TC2014/2015/2185

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

Features

- Extremely Low Supply Current: 80µA (Max)
- Very Low Dropout Voltage: 140mV (Typ) @ 150mA
- High Output Voltage Accuracy: ±0.4% (Typ)
- Standard or Custom Output Voltages
- Power-Saving Shutdown Mode
- Reference Bypass Input for Ultra Low-Noise Operation
- Fast Shutdown Response Time: 60µsec (Typ)
- Over-Current 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

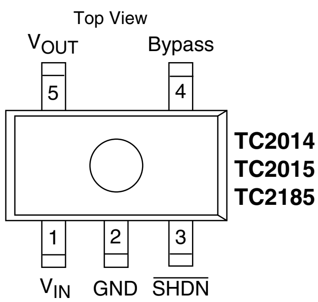
Device Selection Table

Part Number	Package	Junction Temperature Range
TC2014-xxVCT	5-Pin SOT-23A*	– 40°C to +125°C
TC2015-xxVCT	5-Pin SOT-23A*	– 40°C to +125°C
TC2185-xxVCT	5-Pin SOT-23A*	– 40°C to +125°C

NOTE 1: *5-Pin SOT-23A is equivalent to EIAJ SC-74A.

2: xx indicates output voltages. Available output voltages: 1.8, 2.7, 2.8, 2.85, 3.0, 3.3 Other output voltages are available. Please contact Microchip Technology Inc. for details.

Package Type



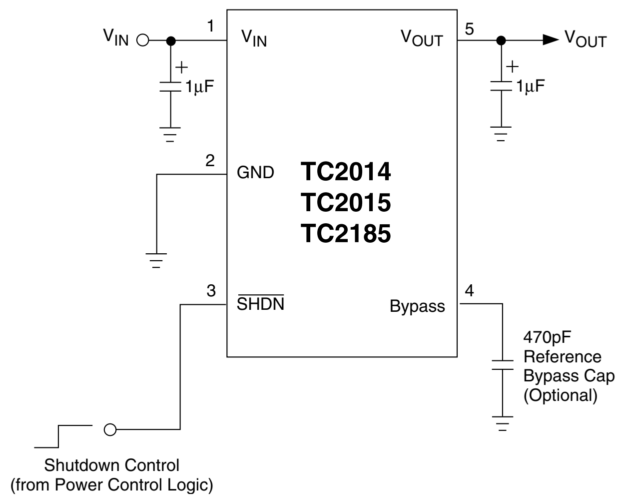
General Description

The TC2014, TC2015 and TC2185 are high accuracy (typically ±0.4%) CMOS upgrades for older (bipolar) low drop-out regulators, such as the LP2980. Total supply current is typically 55µA; 20 to 60 times lower than in bipolar regulators.

The devices' key features include ultra low noise operation (plus bypass reference), very low dropout voltage – typically 45mV for the TC2014, 90mV for the TC2015, and 140mV for the TC2185, at full load – and fast response to step changes in load. Supply current is reduced to 0.5µA (max) and V_{OUT} falls to zero when the shutdown input is low. The devices also incorporate over-current protection.

The TC2014, TC2015, and TC2185 are stable with an output capacitor of only 1µF and have a maximum output current of 50mA, 100mA and 150mA, respectively. For higher output versions, see the TC1107, TC1108, and TC1173 (I_{OUT} = 300mA) data sheets.

Typical Application



Related Literature

- Application Notes: 765, 766 and 776
- Article: "Microchip's CMOS LDOs Exhibit Excellent Stability While Offering the Advantages of Low-Value Ceramic Capacitors"

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Input Voltage 6.5V

Output Voltage .... (– 0.3) to (V_{IN} + 0.3)

Operating Temperature .... – 40°C < T_J< 125°C

Storage Temperature .... – 65°C to +150°C

Maximum Voltage on Any Pin ...... V_{IN} +0.3V to – 0.3V

*Stresses beyond 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 beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

TC2014/2015/2185 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: V_{IN} = V_R + 1V, I_L = 100µA, C_L = 3.3µF, $\overline{SHDN}$ > V_{IH}, T_A = 25°C, unless otherwise specified.
BOLDFACE type specifications apply for junction temperature of -40°C to +125°C.

