

## Low Dropout, Negative Output Voltage Regulator

### Features

- Low Dropout Voltage
  - Typically 120mV @ 50mA; 380mV @ 100mA for -5.0V Output Part
- Tight Output Voltage Tolerance:  $\pm 2\%$  Max
- Low Supply Current: 3.5 $\mu$ A, Typ
- Small Package: 3-Pin SOT-23A

### Applications

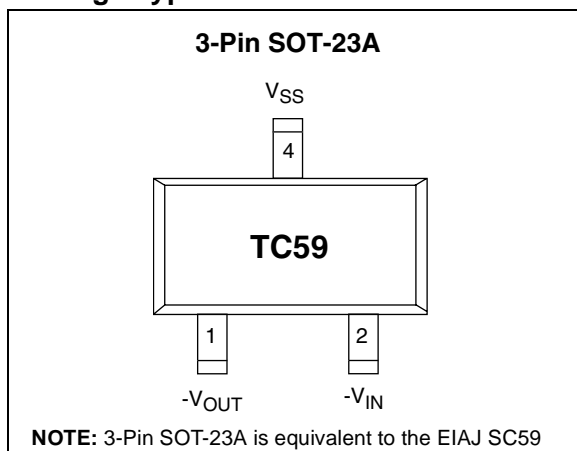
- Cellular Phones
- Battery Operated Systems
- Palmtops
- Portable Cameras

### Device Selection Table

Part Number	Output Voltage	Package	Temperature Range
TC593002ECB	3.0V	3-Pin SOT-23A	-40°C to +85°C
TC595002ECB	5.0V	3-Pin SOT-23A	-40°C to +85°C

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

### Package Type

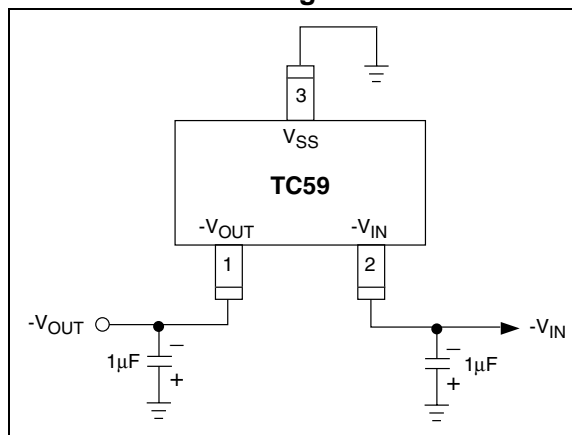


### General Description

The TC59 is a low dropout, negative output voltage regulator designed specifically for battery-operated systems. Its full CMOS construction eliminates the wasted ground current typical of bipolar LDOs. This reduced supply current significantly extends battery life, particularly when the TC59 is operated in dropout.

Other TC59 key features include low supply current (typically 3.0 $\mu$ A) and low dropout operation (typically 120mV at 50mA). The TC59 is packaged in a small 3-Pin SOT-23A package.

### Functional Block Diagram



# TC59

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings\*

Input Voltage .....	-12V
Output Current .....	200mA
Output Voltage.....	$-V_{DD} - 0.3V$ to $V_{IN} + 0.3V$
Power Dissipation.....	150mW
Operating Temperature Range.....	-40°C to +85°C
Storage Temperature Range .....	-40°C to +125°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.

### TC59 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: $V_{IN} = V_R - 1.0V$ (Note 1), $C_L = 10\mu F$ , $T_A = 25^\circ C$ unless otherwise noted.						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$V_{IN}$	Input Voltage	—	—	-10	V	$I_{OUT} = 20mA$
$I_{DD}$	Supply Current	—	3	7	$\mu A$	
$I_{OUT(MAX)}$	Maximum Output Current	100 80 60	— — —	— — —	mA mA mA	$V_{IN} = -6.0V; V_R = -5.0V, V_{OUT} \leq -4.5V$ $V_{IN} = -5.0V; V_R = -4.0V, V_{OUT} \leq -3.6V$ $V_{IN} = -4.0V; V_R = -3.0V, V_{OUT} \leq -2.7V$
$V_{OUT}$	Output Voltage	$1.02 \times V_R$	—	$0.98 \times V_R$	V	$I_{OUT} = 20mA$
TC $V_{OUT}$	Output Voltage Temperature Coefficient	—	$\pm 100$	—	ppm/ $^\circ C$	$I_{OUT} = 20mA$
$\frac{\Delta V_{OUT}}{(\Delta V_{IN} \times V_{OUT})}$	Line Regulation	—	0.1	0.3	%/V	$I_{OUT} = 20mA; V_R = -5.0V; -6.0 < V_{IN} < -10.0V$ $V_R = -4.0V; -5.0 < V_{IN} < -10.0V$ $V_R = -3.0V; -4.0 < V_{IN} < -10.0V$
$\Delta V_{OUT}$	Load Regulation	—	40	80	mV	$V_R = -5.0V; 1mA < I_{OUT} < 50mA$ $V_R = -4.0V; 1mA < I_{OUT} < 45mA$ $V_R = -3.0V; 1mA < I_{OUT} < 40mA$
$V_{IN} - V_{OUT}$	Dropout Voltage	— — — — — —	120 380 120 380 120 380	300 600 300 600 300 600	mV mV mV mV mV mV	$V_R = -5.0V; I_{OUT} = 50mA$ $I_{OUT} = 100mA$ $V_R = -4.0V; I_{OUT} = 45mA$ $I_{OUT} = 90mA$ $V_R = -3.0V; I_{OUT} = 40mA$ $I_{OUT} = 80mA$

**Note 1:**  $V_R$  is the regulator output voltage setting. For example:  $V_R = -2.5V, -2.7V, -3.0V, -3.3V, -3.6V, -4.0V, -5.0V$ .

## 2.0 PIN DESCRIPTIONS

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

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

Pin No. (3-Pin SOT-23A)	Symbol	Description
1	$V_{OUT}$	Regulated voltage output.
2	$V_{IN}$	Supply voltage input.
3	$V_{SS}$	Ground.

## 3.0 DETAILED DESCRIPTION

The TC59 is a low quiescent current, precision fixed negative output voltage LDO. Unlike bipolar linear regulators, the TC59 supply current does not increase proportionally with load current.

