TC1014/TC1015/TC1185

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

Features

- Extremely Low Supply Current (50µA, 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

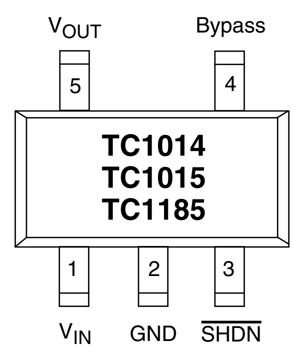
Part Number	Package	Junction Temp. Range
TC1014-xxVCT	5-Pin SOT-23A	-40°C to +125°C
TC1015-xxVCT	5-Pin SOT-23A	-40°C to +125°C
TC1185-xxVCT	5-Pin SOT-23A	-40°C to +125°C

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

5-Pin SOT-23A



NOTE: 5-Pin SOT-23A is equivalent to the EIAJ (SC-74A)

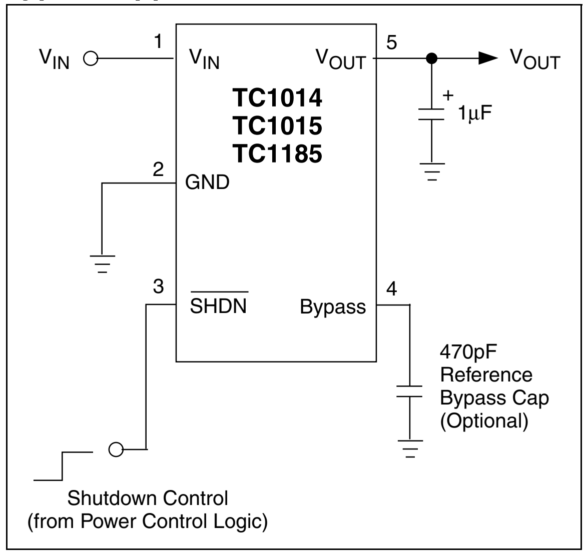
General Description

The TC1014/TC1015/TC1185 are high accuracy (typically ±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 50µA 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 85mV (TC1014); 180mV (TC1015); and 270mV (TC1185) at full load. Supply current is reduced to 0.5µA (max) and V_{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 1µF and have a maximum output current of 50mA, 100mA and 150mA, respectively. For higher output current regulators, please see the TC1107/TC1108/TC1173 (I_{OUT} = 300mA) data sheets.

Typical Application



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings*

Input Voltage.. 6.5V
Output Voltage...........................(-0.3V) to (V_{IN} + 0.3V)
Power Dissipation............... Internally Limited **(Note 7)**
Maximum Voltage on Any Pin ....V_{IN} +0.3V to -0.3V
Operating Temperature Range......-40°C < T_J < 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: $V_{IN} = V_R + 1V$, $I_L = 100\mu A$, $C_L = 3.3\mu F$, $\overline{SHDN} > V_{IH}$, $T_A = 25°C$, unless otherwise noted. **Boldface** type specifications apply for junction temperatures of -40°C to +125°C.

Symbol	Parameter	Min	Typ	Max	Units	Device	Test Conditions
V_{IN}	Input Operating Voltage	**2.7**	—	**6.0**	V		**Note 1**
I_{OUTMAX}	Maximum Output Current	**50** **100** **150**	— — —	— — —	mA	TC1014 TC1015 TC1185	
V_{OUT}	Output Voltage	**V_R – 2.5%**	V_R ±0.5%	**V_R + 2.5%**	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	**0.35**	%		$(V_R + 1V) \le V_{IN} \le 6V$
$\Delta V_{OUT}/V_{OUT}$	Load Regulation	— —	0.5 0.5	**2** **3**	%	TC1014; TC1015 TC1185	I_L = 0.1mA to I_{OUTMAX} I_L = 0.1mA to I_{OUTMAX} **(Note 4)**
V_{IN}-V_{OUT}	Dropout Voltage	— — — — —	2 65 85 180 270	— — **120** **250** **400**	mV	 TC1015; TC1185 TC1185	$I_L = 100\mu A$ I_L = 20mA I_L = 50mA I_L = 100mA I_L = 150mA **(Note 5)**
I_{IN}	Supply Current (Note 8)	—	50	**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	—	64	—	dB		$F_{RE} \le 1kHz$
I_{OUTSC}	Output Short Circuit Current	—	300	450	mA		V_{OUT} = 0V
$\Delta V_{OUT}/\Delta P_D$	Thermal Regulation	—	0.04	—	V/W		**Notes 6, 7**
T_{SD}	Thermal Shutdown Die Temperature	—	160	—	°C		
ΔT_{SD}	Thermal Shutdown Hysteresis	—	10	—	°C		
eN	Output Noise	—	600	—	$nV/\sqrt{Hz}$		$I_L = I_{OUTMAX}$, F = 10kHz 470pF from Bypass to GND

Note 1: The minimum V_{IN} has to meet two conditions: $V_{IN} \ge 2.7V$ and $V_{IN} \ge V_R + V_{DROPOUT}$.
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, θ_{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°C to +85°C.