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
V_{IN}	Input Operating Voltage	2.7	—	6.0	V	Note 1
I_{OUTMAX}	Maximum Output Current	50 100 150	— — —	— — —	mA	TC2014 TC2015 TC2185
V_{OUT}	Output Voltage	V_R - 2.0%	V_R ± 0.4%	V_R + 2.0%	V	Note 2
TCV_{OUT}	V_{OUT} Temperature Coefficient	— —	20 40	— —	ppm/°C	Note 3
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	—	0.05	0.5	%	(V_R + 1V) ≤ V_{IN} ≤ 6V
$\Delta V_{OUT}/V_{OUT}$	Load Regulation	-1.5 -2.5	0.5 0.5	0.5 0.5	%	TC2014;TC2015 I_L = 0.1mA to I_{OUTMAX} TC2185 I_L = 0.1mA to I_{OUTMAX} (Note 4)
V_{IN} - V_{OUT}	Dropout Voltage	— — — —	2 45 90 140	— 70 140 210	mV	(Note 5) I_L = 100µA I_L = 50µA TC2015; TC2185 I_L = 100µA TC2185 I_L = 150µA
I_{IN}	Supply Current	—	55	80	µA	$\overline{SHDN}$ = V_{IH}, I_L=0
I_{INSD}	Shutdown Supply Current	—	0.05	0.5	µA	$\overline{SHDN}$ = 0V
PSRR	Power Supply Rejection Ratio	—	55	—	dB	F_{RE} ≤ 1 kHz (with bypass)
I_{OUTSC}	Output Short Circuit Current	—	160	300	mA	V_{OUT} = 0V
$\Delta V_{OUT}/\Delta P_D$	Thermal Regulation	—	0.04	—	V/W	Note 6, Note 7
eN	Output Noise	—	200	—	$nV/\sqrt{Hz}$	I_L = I_{OUTMAX}, F = 10kHz 470pF from Bypass to GND
T_R	Response Time, (Note 8) (from Shutdown Mode)	—	60	—	µsec	V_{IN} = 4V, I_L = 30 mA, C_{IN} = 1 µF, C_{OUT} = 10 µF

Note 1: The minimum V_{IN} has to meet two conditions: V_{IN} = 2.7V and V_{IN} = V_R + $V_{DROPOUT}$.

2: V_R is the regulator output voltage setting. For example: V_R = 1.8V, 2.7V, 2.8V, 2.85V, 3.0V, 3.3V.

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

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_{MAX} at V_{IN} = 6V for T = 10msec.

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, θ_{JA}).

8: Time required for V_{OUT} to reach 95% of V_R (output voltage setting), after V_{SHDN} is switched from 0 to V_{IN}.

TC2014/2015/2185 ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: $V_{IN} = V_R + 1V$, $I_L = 100\mu A$, $C_L = 3.3\mu F$, $\overline{SHDN} > V_{IH}$, $T_A = 25°C$, unless otherwise specified. **BOLDFACE** type specifications apply for junction temperature of -40°C to +125°C.						
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Units**	**Test Conditions**
$\overline{SHDN}$ Input						
V_{IH}	$\overline{SHDN}$ Input High Threshold	60	—	—	$\%V_{IN}$	V_{IN} = 2.5V to 6.0V
V_{IL}	$\overline{SHDN}$ Input Low Threshold	—	—	15	$\%V_{IN}$	V_{IN} = 2.5V to 6.0V

Note 1: The minimum V_{IN} has to meet two conditions: $V_{IN} = 2.7V$ and $V_{IN} = V_R + V_{DROPOUT}$.