### 3.1 Output Capacitor

A minimum of 1 $\mu$ F tantalum output capacitor is required. The requirements for the output capacitor are an equivalent series resistance (esr) greater than 0.1 $\Omega$  and less than 5 $\Omega$ , with a self-resonant frequency greater than 1MHz. To improve supply noise rejection and transient response, larger output capacitors can be used. Care should be taken when increasing  $C_{OUT}$ , that the input impedance is not high enough to cause high input impedance oscillation.

### 3.2 Input Capacitor

A 1 $\mu$ F input capacitor is recommended for most applications when the input impedance is on the order of 10 $\Omega$ . When operating off of a battery input, or there is a large distance from the input source to the LDO, larger input capacitance may be required for stability. When large values of output capacitance are used, the input capacitance should be increased to prevent high source impedance oscillations.

## 4.0 THERMAL CONSIDERATIONS

### 4.1 Power Dissipation

The amount of power dissipated internal to the low drop out linear regulator is the sum of the power dissipation within the linear pass device (P-Channel MOSFET), and the quiescent current required to bias the internal reference and error amplifier. The internal linear pass device power dissipation is calculated multiplying the voltage across the linear device times the current through the device. The input and output voltages are negative for the TC59. The power dissipation is calculated using the absolute value of the voltage difference between the input and output voltage.

**TABLE 4-1: MAXIMUM POWER DISSIPATION**

Package Type	Maximum Power Dissipation
SOT-23-3	150mW

#### EQUATION 4-1:

$$P_D (\text{Pass Device}) = (V_{IN} - V_{OUT}) \times I_{OUT}$$

The internal power dissipation as a result of the bias current for the LDO internal reference and error amplifier is calculated by multiplying the ground or quiescent current times the input voltage.

#### EQUATION 4-2:

$$P_D (\text{Bias}) = V_{IN} \times I_{GND}$$

The total internal power dissipation is the sum of Equation 4-1 and Equation 4-2.

#### EQUATION 4-3:

$$P_{TOTAL} = P_D (\text{Pass Device}) + P_D (\text{Bias})$$

For the TC59, the internal quiescent bias current is so low (3μA typical), the  $P_D$  (Bias) term of the power dissipation equation can be ignored. The maximum power dissipation can be estimated by using the maximum input voltage and the minimum output voltage to obtain a maximum voltage differential between input and output and multiplying the maximum voltage differential by the maximum output current.

#### EQUATION 4-4:

$$P_{MAX} = (V_{IN (MAX)} - V_{OUT (MIN)}) \times I_{OUT (MAX)}$$

For example, given the following conditions:

$$V_{IN} = -7.0V \pm 5\%$$

$$V_{OUT} = -5.0V \pm 2\%$$

$$I_{OUT} = 1mA \text{ to } 40mA$$

$$T_{AMBIENT (MAX)} = 55^\circ C$$

$$P_{MAX} = (7V \times (1.05) - (5.0V \times 0.98)) \times 40mA$$

$$P_{MAX} = 98.0 \text{ milli-Watts}$$

To determine the junction temperature of the device, the thermal resistance from junction to air must be known. The SOT-23-3  $R_{\theta JA}$  is estimated to be approximately 359°C/W when mounted on a 4-layer board. The  $R_{\theta JA}$  will vary with physical layout, airflow and other application specific conditions.

The device junction temperature is determined by calculating the junction temperature rise above ambient, then adding the rise to the ambient temperature.

#### EQUATION 4-5: JUNCTION TEMPERATURE (SOT-23 EXAMPLE)

$$T_{JUNCTION} = P_D (MAX) \times R_{\theta JA} + T_{AMBIENT}$$

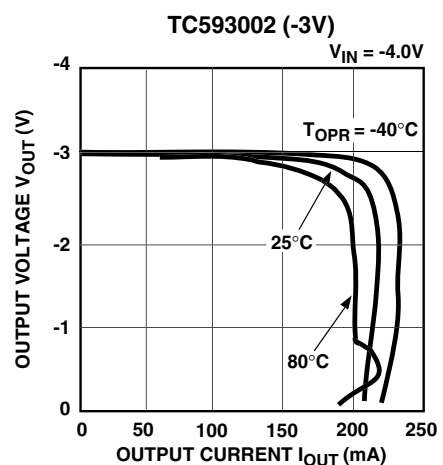
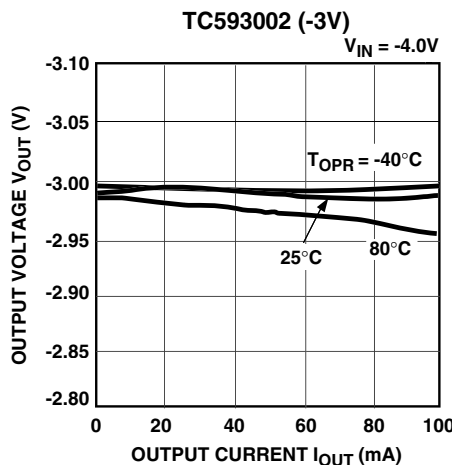
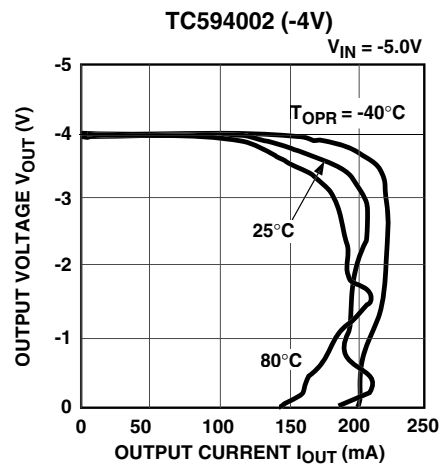
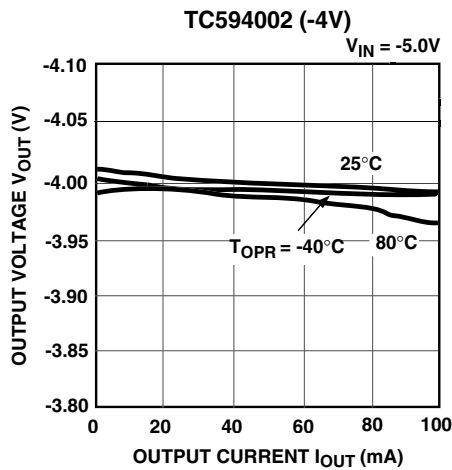
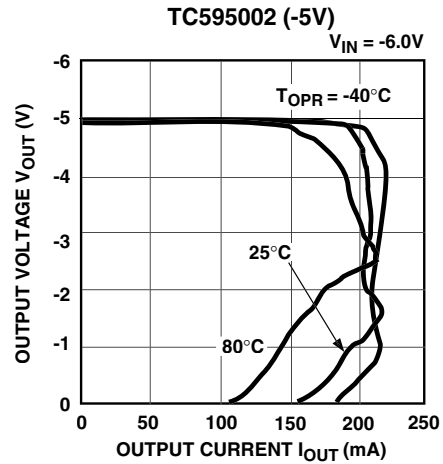
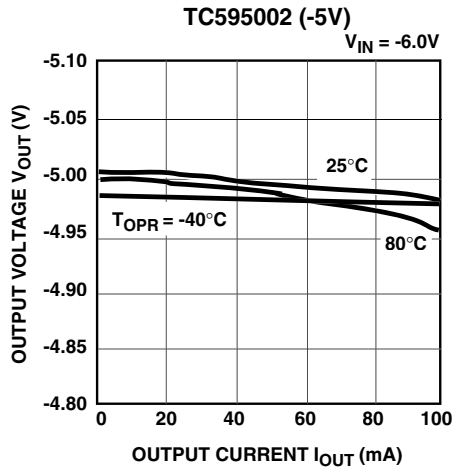
$$T_{JUNCTION} = 98.0 \text{ milli-Watts} \times 359^\circ C/W + 55^\circ C$$