TC1014/TC1015/TC1185 ELECTRICAL SPECIFICATIONS (CONTINUED)

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

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$\overline{SHDN}$ Input						
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, θ_{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°C to +85°C.

2.0 PIN DESCRIPTIONS

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

TABLE 2-1: PIN FUNCTION TABLE

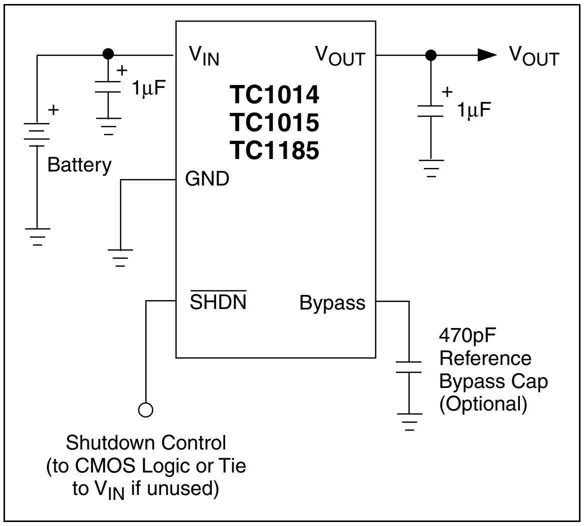
Pin No. (5-Pin SOT-23A)	Symbol	Description
1	V_{IN}	Unregulated supply input.
2	GND	Ground terminal.
3	$\overline{SHDN}$	Shutdown control input. The regulator is fully enabled when a logic high is applied to this input. The regulator enters shutdown when a logic low is applied to this input. During shutdown, output voltage falls to zero, $\overline{ERROR}$ is open circuited 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 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 0.05µA (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 1µF (min) capacitor from V_{OUT} to ground is required. The output capacitor should have an effective series resistance greater than 0.1Ω and less than 5Ω. 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 tantalums 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 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 (θ_{JA}). The 5-Pin SOT-23A package has a θ_{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:

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:

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

Maximum allowable power dissipation:

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

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.

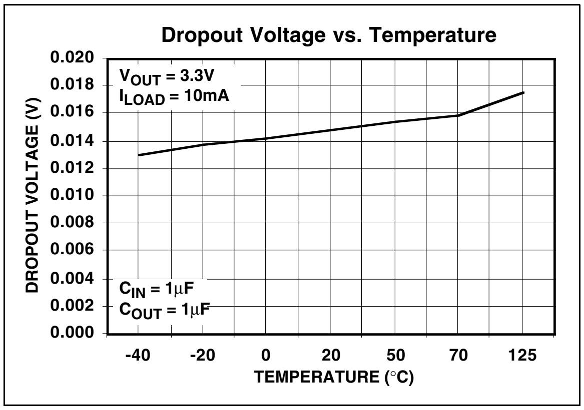
4.3 Layout Considerations

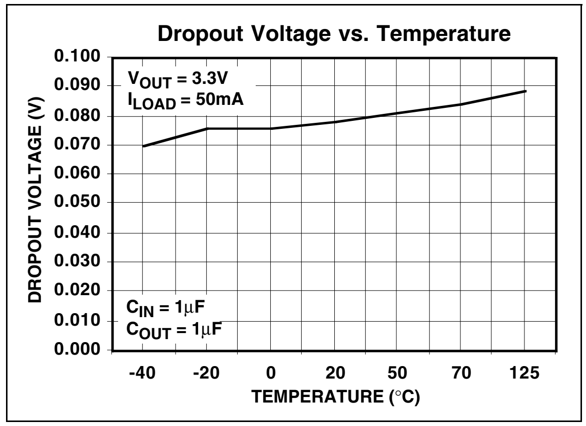
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower θ_{JA} and therefore increase the maximum allowable power dissipation limit.

