TC59

Low Dropout, Negative Output Voltage Regulator

Features

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

Applications

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

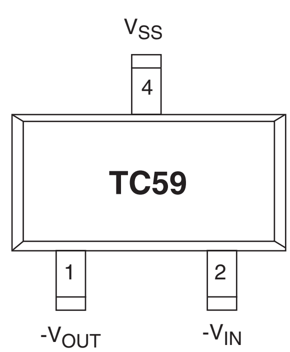
Device Selection Table

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

3-Pin SOT-23A



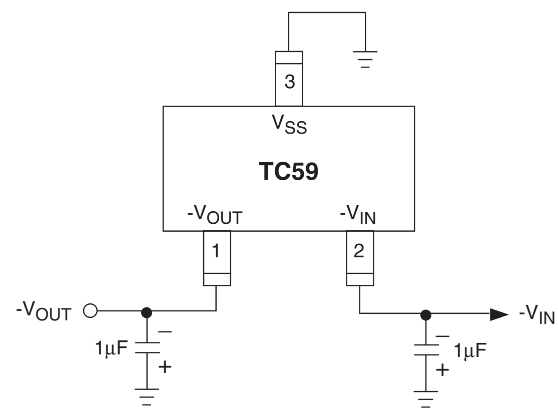
NOTE: 3-Pin SOT-23A is equivalent to the EIAJ SC59

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 3.0μA) and low dropout operation (typically 120mV at 50mA). The TC59 is packaged in a small 3-Pin SOT-23A package.

Functional Block Diagram



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 = 10µF, T_A = 25°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	µA	
$I_{OUT(MAX)}$	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 x V_R	—	0.98 x V_R	V	I_{OUT} = 20mA
TC V_{OUT}	Output Voltage Temperature Coefficient	—	±100	—	ppm/°C	I_{OUT} = 20mA
ΔV_{OUT}/ (ΔV_{IN} x 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
ΔV_{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 1μF tantalum output capacitor is required. The requirements for the output capacitor are an equivalent series resistance (esr) greater than 0.1Ω and less than 5Ω, 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 1μF input capacitor is recommended for most applications when the input impedance is on the order of 10Ω. 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:

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

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:

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

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:

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

For example, given the following conditions:

V_{IN} = -7.0V ±5%

V_{OUT} = -5.0V ±2%

I_{OUT} = 1mA to 40mA

$T_{AMBIENT\ (MAX)}$ = 55°C

P_{MAX} = (7V X (1.05) – (5.0V X 0.98)) X 40mA

P_{MAX} = 98.0 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)

$$T_{JUNCTION} = P_{D\ (MAX)} \text{ X } R_{\theta JA} + T_{AMBIENT}$$

$$T_{JUNCTION} = 98.0 \text{ milli-Watts X } 359°C/W + 55°C$$

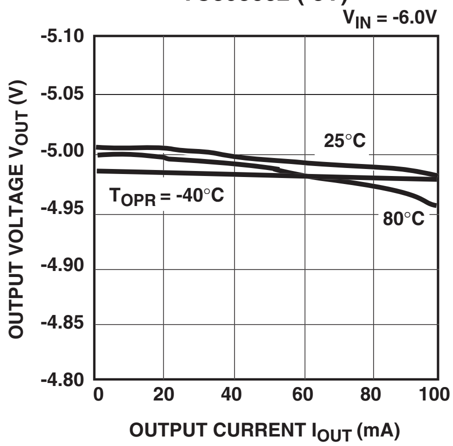
$$T_{JUNCTION} = 90.2°C$$

5.0 TYPICAL CHARACTERISTICS

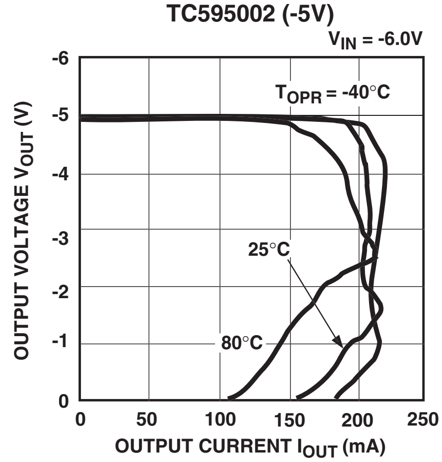
Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside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

1. OUTPUT VOLTAGE vs. OUTPUT CURRENT

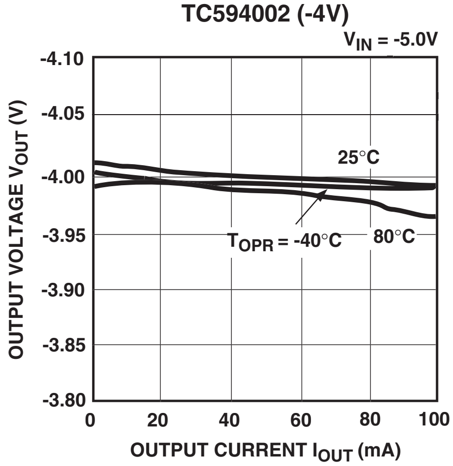
TC595002 (-5V)



TC595002 (-5V)



TC594002 (-4V)