$$T_{JUNCTION} = 90.2^\circ C$$

## 5.0 TYPICAL CHARACTERISTICS

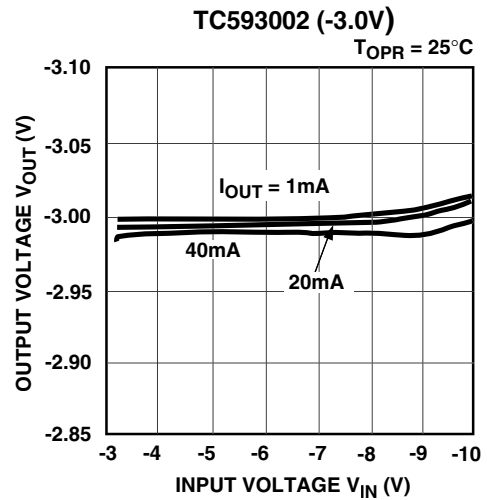
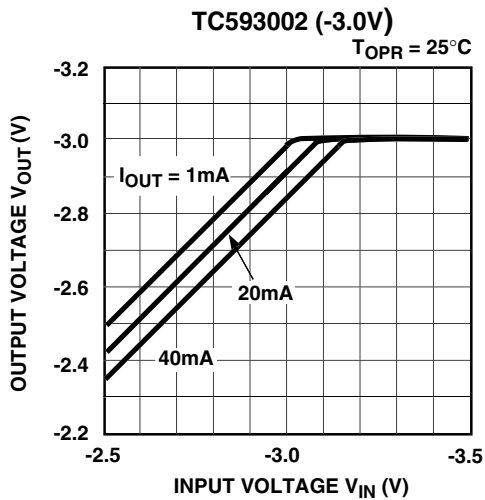
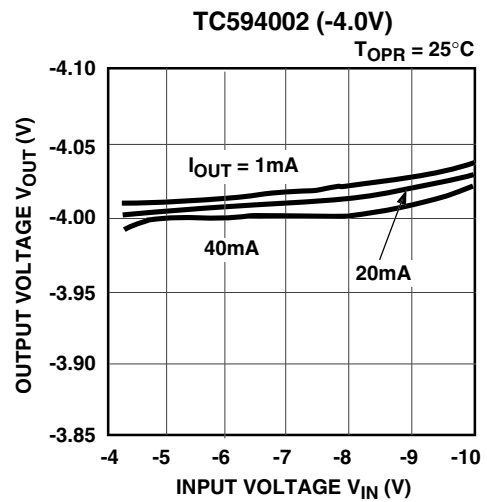
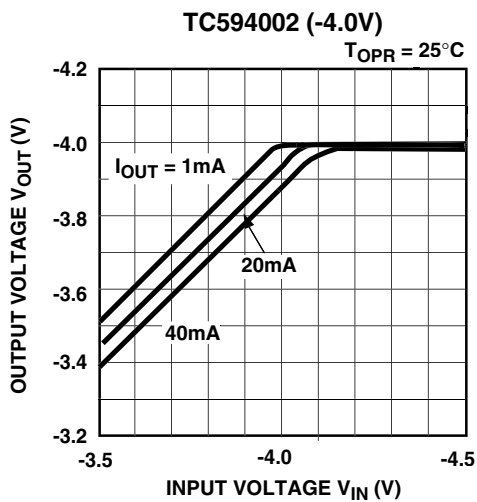
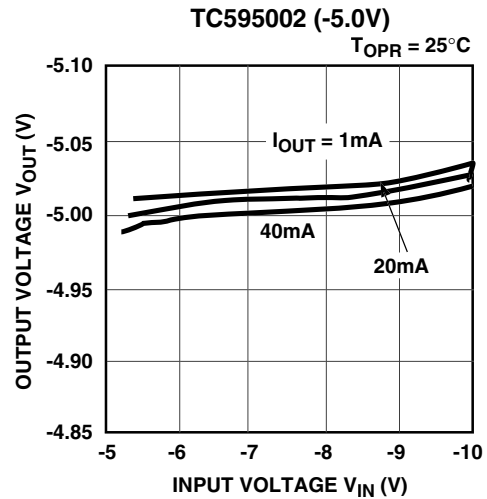
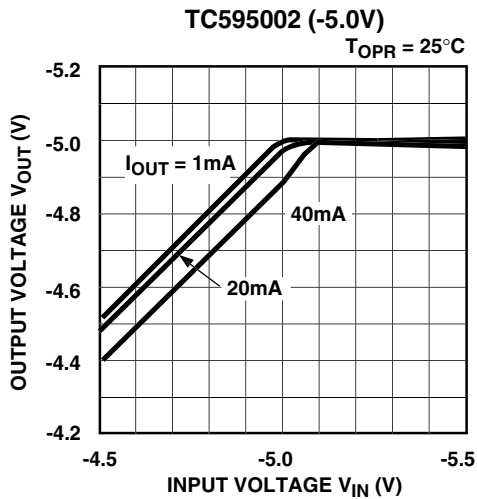
**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be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