2: V_R is the regulator output voltage setting. For example: V_R = 1.8V, 2.7V, 2.8V, 2.85V, 3.0V, 3.3V.

3: $TCV_{OUT} = \dfrac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^{-6}}{V_{OUT} \times \Delta T}$

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_{MAX} at V_{IN} = 6V for T = 10msec.

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, θ_{JA}).

8: Time required for V_{OUT} to reach 95% of V_R (output voltage setting), after V_{SHDN} is switched from 0 to V_{IN}.

2.0 PIN DESCRIPTIONS

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

TABLE 2-1: PIN FUNCTION TABLE

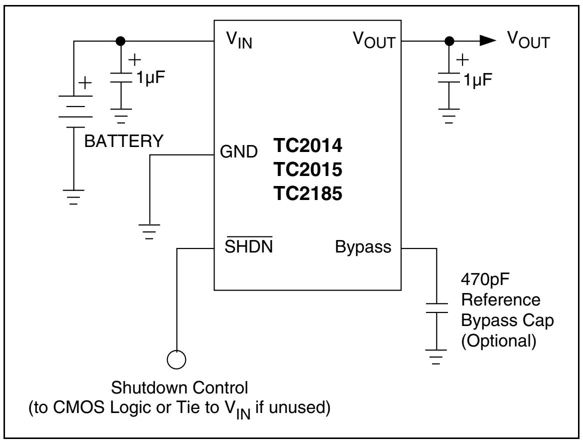
Pin No. (5-Pin SOT-23A)	Symbol	Description
1	V_{IN}	Unregulated supply input.
2	GND	Ground terminal.
3	$\overline{SHDN}$	Shutdown control input. The regulator is fully enabled when a logic high is applied to this input. The regulator enters shutdown when a logic low is applied to this input. During shutdown,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

3.0 DETAILED DESCRIPTION

The TC2014, TC2015 and TC2185 are precision fixed output voltage regulators. (If an adjustable version is desired, please see the TC1070, TC1071, or TC1187 data sheets.) Unlike bipolar regulators, the TC2014, TC2015 and TC2185 supply current does not increase with load current. In addition, V_{OUT} remains stable and within regulation at very low load currents (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 0.05µA (typical) and 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 the result is a longer time period to rated output voltage when power is initially applied.

3.2 Output Capacitor

A 1µF (min) capacitor from V_{OUT} to ground is required. The output capacitor should have an effective series resistance of 0.01Ω to 5Ω for $V_{OUT} \geq 2.5V$, and 0.05Ω. to 5Ω for $V_{OUT} < 2.5V$. A 1µF 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°C, solid tantalum are recommended for applications operating below -25°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 Power Dissipation

The amount of power the regulator dissipates is primarily a function of input voltage, output voltage and output current.

The following equation is used to calculate worst case power dissipation:

EQUATION 4-1:

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

Where:

P_D	=	Worst case actual power dissipation
$V_{IN_{MAX}}$	=	Maximum voltage on V_{IN}
$V_{OUT_{MIN}}$	=	Minimum regulator output voltage
$I_{LOAD_{MAX}}$	=	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 (125 °C) and the thermal resistance from junction-to-air (θ_{JA}). The 5-Pin SOT-23A package has a θ_{JA} of approximately 220°C/Watt when mounted on a typical two layer FR4 dielectric copper clad PC board.