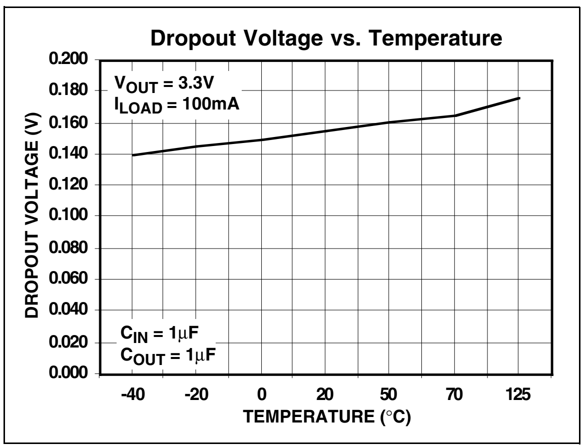
5.0 TYPICAL CHARACTERISTICS

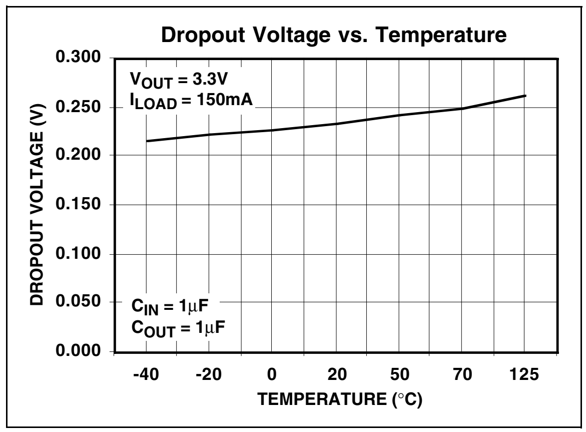
(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)

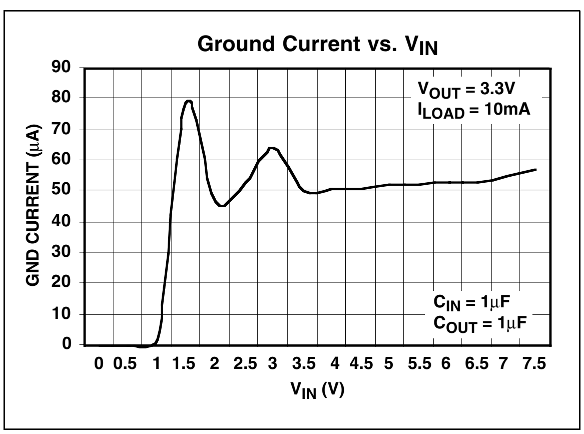
Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside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