### 1. OUTPUT VOLTAGE vs. OUTPUT CURRENT



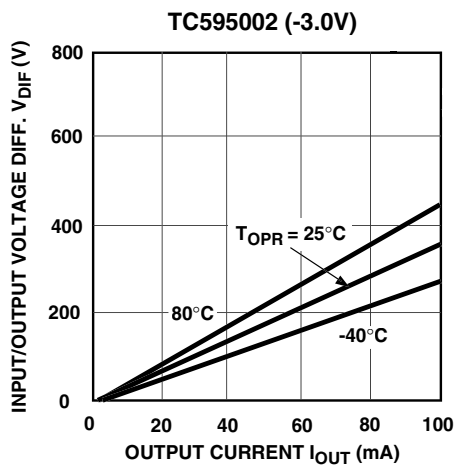
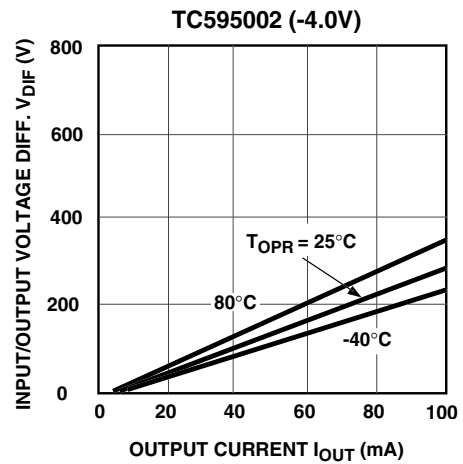
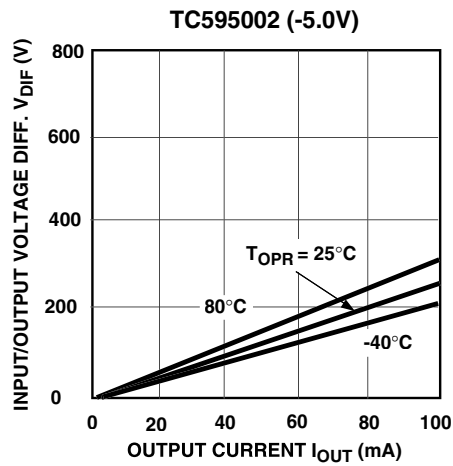
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 2. OUTPUT VOLTAGE vs. INPUT VOLTAGE

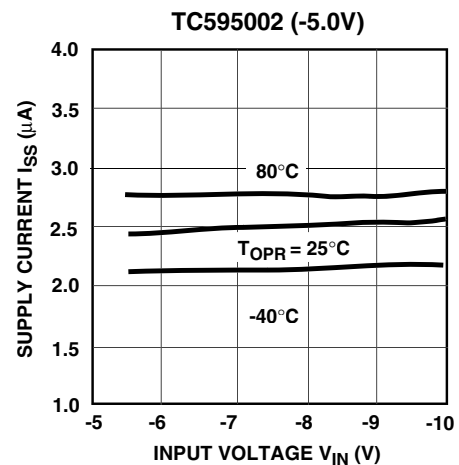
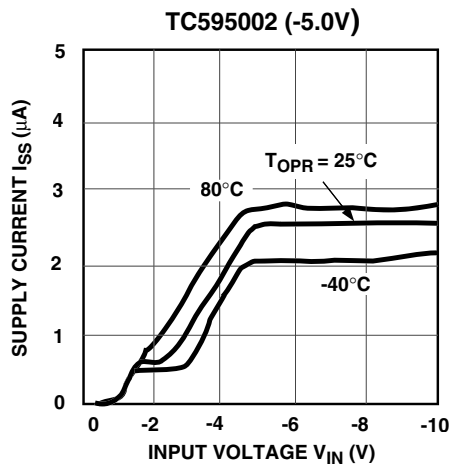


## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 3. INPUT/OUTPUT VOLTAGE DIFFERENTIAL vs. OUTPUT CURRENT

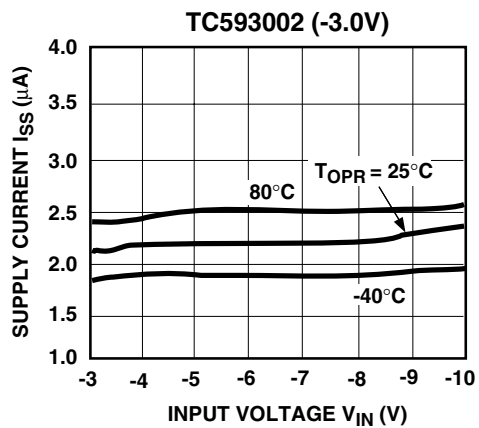
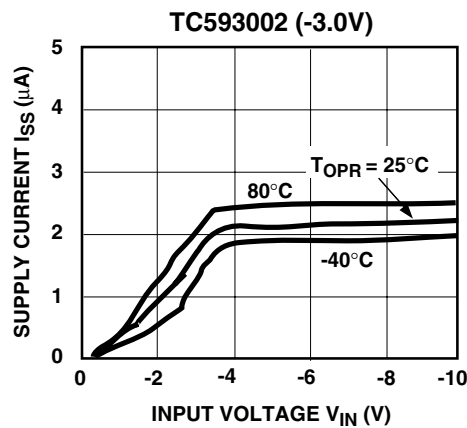
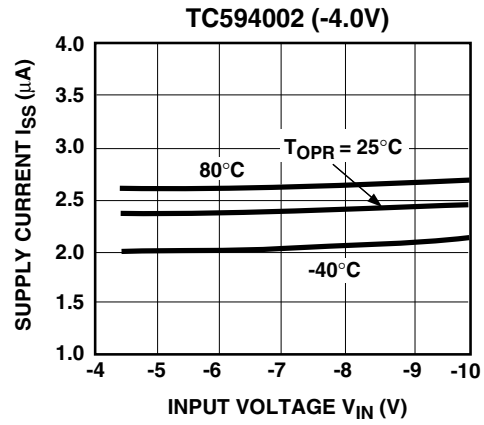
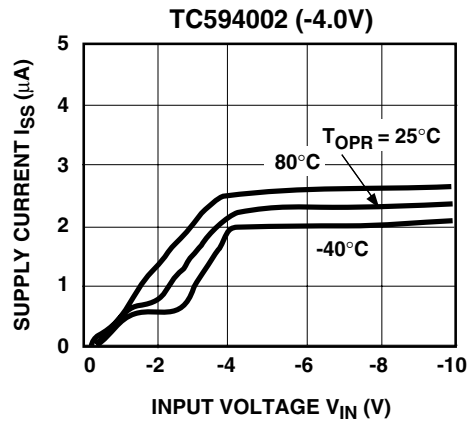