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:

V_{INMAX} = 3.0V +10%
V_{OUTMIN} = 2.7V – 2.5%
$I_{LOADMAX}$ = 40mA
T_{JMAX} = 125 °C
T_{AMAX} = 55 °C

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

Actual power dissipation:

$$P_D = (V_{INMAX} - V_{OUTMIN})I_{LOADMAX}$$
$$= [(3.0 \times 1.1) - (2.7 \times .975)]40 \times 10^{-3}$$
$$= 26.7\ m\Omega$$

Maximum allowable power dissipation:

$$P_{DMAX} = \frac{T_{JMAX} - T_{AMAX}}{\theta_{JA}}$$
$$= \frac{125 - 55}{220}$$
$$= 318m\Omega$$

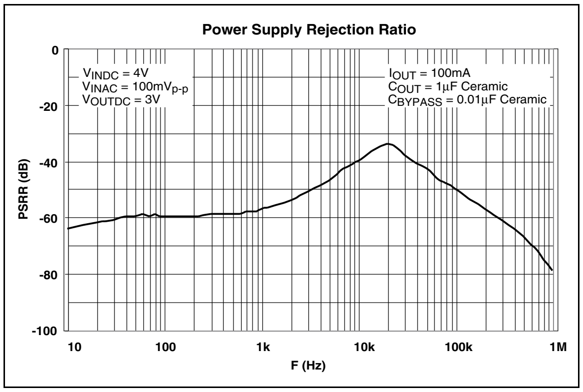
In this example, the TC2014 dissipates a maximum of only 26.7mΩ; far below the allowable limit of 318mΩ. In a similar manner, Equation 4-1 and Equation 4-2 can be used to calculate maximum current and/or input voltage limits.

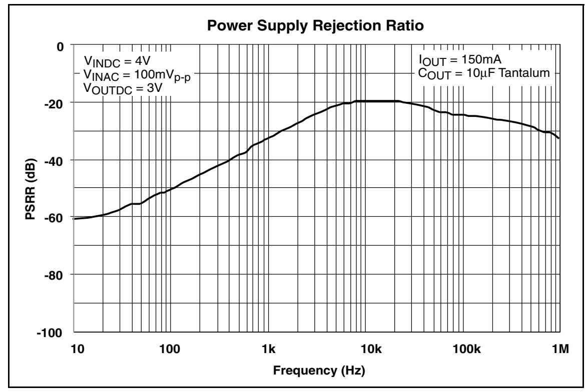
4.2 Layout Considerations

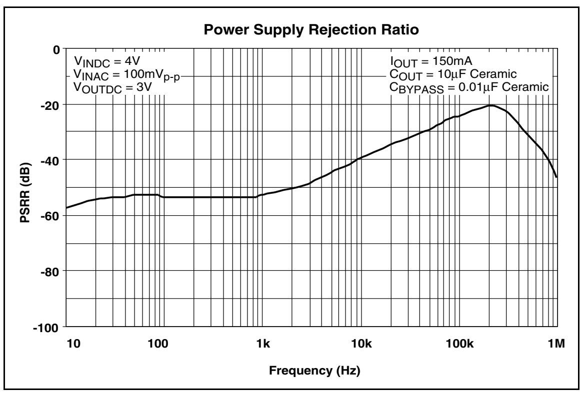
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower θ_{JA} and, therefore, increase the maximum allowable power dissipation limit.