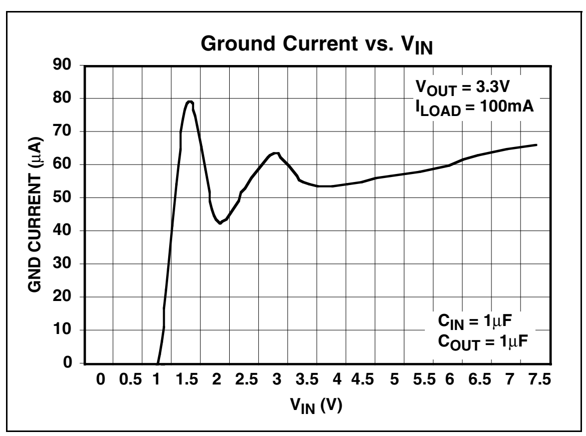






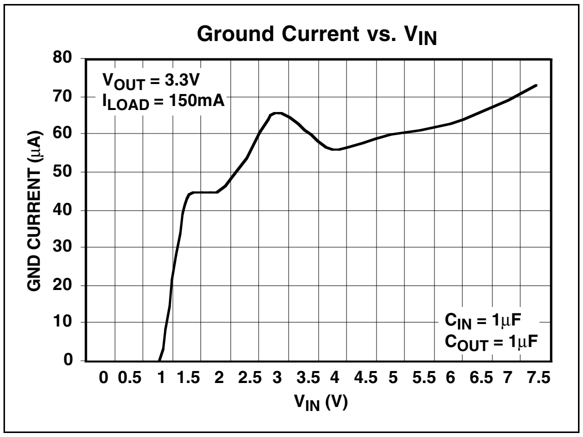


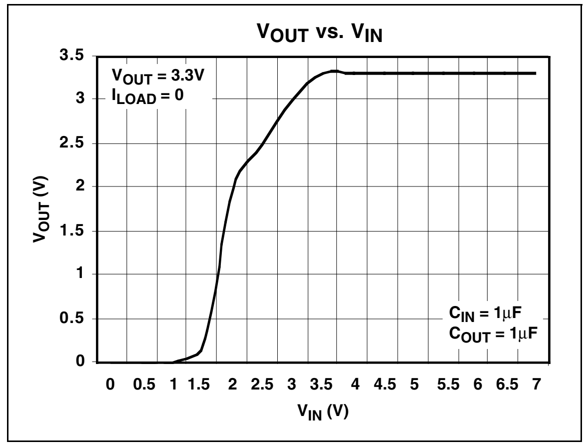


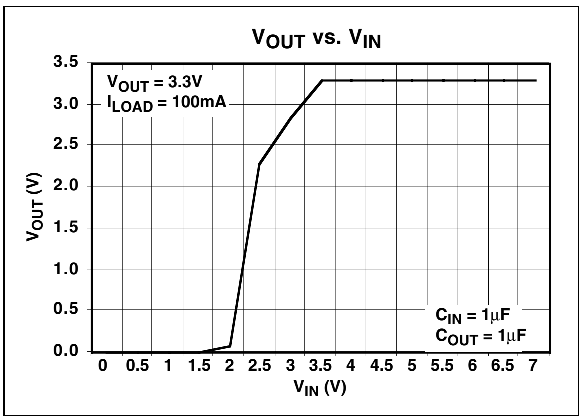


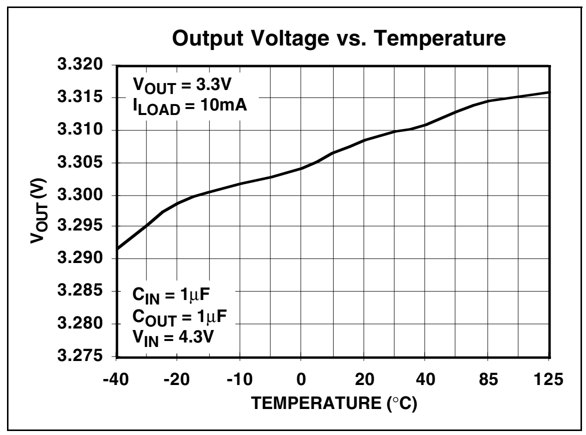
5.0 TYPICAL CHARACTERISTICS (CONTINUED)

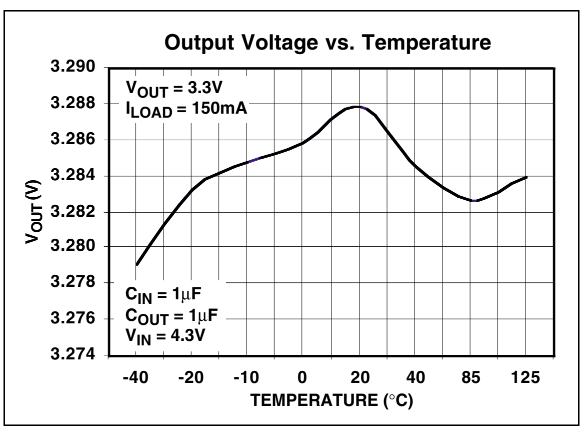
(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)