### 4. SUPPLY CURRENT vs. INPUT VOLTAGE

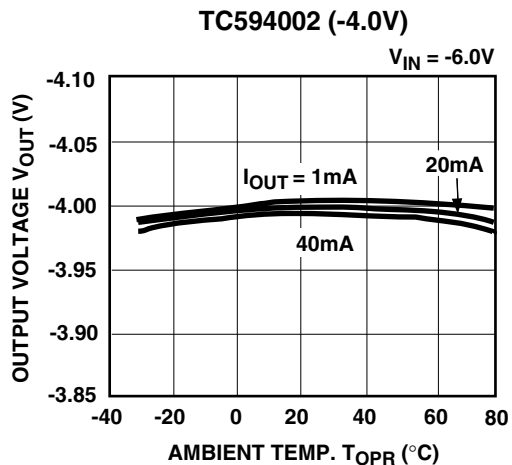
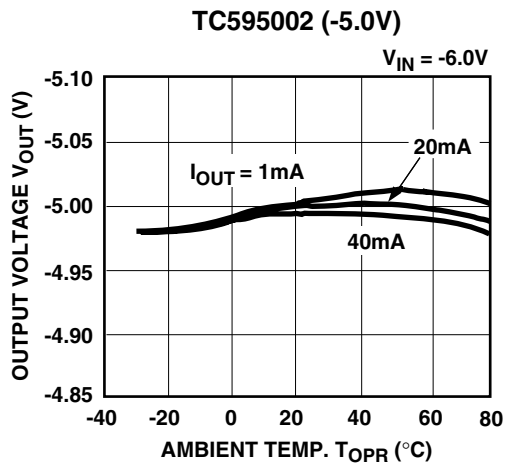


## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 4. SUPPLY CURRENT vs. INPUT VOLTAGE (CONTINUED)



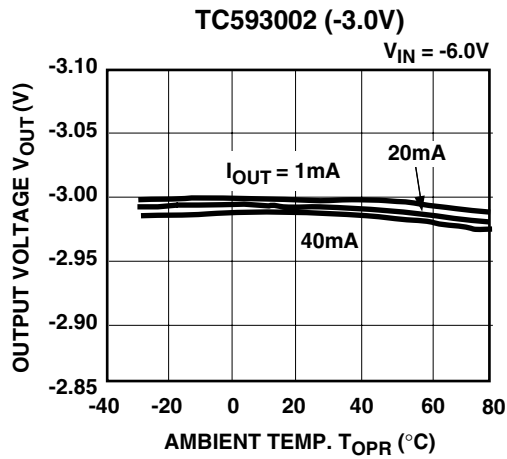
### 5. OUTPUT VOLTAGE vs. AMBIENT TEMPERATURE



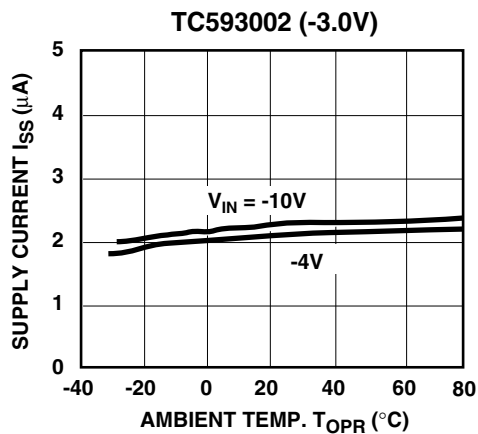
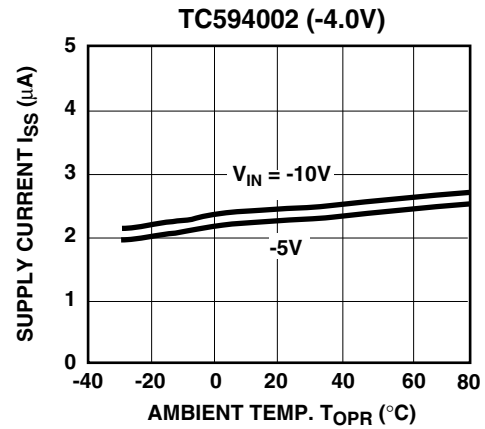
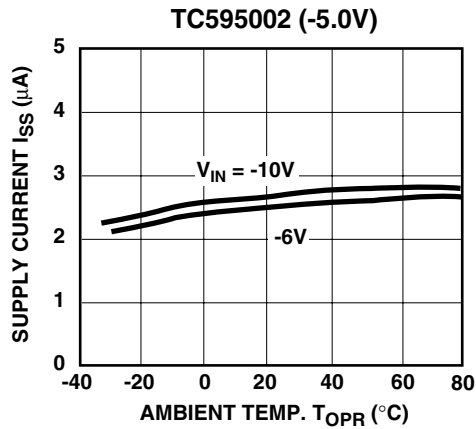


## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 5. OUTPUT VOLTAGE vs. AMBIENT TEMPERATURE (CONTINUED)