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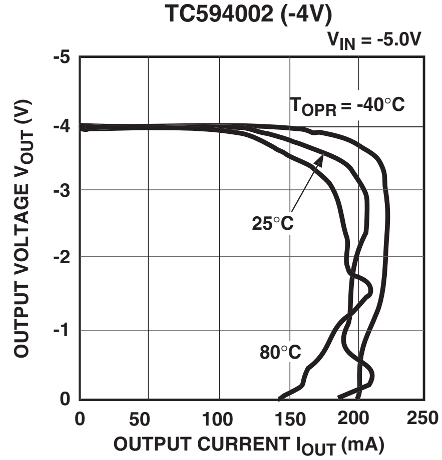
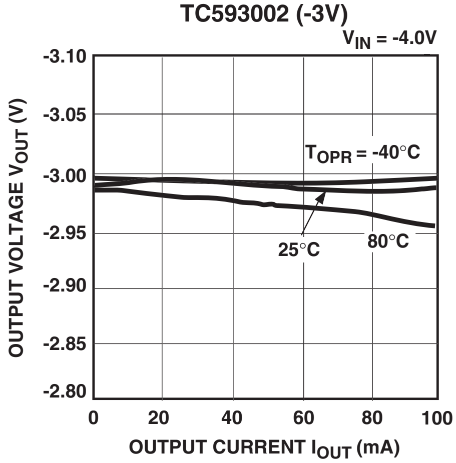
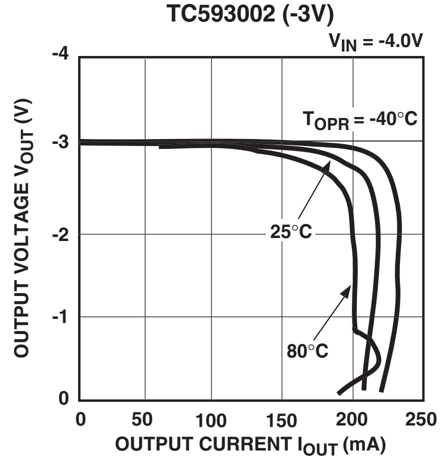


TC593002 (-3V)



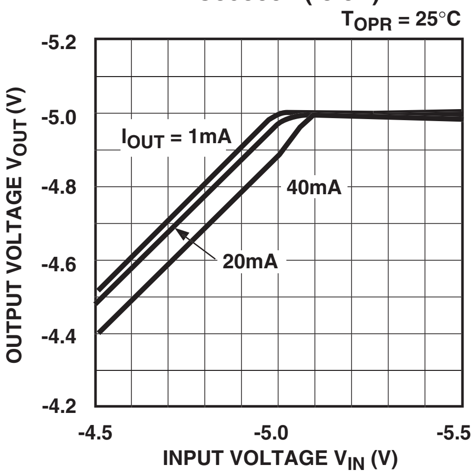
TC593002 (-3V)



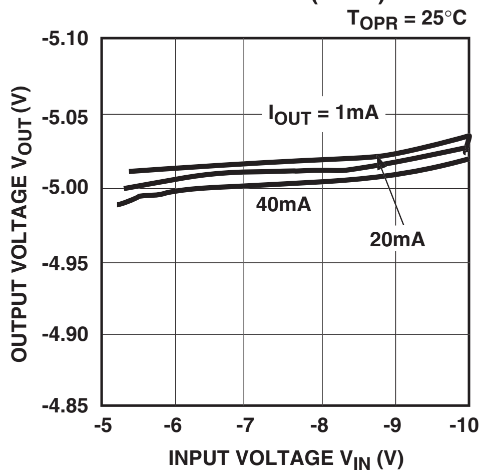
5.0 TYPICAL CHARACTERISTICS (CONTINUED)

2. OUTPUT VOLTAGE vs. INPUT VOLTAGE

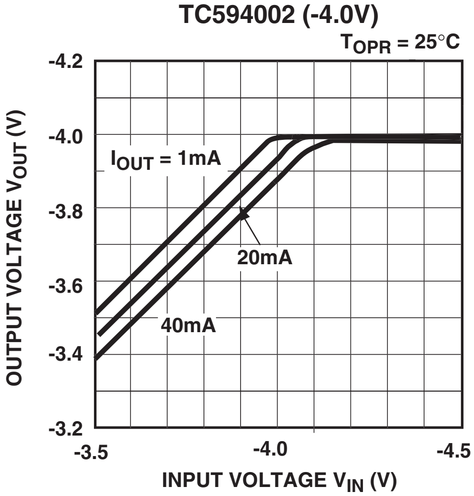
TC595002 (-5.0V)



TC595002 (-5.0V)



TC594002 (-4.0V)



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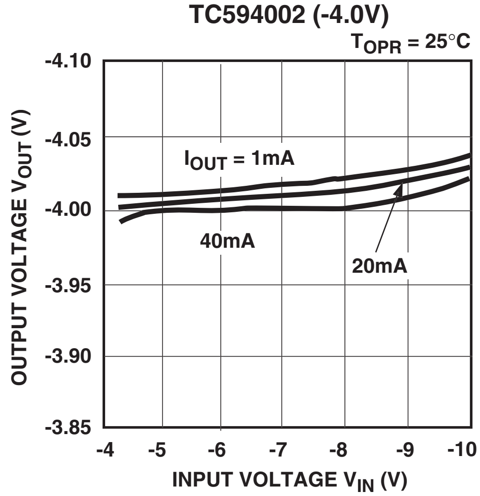

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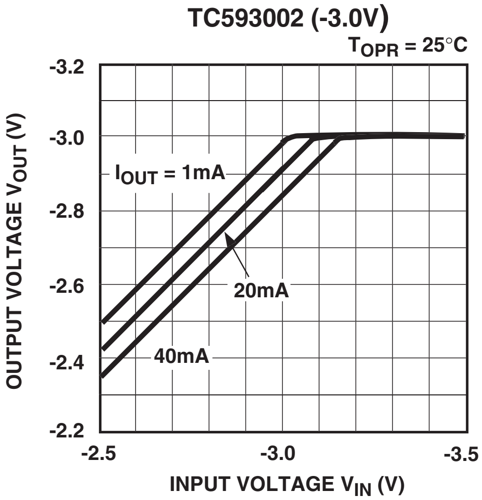