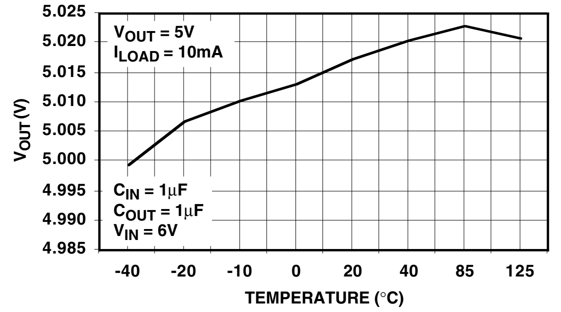




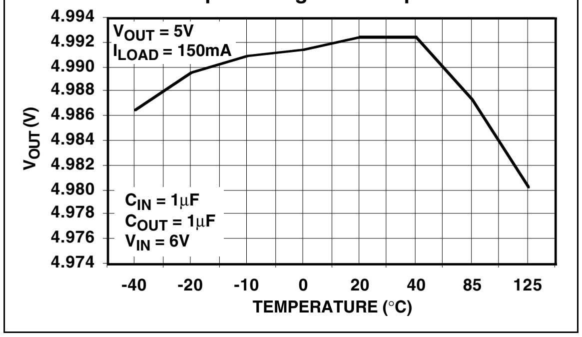


5.0 TYPICAL CHARACTERISTICS (CONTINUED)

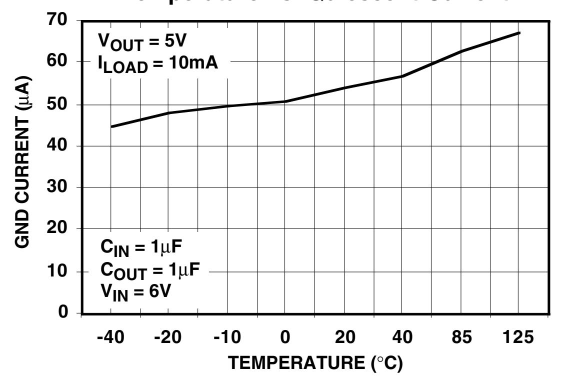
(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)