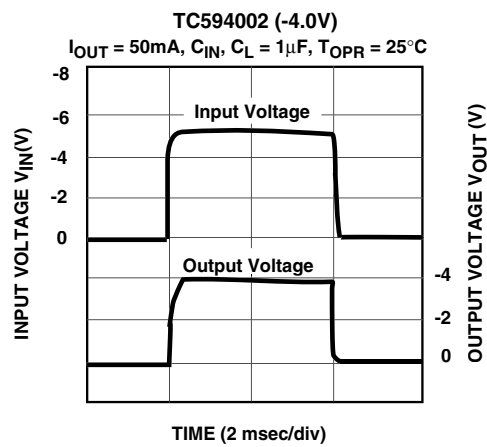
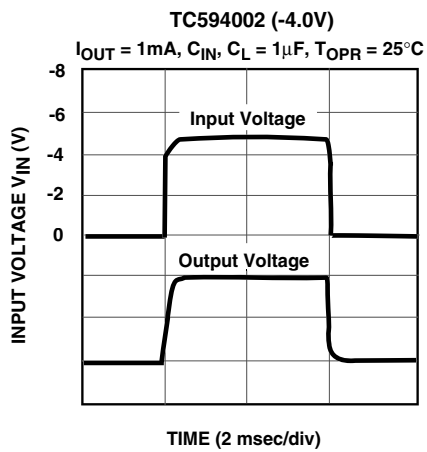
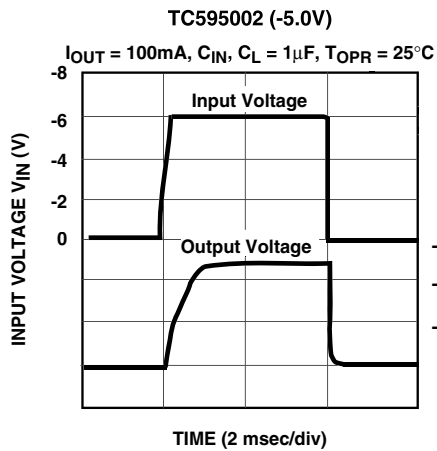
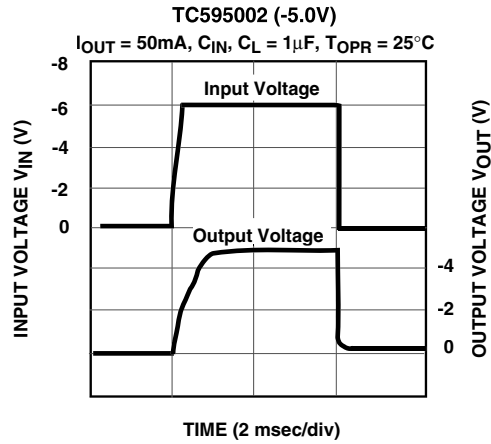
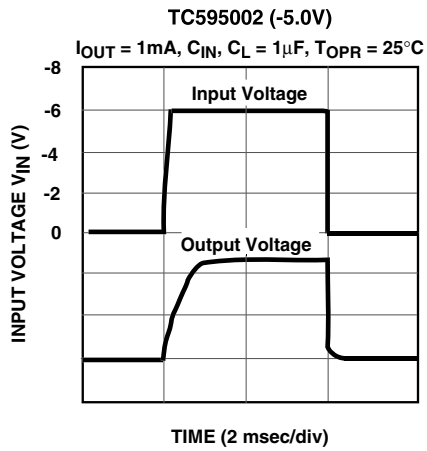


### 6. SUPPLY CURRENT vs. AMBIENT TEMPERATURE



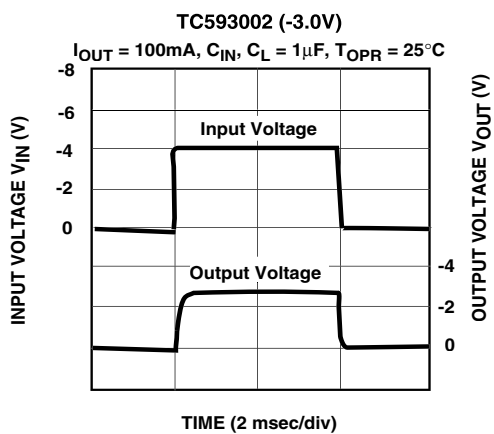
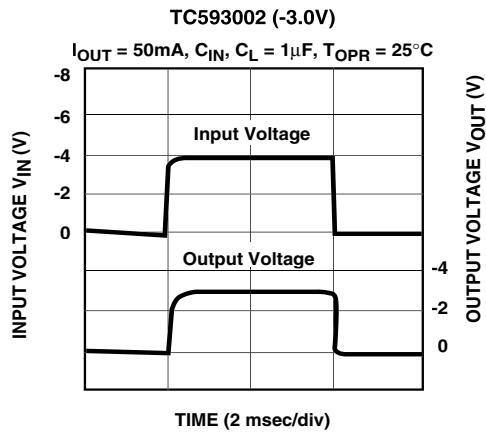
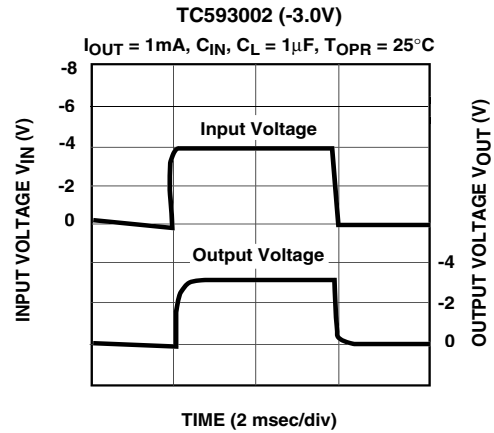
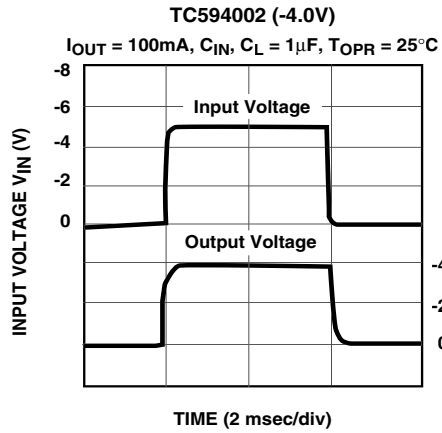
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 7. INPUT TRANSIENT RESPONSE