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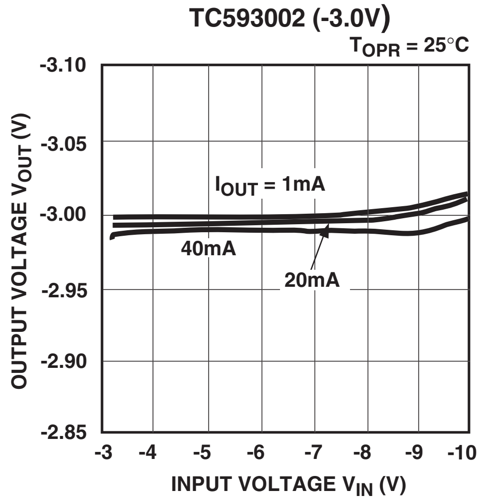
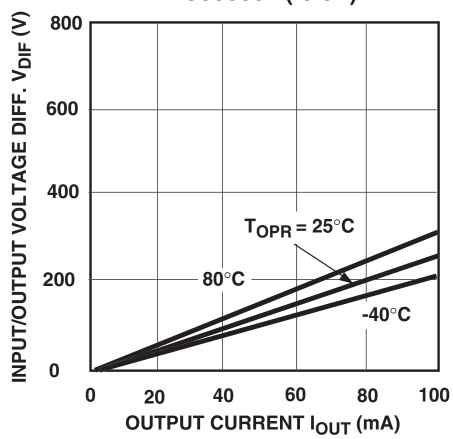


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

3. INPUT/OUTPUT VOLTAGE DIFFERENTIAL vs. OUTPUT CURRENT

TC595002 (-5.0V)



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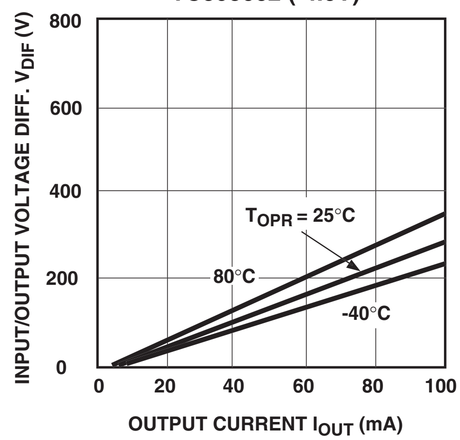

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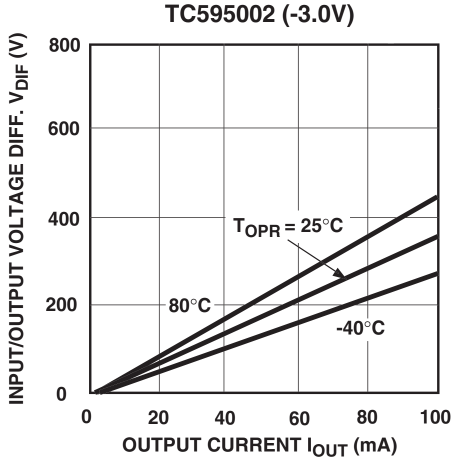

4. SUPPLY CURRENT vs. INPUT VOLTAGE

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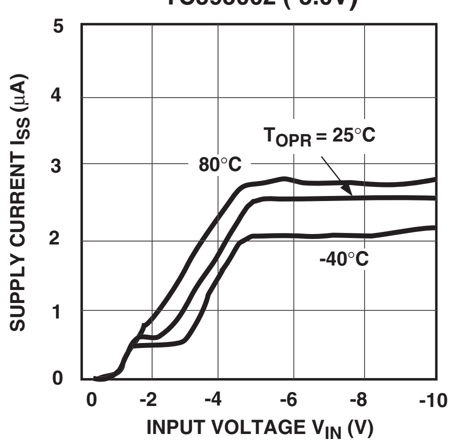
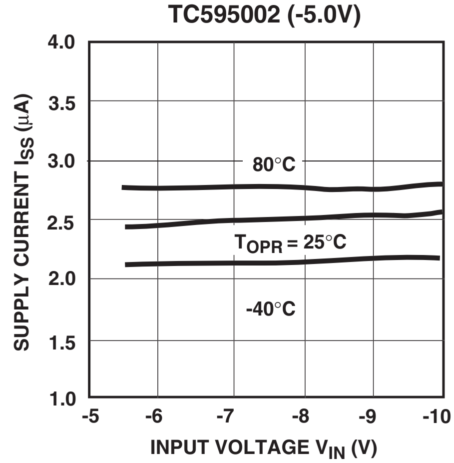


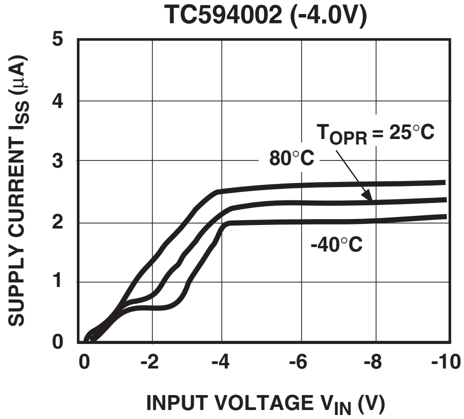
TC595002 (-5.0V)