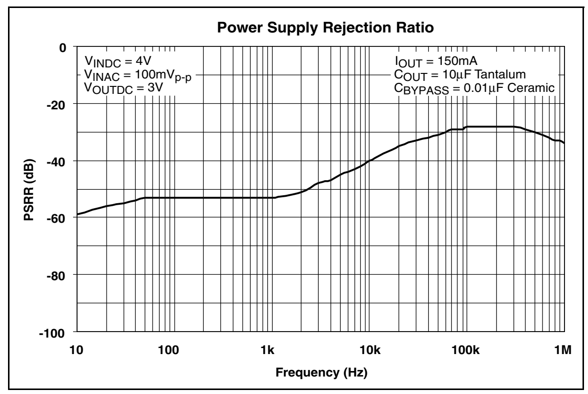
5.0 TYPICAL CHARACTERISTICS

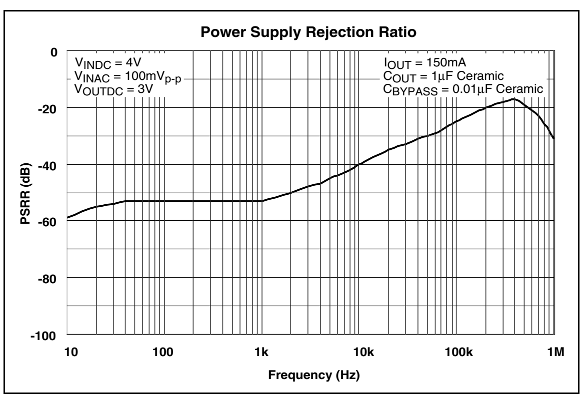
Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside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