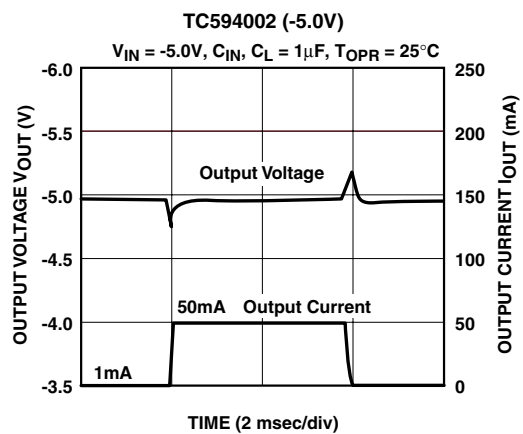
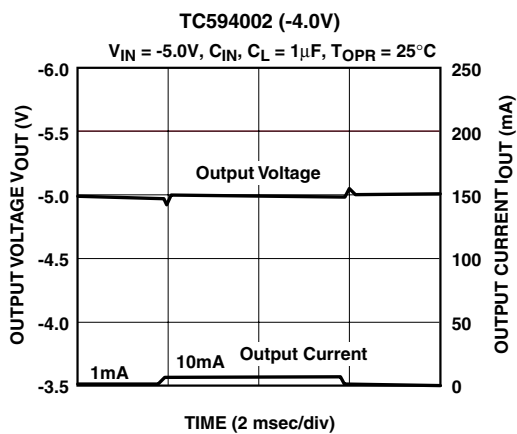
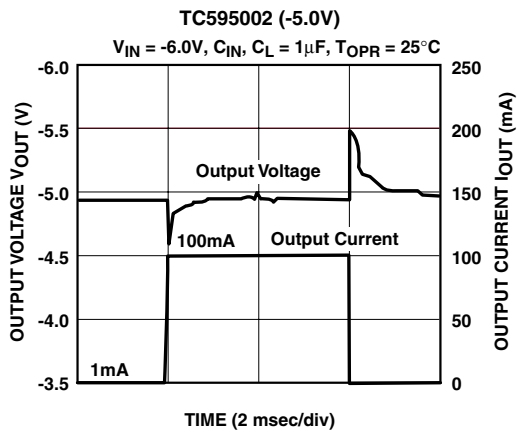
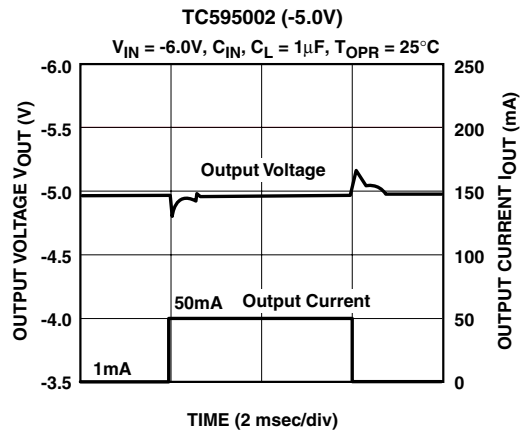
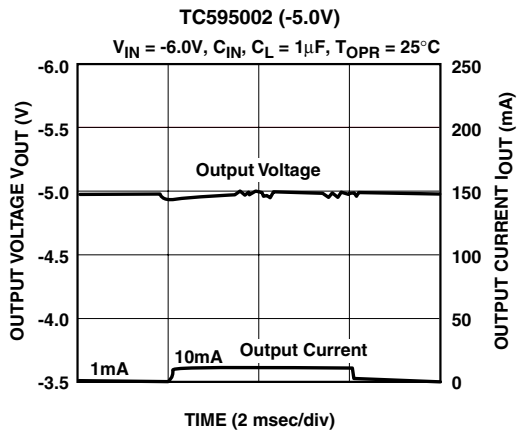
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 7. INPUT TRANSIENT RESPONSE (CONT.)



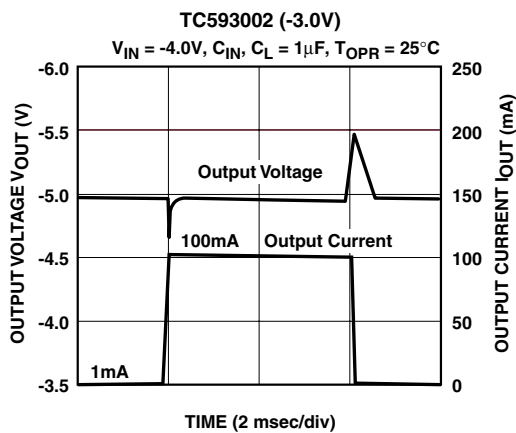
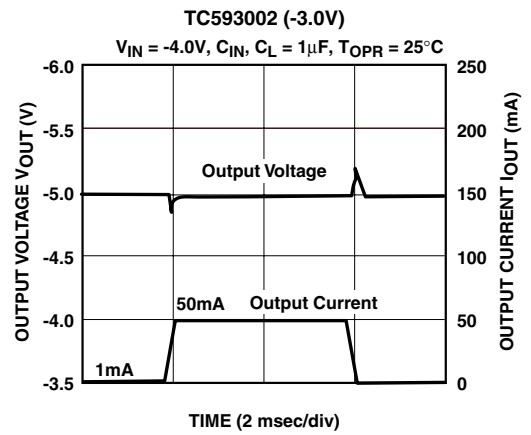
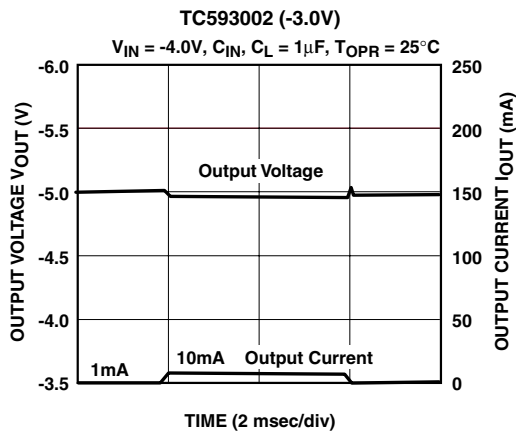
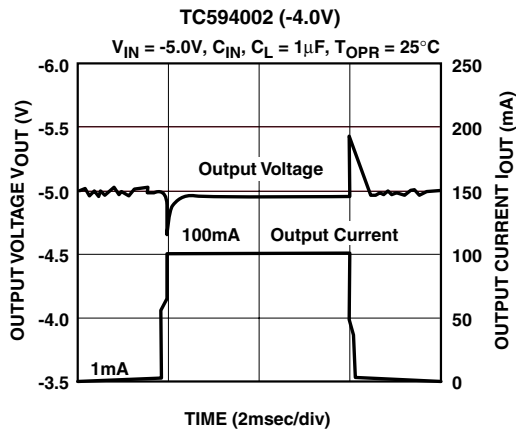
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 8. LOAD TRANSIENT RESPONSE