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

4. SUPPLY CURRENT vs. INPUT VOLTAGE (CONTINUED)

TC594002 (-4.0V)



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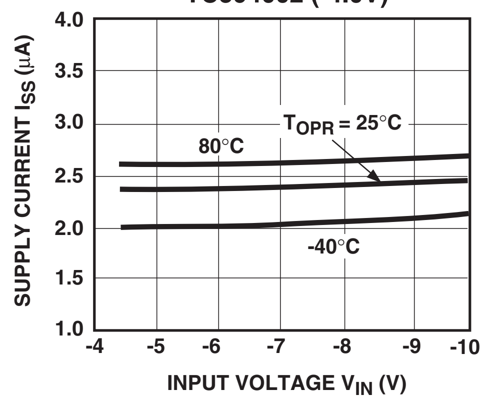

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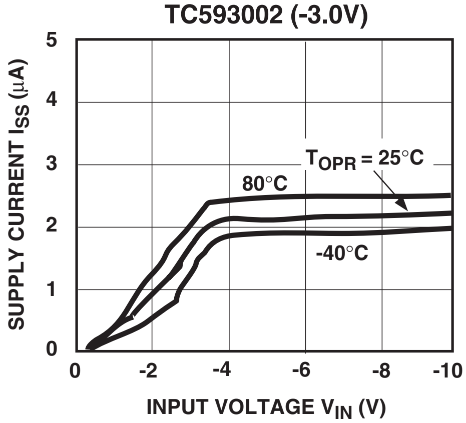

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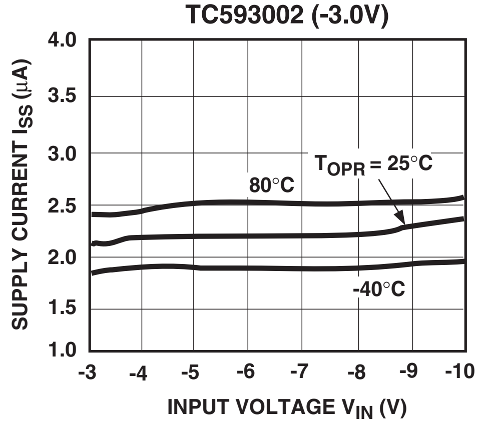
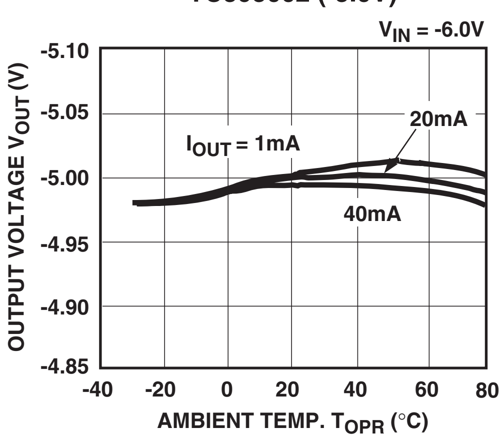


5. OUTPUT VOLTAGE vs. AMBIENT TEMPERATURE

TC595002 (-5.0V)



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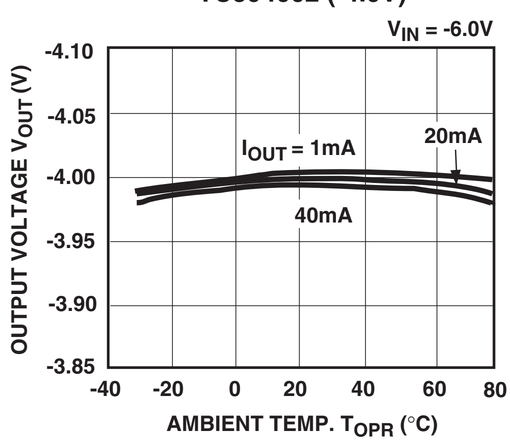

5.0 TYPICAL CHARACTERISTICS (CONTINUED)

5. OUTPUT VOLTAGE vs. AMBIENT TEMPERATURE (CONTINUED)

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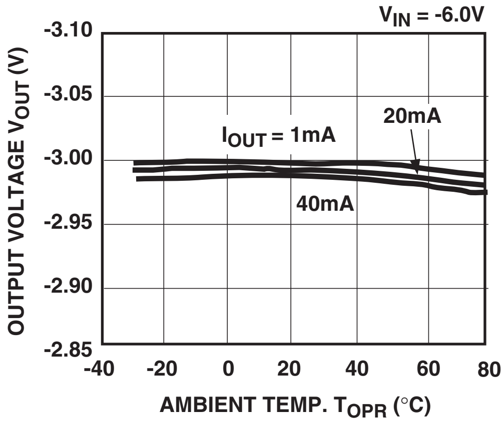
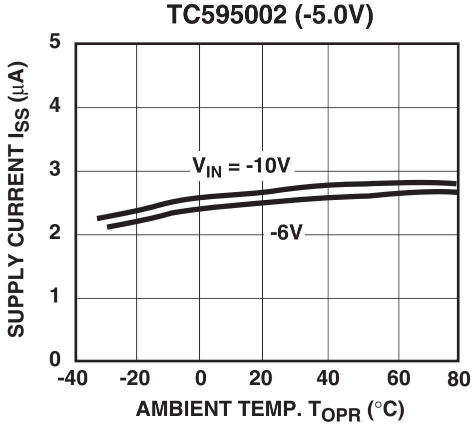


