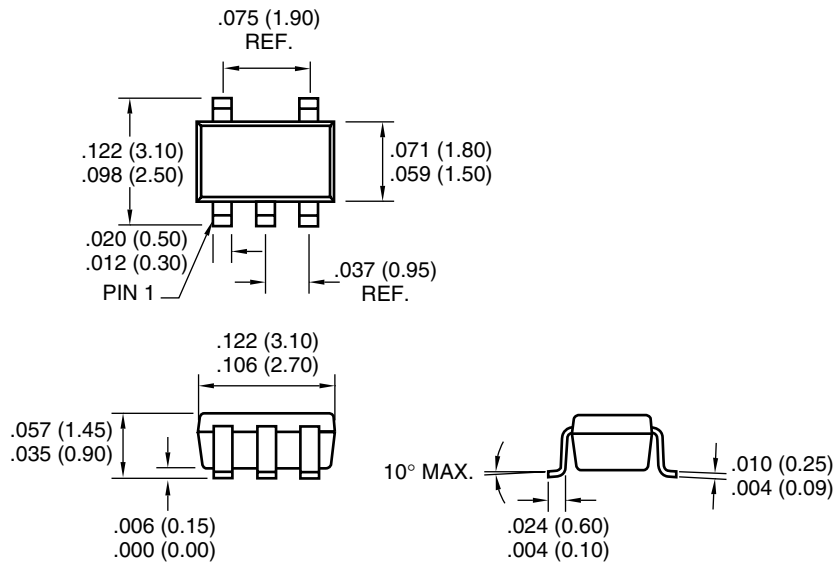
#### Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
5-Pin SOT-23A	8 mm	4 mm	3000	7 in

# TC1014/TC1015/TC1185

## 6.3 Package Dimensions

### SOT-23A-5



Dimensions: inches (mm)



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# TC1014/TC1015/TC1185

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