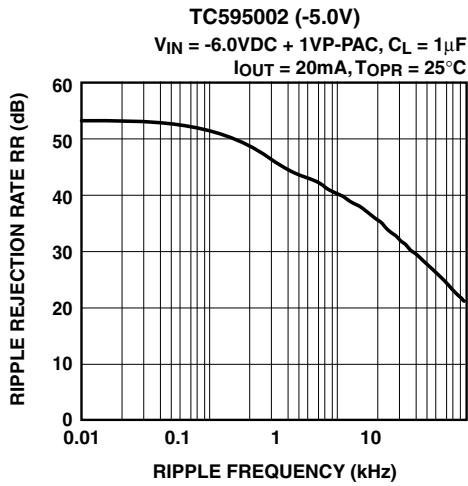
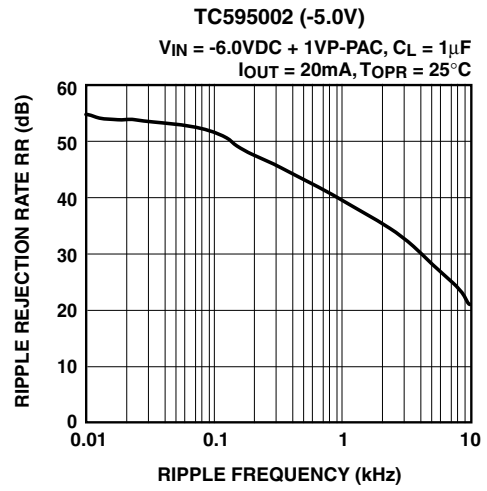
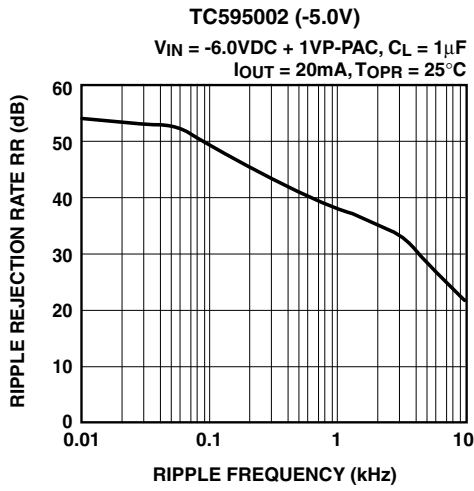
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 8. LOAD TRANSIENT RESPONSE (CONT.)



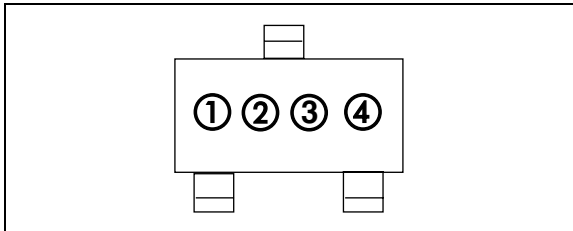
## 5.0 TYPICAL CHARACTERISTICS (CONTINUED)

### 9. RIPPLE REJECTION RATE



## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information



① represents first integer of output voltage

Symbol	Voltage
0	0.
1	1.
2	2.
3	3.
4	4.
5	5.
6	6.
7	7.
8	8.
9	9.

② represents first decimal of output voltage

Symbol	Voltage	Symbol	Voltage
A	.0	F	.5
B	.1	H	.6
C	.2	K	.7
D	.3	L	.8
E	.4	M	.9

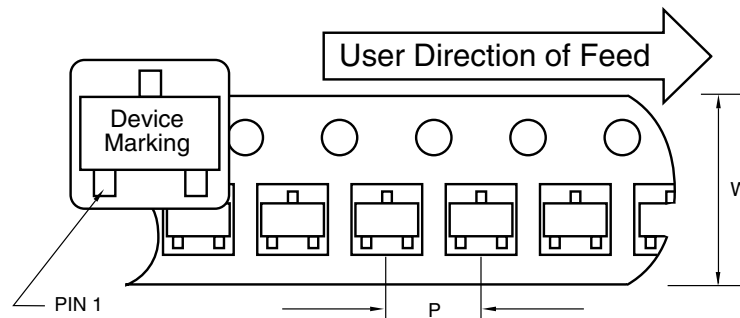
③ represents voltage polarity

Symbol	Polarity
5	-

④ represents assembly lot code

### 6.2 Taping Form

#### Component Taping Orientation for 3-Pin SOT-23A (EIAJ SC-59) Devices



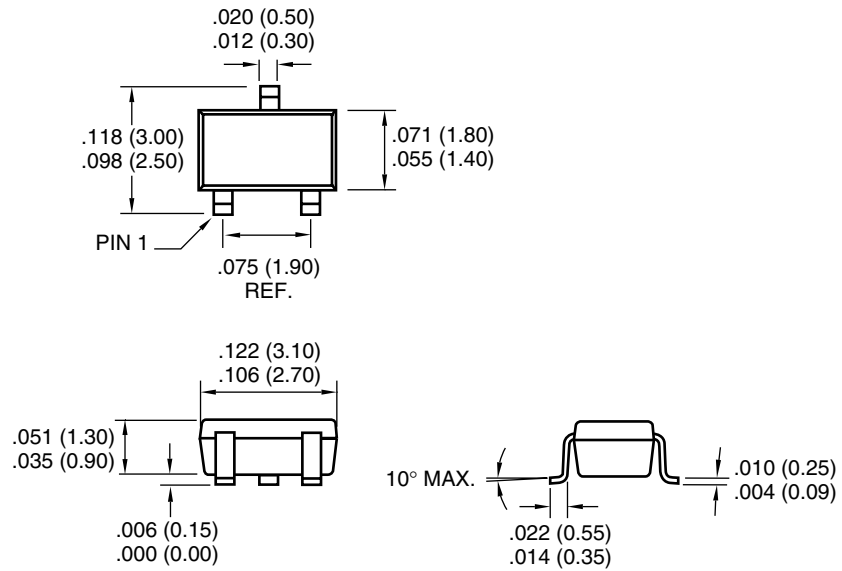
Standard Reel Component Orientation  
for TR Suffix Device  
(Mark Right Side Up)

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

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

## 6.3 Package Dimensions

### SOT-23A-3



Dimensions: inches (mm)



## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<b>PART CODE</b>	<b>TC59</b>	<b>30</b>	<b>02</b>	<b>ECB</b>	<b>XX</b>
	<b>TC59</b>	<b>50</b>	<b>02</b>	<b>ECB</b>	<b>XX</b>
<b>Output Voltage:</b>	_____				
	50 = -5.0V; 30 = -3.0V				
<b>Tolerance:</b>	_____				
	02 = 2%				
<b>Temperature/Package:</b>	_____				
	-40°C to +85°C 3-Pin SOT-23A				
<b>Taping Direction:</b>	_____				
	TR: Standard Taping				

## Sales and Support

### **Data Sheets**

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
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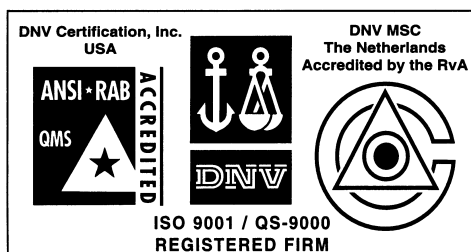
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