6. SUPPLY CURRENT vs. AMBIENT TEMPERATURE

TC595002 (-5.0V)



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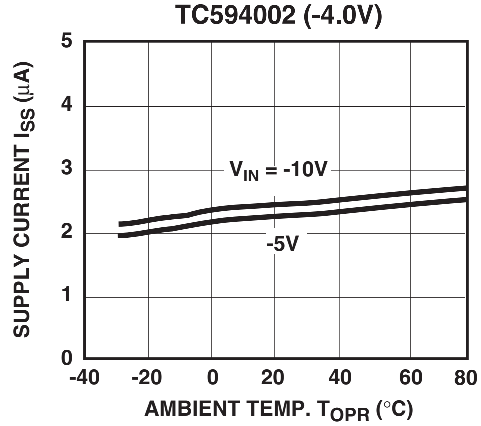

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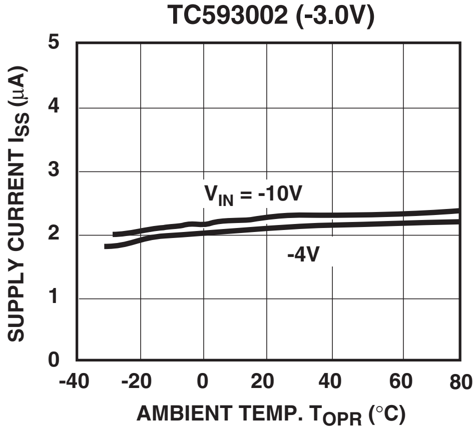
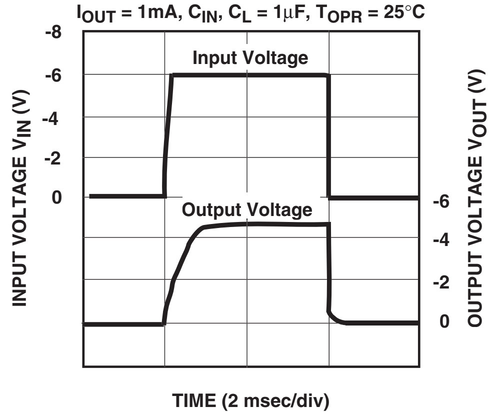


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

7. INPUT TRANSIENT RESPONSE

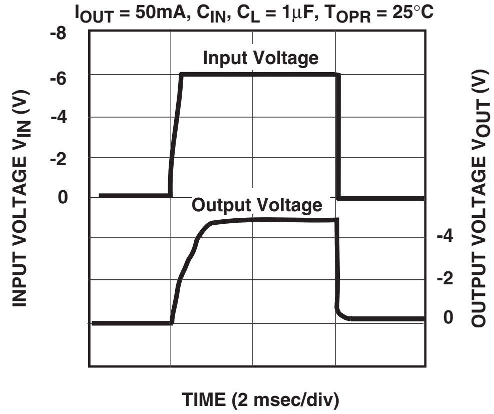
TC595002 (-5.0V)

I_{OUT} = 1mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



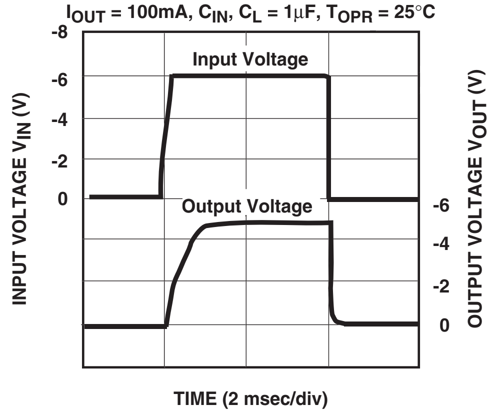
TC595002 (-5.0V)

I_{OUT} = 50mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



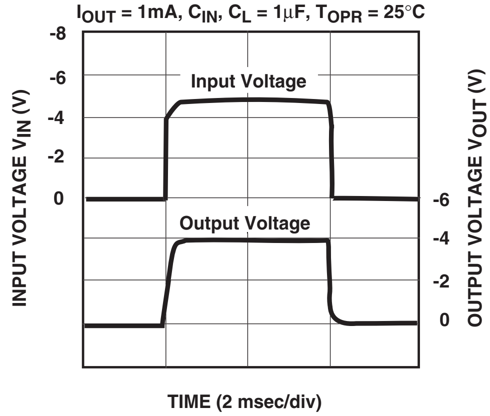
TC595002 (-5.0V)

I_{OUT} = 100mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



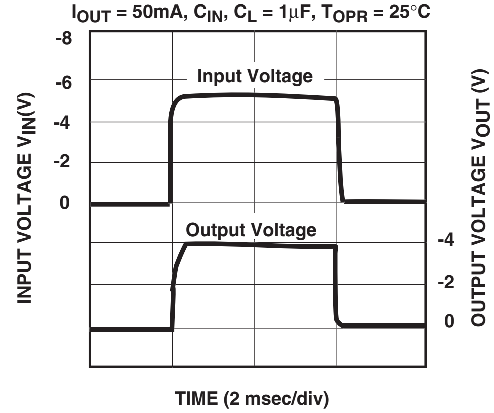
TC594002 (-4.0V)

I_{OUT} = 1mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



TC594002 (-4.0V)