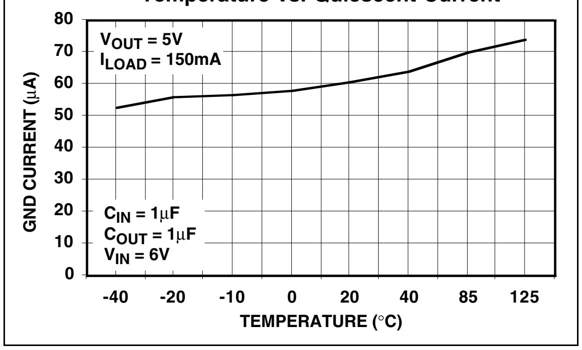
Output Voltage vs. Temperature



Output Voltage vs. Temperature

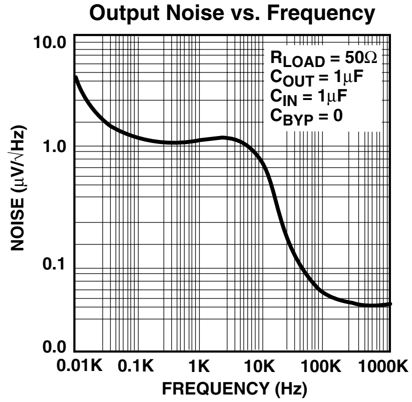


Temperature vs. Quiescent Current

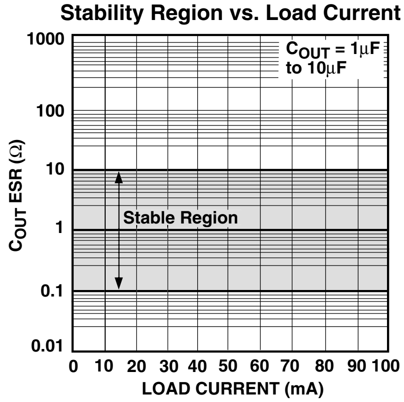


Temperature vs. Quiescent Current

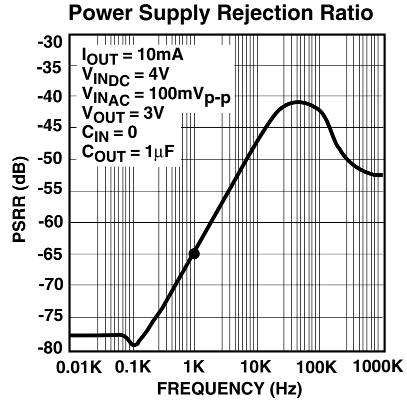
Output Noise vs. Frequency



Stability Region vs. Load Current



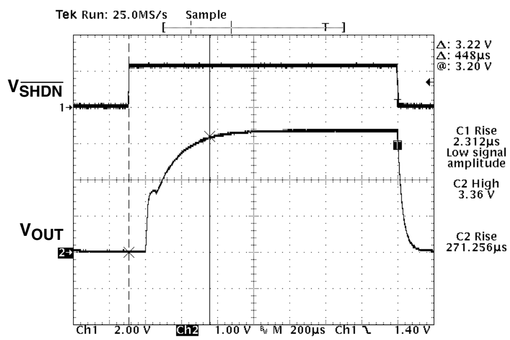
Power Supply Rejection Ratio



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

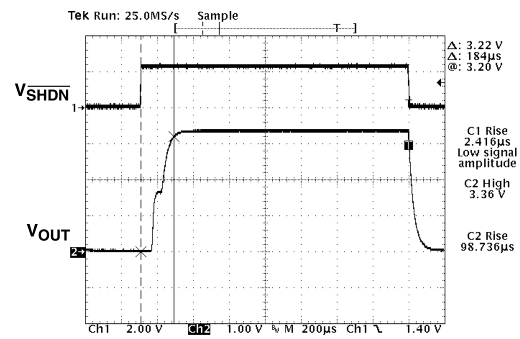
Measure Rise Time of 3.3V LDO With Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Rise Time = 448µS



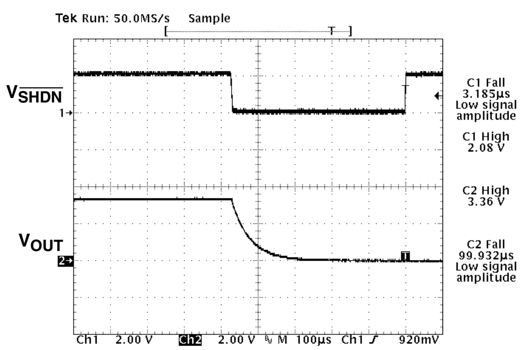
Measure Rise Time of 3.3V LDO Without Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Rise Time = 184µS



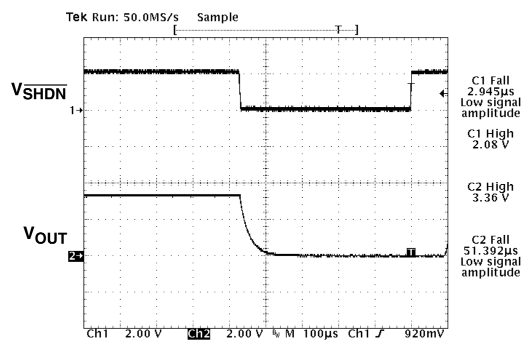
Measure Fall Time of 3.3V LDO With Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 50mA
V_{IN} = 4.3V, Temp = 25°C, Fall Time = 100µS



Measure Fall Time of 3.3V LDO Without Bypass Capacitor

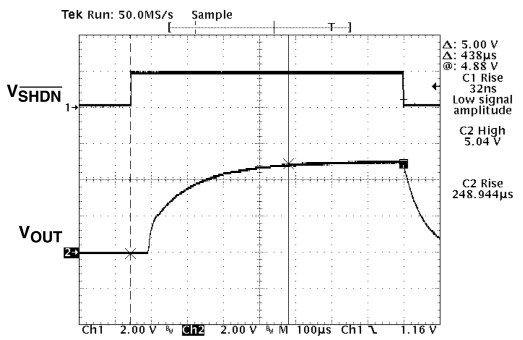
Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Fall Time = 52µS



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

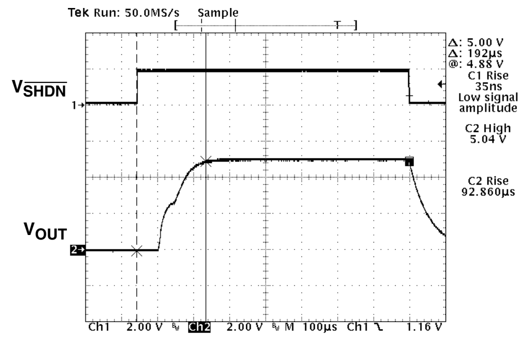
Measure Rise Time of 5.0V LDO With Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Rise Time = 390µS



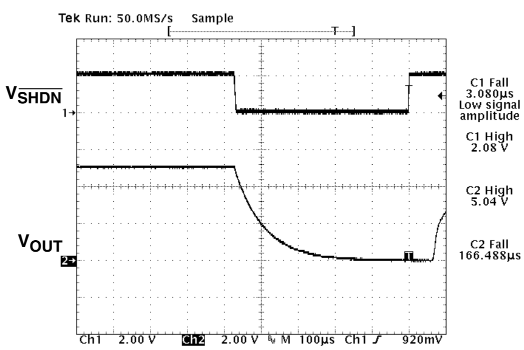
Measure Rise Time of 5.0V LDO Without Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Rise Time = 192µS