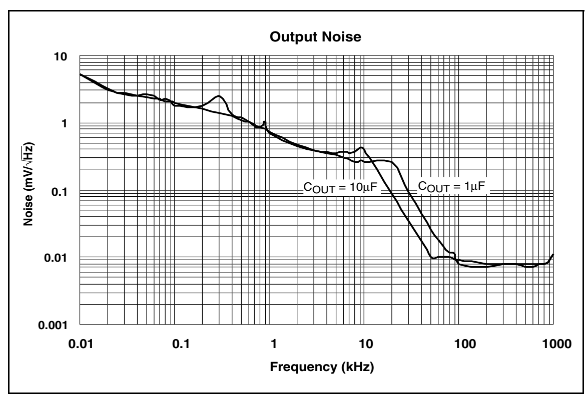




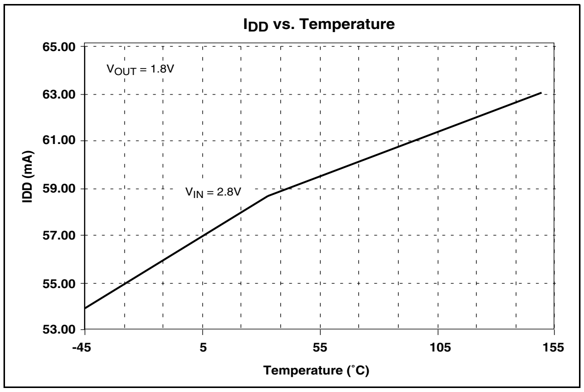


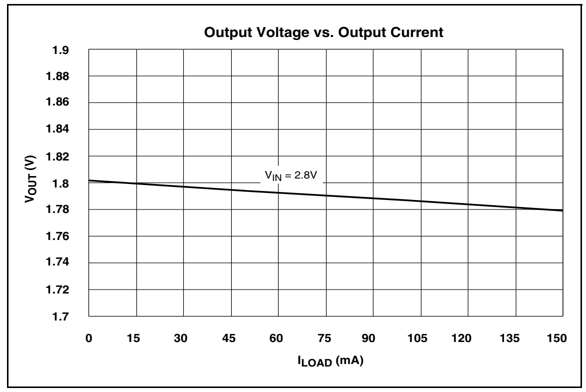


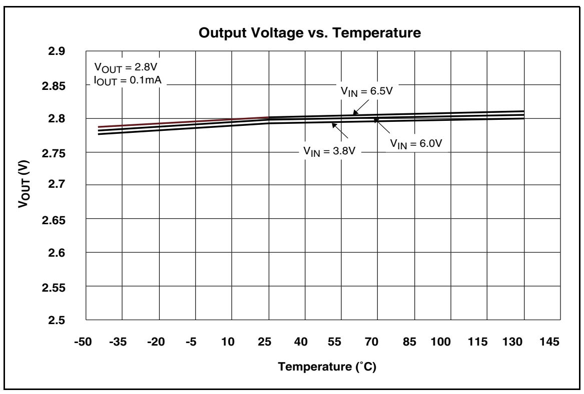


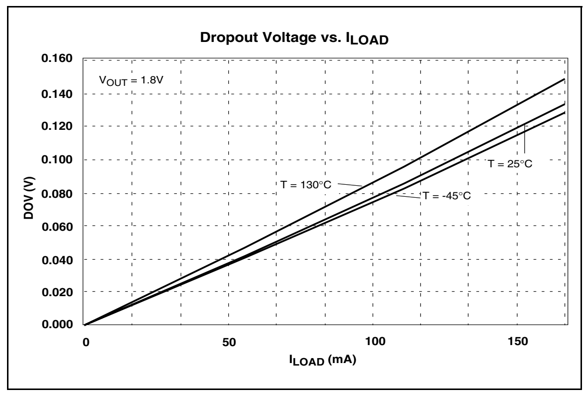


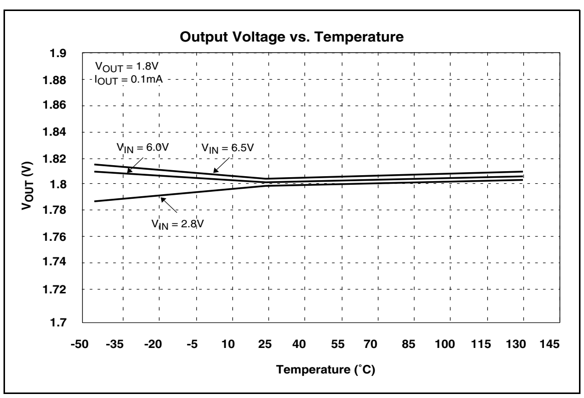
5.0 TYPICAL CHARACTERISTICS (Continued)