I_{OUT} = 50mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C

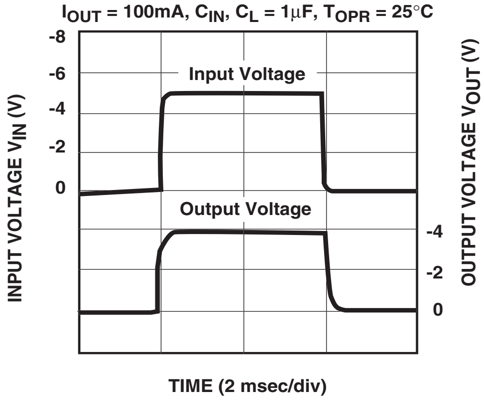


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

7. INPUT TRANSIENT RESPONSE (CONT.)

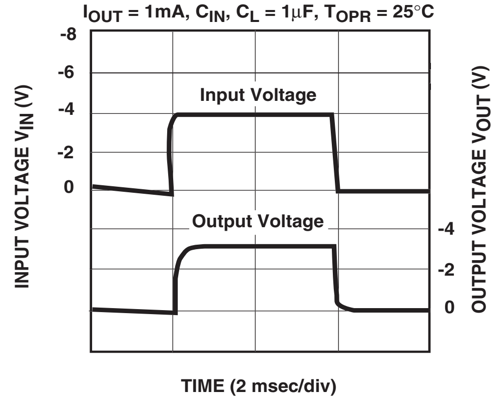
TC594002 (-4.0V)

I_{OUT} = 100mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



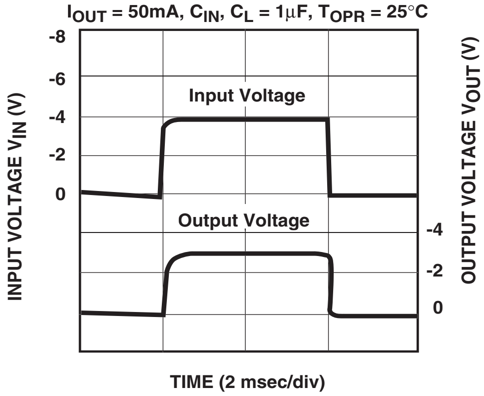
TC593002 (-3.0V)

I_{OUT} = 1mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



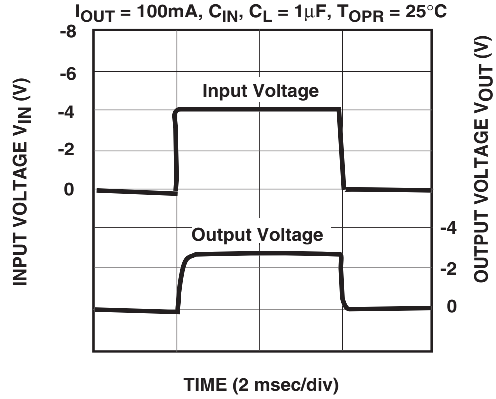
TC593002 (-3.0V)

I_{OUT} = 50mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C



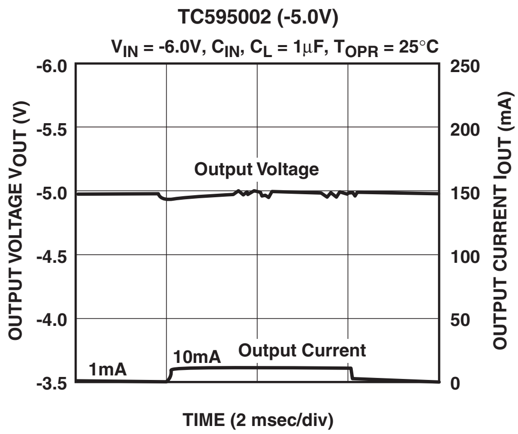
TC593002 (-3.0V)

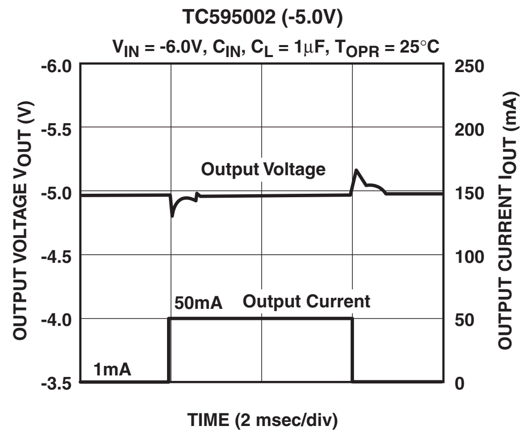
I_{OUT} = 100mA, C_{IN}, C_L = 1µF, T_{OPR} = 25°C

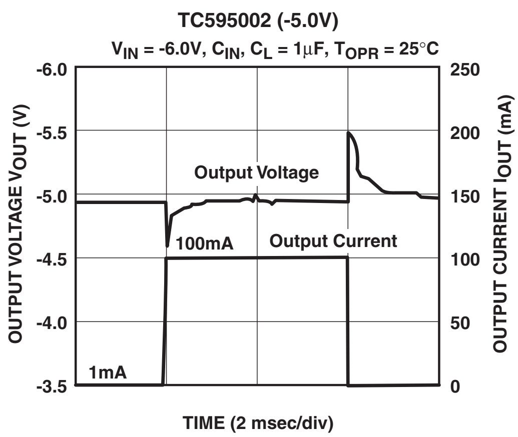


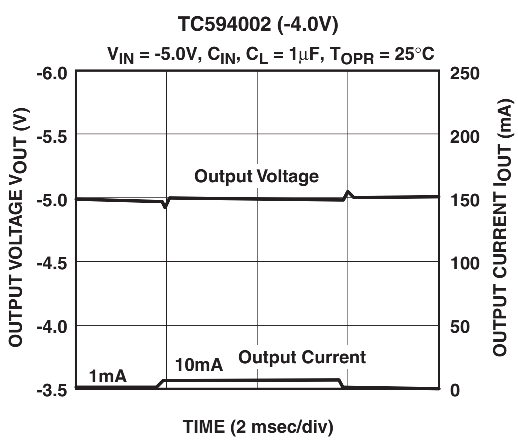
5.0 TYPICAL CHARACTERISTICS (CONTINUED)