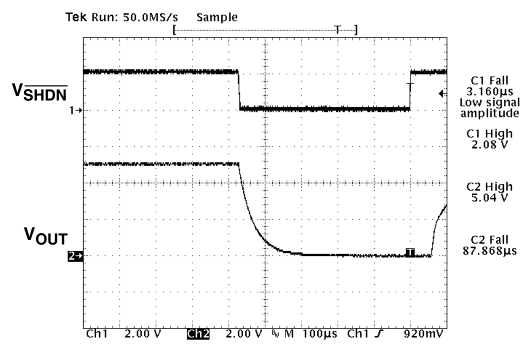
Measure Fall Time of 5.0V LDO With Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 50mA
V_{IN} = 6V, Temp = 25°C, Fall Time = 167µS



Measure Fall Time of 5.0V LDO Without Bypass Capacitor

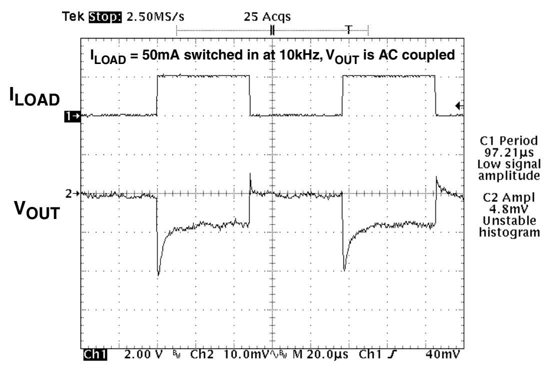
Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Fall Time = 88µS



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

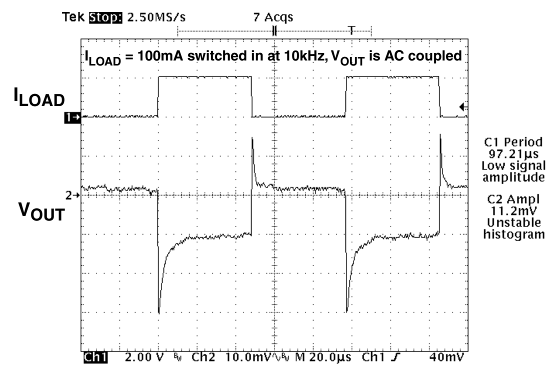
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1µF, C_{OUT} = 2.2µF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



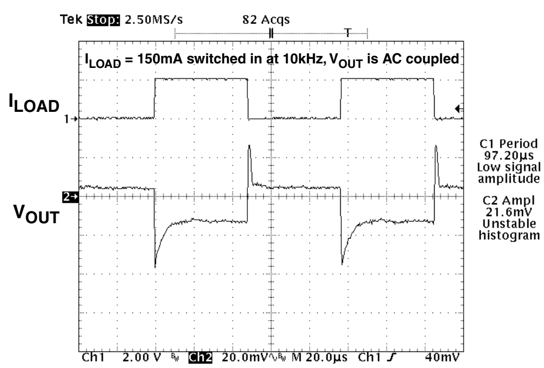
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1µF, C_{OUT} = 2.2µF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



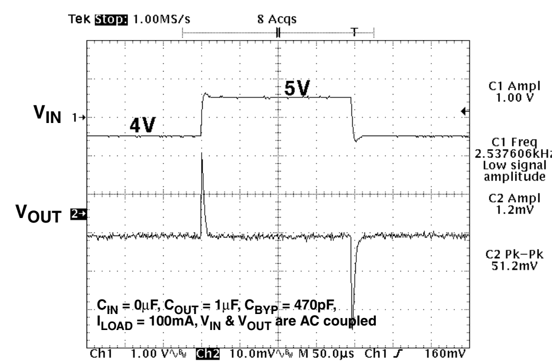
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1µF, C_{OUT} = 2.2µF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



Line Regulation of 3.3V LDO

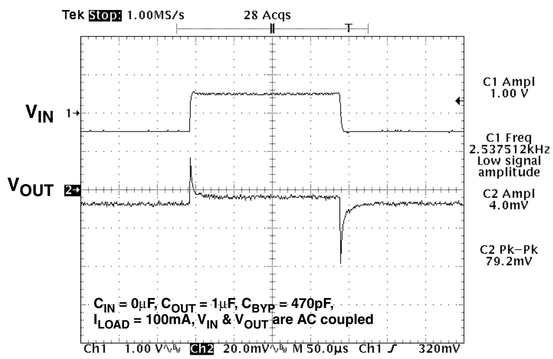
Conditions: V_{IN} = 4V, + 1V Squarewave @2.5kHz