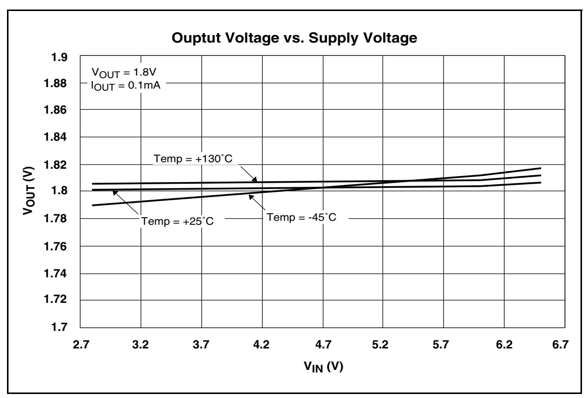




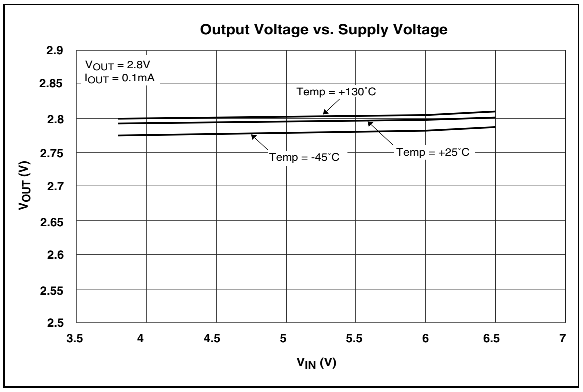


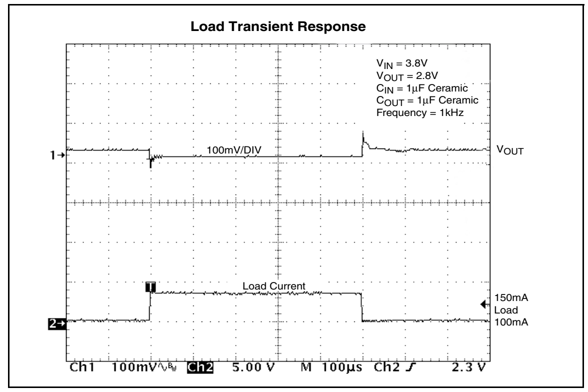


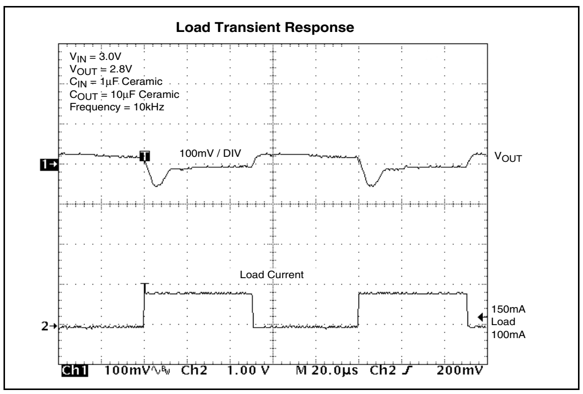


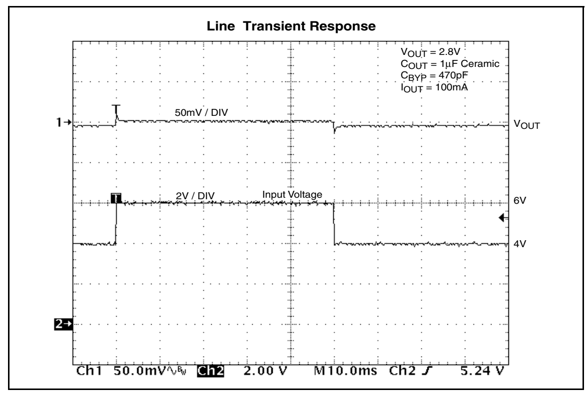


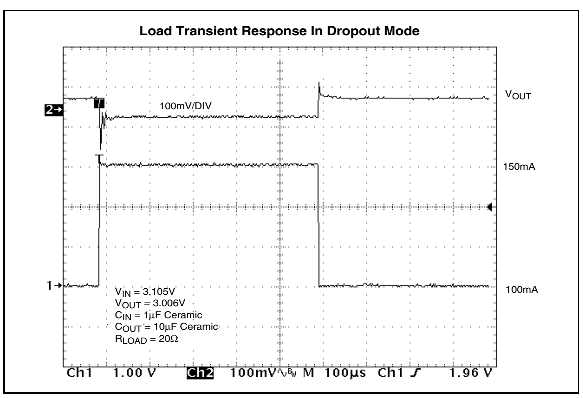
5.0 TYPICAL CHARACTERISTICS (Continued)