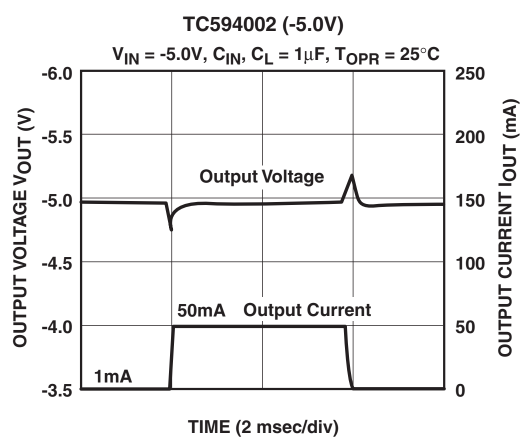
8. LOAD TRANSIENT RESPONSE





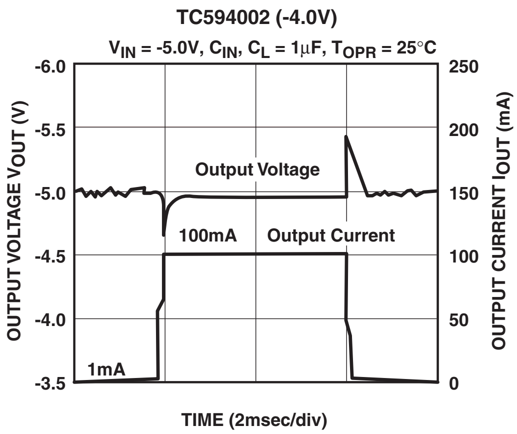


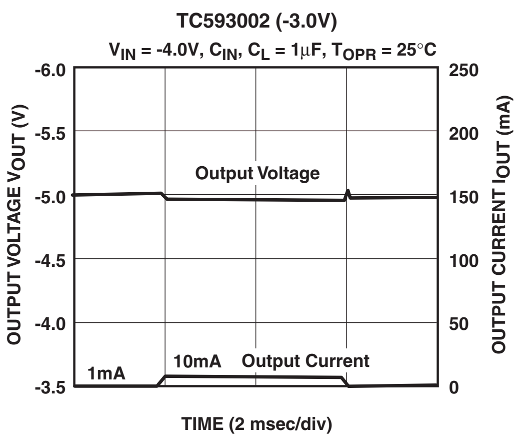


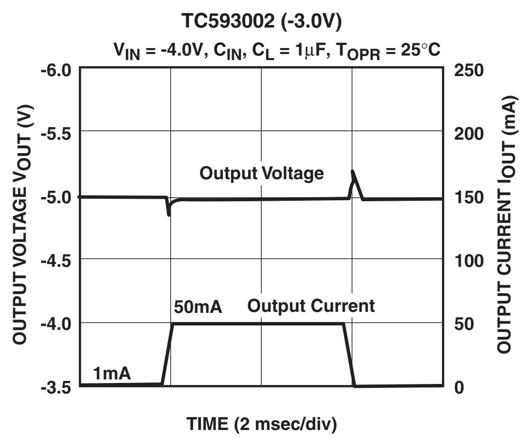


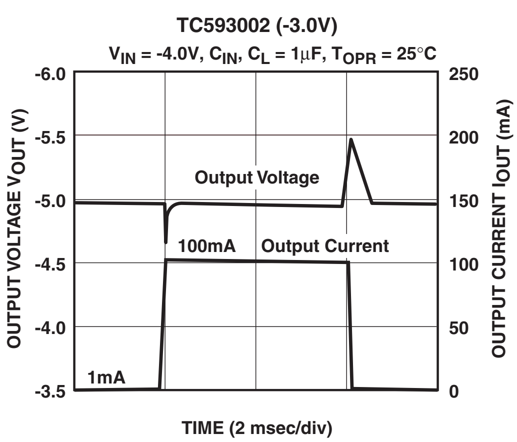
5.0 TYPICAL CHARACTERISTICS (CONTINUED)