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

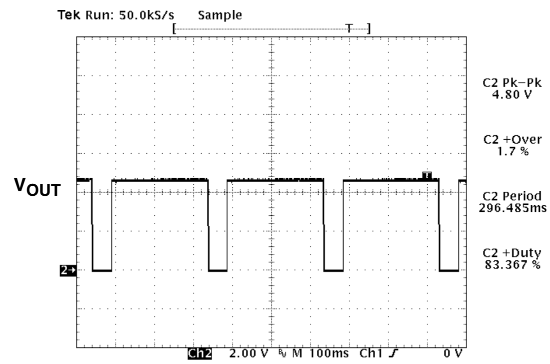
Line Regulation of 5.0V LDO

Conditions: V_{IN} = 6V, + 1V Squarewave @2.5kHz



Thermal Shutdown Response of 5.0V LDO

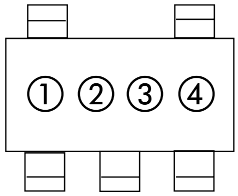
Conditions: V_{IN} = 6V, C_{IN} = 0µF, C_{OUT} = 1µF



I_{LOAD} was increased until temperature of die reached about 160°C, at which time integrated thermal protection circuitry shuts the regulator off when die temperature exceeds approximately 160°C. The regulator remains off until die temperature drops to approximately 150°C.

6.0 PACKAGING INFORMATION

6.1 Package Marking Information



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

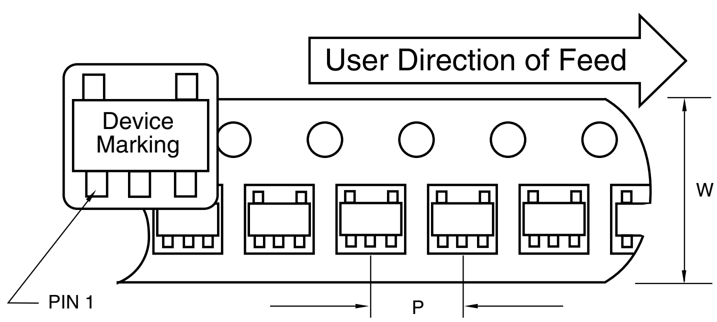
(V)	TC1014 Code	TC1015 Code	TC1185 Code
1.8	AY	BY	NY
2.5	A1	B1	N1
2.6	NB	BT	NT
2.7	A2	B2	N2
2.8	AZ	BZ	NZ
2.85	A8	B8	N8
3.0	A3	B3	N3
3.3	A5	B5	N5
3.6	A9	B9	N9
4.0	A0	B0	N0
5.0	A7	B7	N7

"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



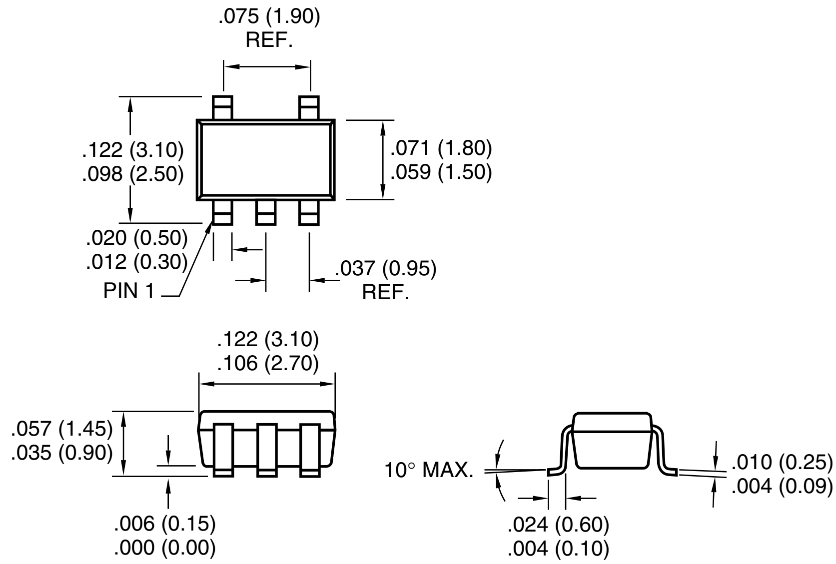
Standard Reel Component Orientation
TR Suffix Device
(Mark Right Side Up)

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

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:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site (www.microchip.com)

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

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