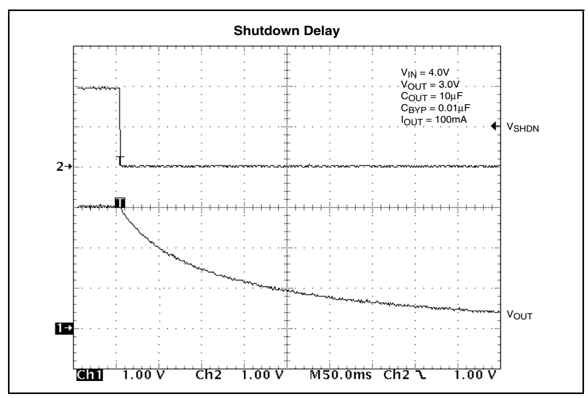




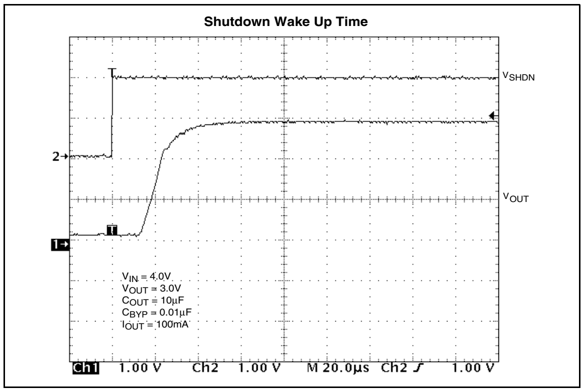






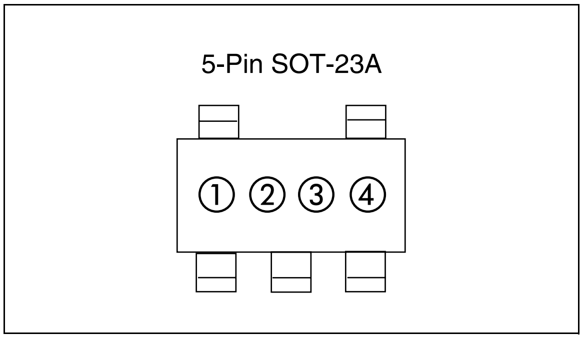


5.0 TYPICAL CHARACTERISTICS (Continued)



6.0 PACKAGING INFORMATION

6.1 Package Marking Information



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

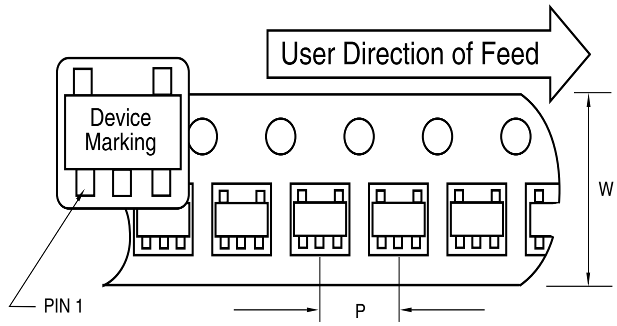
(V)	TC2014 Code	TC2015 Code	TC2185 Code
1.8	PA	RA	UA
2.5	PB	RB	UB
2.7	PC	RC	UC
2.8	PD	RD	UD
2.85	PE	RE	UE
3.0	PF	RF	UF
3.3	PG	RG	UG

3 represents year and 2-month period code

4 represents lot ID number

6.2 Taping Information

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



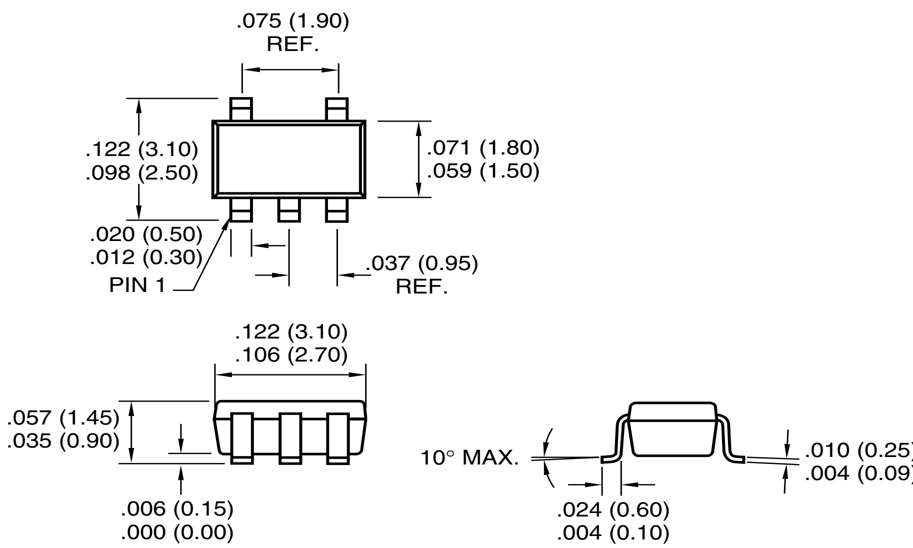
Standard Reel Component Orientation
TR Suffix Device
(Mark Right Side Up)

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

6.3 Package Dimensions

SOT-23A-5



Dimensions: inches (mm)

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:

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2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
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Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

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NOTES:

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04/20/02