8. LOAD TRANSIENT RESPONSE (CONT.)



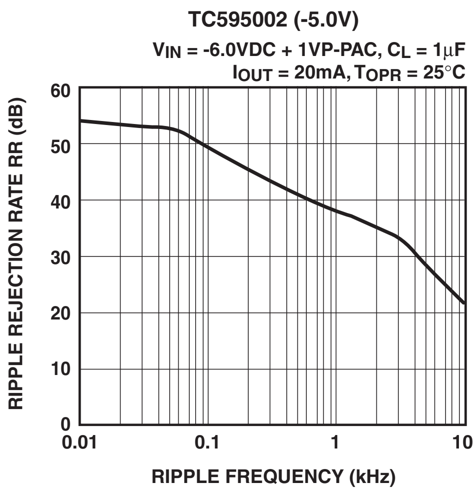


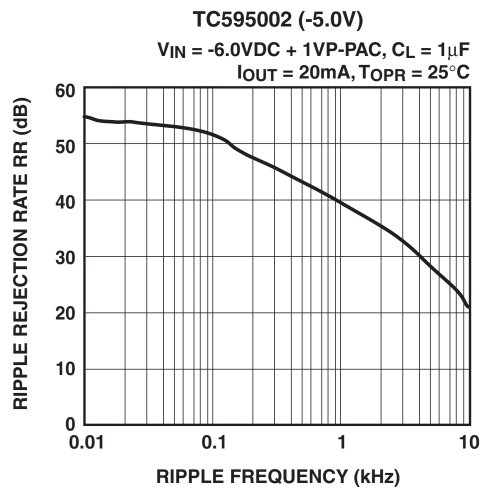


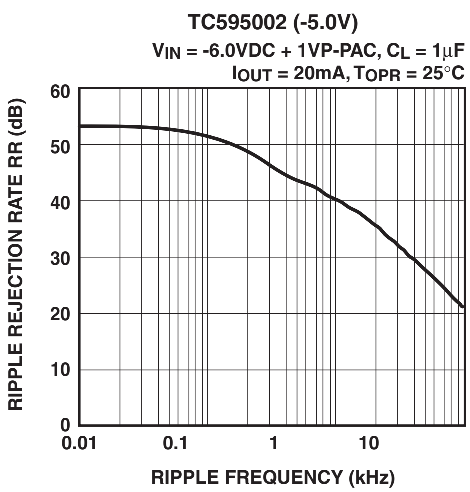


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

9. RIPPLE REJECTION RATE

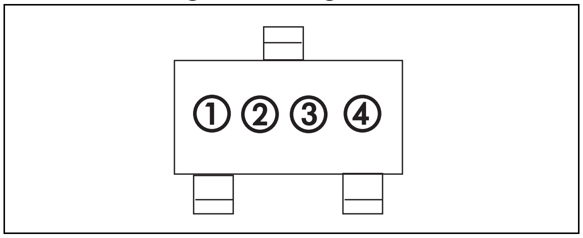






6.0 PACKAGING INFORMATION

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

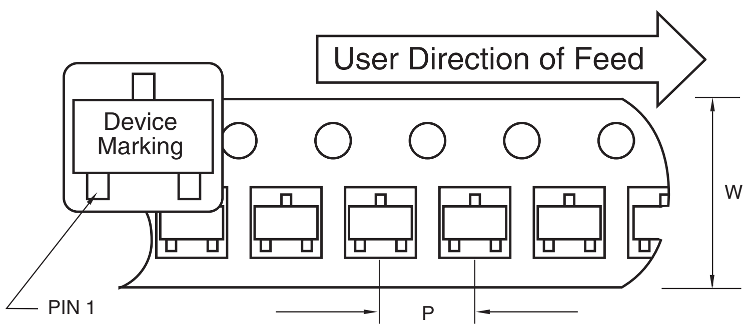
③ represents voltage polarity

Symbol	Polarity
5	–

④ represents assembly lot code

6.2 Taping Form

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



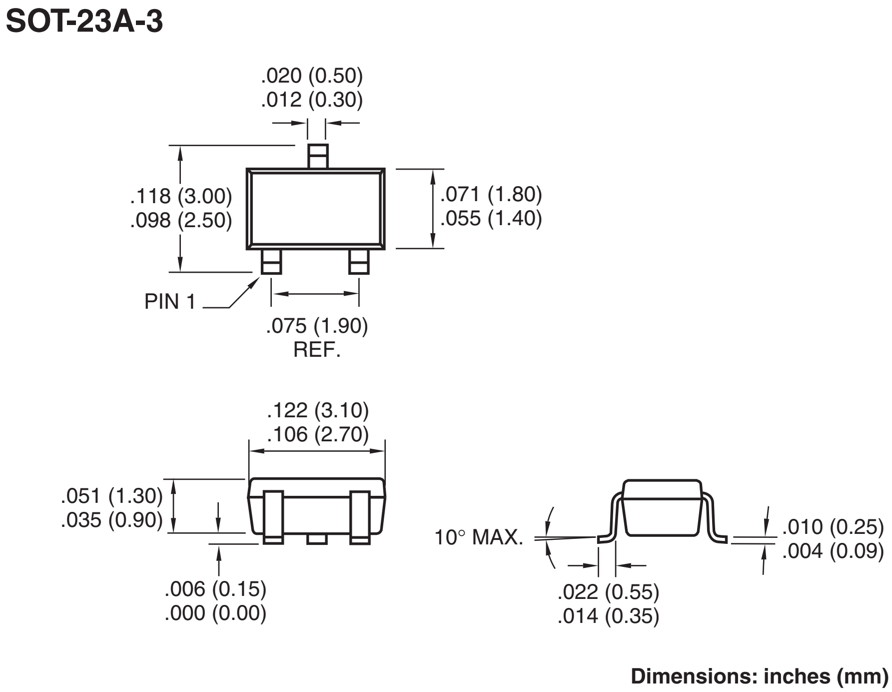
Standard Reel Component Orientation
for TR Suffix Device
(Mark Right Side Up)

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

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



7.0 REVISION HISTORY

Revision C (December 2012)

Added a note to the package outline drawing.

PRODUCT IDENTIFICATION SYSTEM

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

PART CODE TC59 30 02 ECB XX
TC59 50 02 ECB XX

Output Voltage:
50 = -5.0V; 30 = -3.0V

Tolerance:
02 = 2%

Temperature/Package:
-40°C to +85°C
3-Pin SOT-23A

Taping Direction:
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
2. The Microchip Worldwide Site (www.microchip.com)

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

New Customer Notification System
Register on our web site (www.microchip.com/cn) to receive the most current information on our products.

NOTES:

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

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