TC1070/TC1071/TC1187

50mA, 100mA and 150mA Adjustable CMOS LDOs with Shutdown

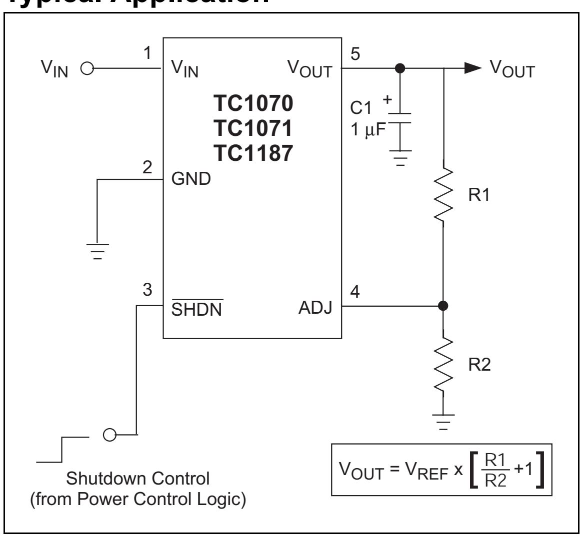
Features:

- 50 µA Ground Current for Longer Battery Life
- Adjustable Output Voltage
- Very Low Dropout Voltage
- Choice of 50 mA (TC1070), 100 mA (TC1071) and 150 mA (TC1187) Output
- Power-Saving Shutdown Mode
- Over Current and Over Temperature Protection
- Space-Saving 5-Pin SOT-23 Package
- Pin Compatible with Bipolar Regulators

Applications:

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

Typical Application



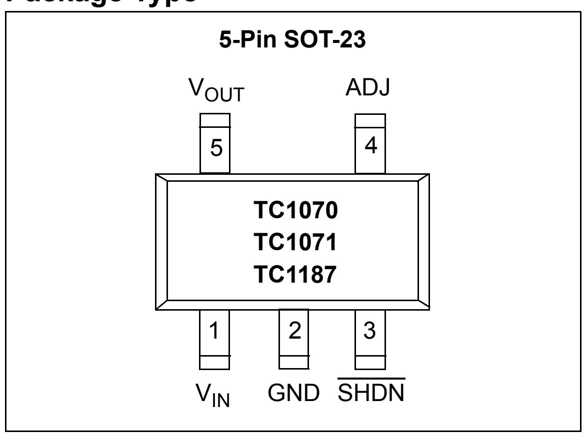
General Description:

The TC1070, TC1071 and TC1187 are adjustable LDOs designed to supersede a variety of older (bipolar) voltage regulators. Total supply current is typically 50 µA at full load (20 to 60 times lower than in bipolar regulators).

The devices' key features include ultra low-noise operation, very low dropout voltage – typically 85 mV (TC1070); 180 mV (TC1071); and 270 mV (TC1187) at full load, and fast response to step changes in load. Supply current is reduced to 0.5 µA (maximum) when the shutdown input is low. The devices incorporate both over-temperature and over-current protection. Output voltage is programmed with a simple resistor divider from V_{OUT} to ADJ to GND.

The TC1070, TC1071 and TC1187 are stable with an output capacitor of only 1 µF and have a maximum output current of 50 mA, 100 mA and 150 mA, respectively. For higher output versions, please see the TC1174 (I_{OUT} = 300 mA) data sheet.

Package Type



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 5)**
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.

ELECTRICAL SPECIFICATIONS

Electrical Characteristics: $V_{IN} = V_{OUT}$ + 1V, I_L = 0.1 mA, C_L = 3.3 µF, $\overline{SHDN} > V_{IH}$, 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
V_{IN}	Input Operating Voltage	**2.7**	—	**6.0**	V	**Note 6**
I_{OUTMAX}	Maximum Output Current	**50** **100** **150**	— — —	— — —	mA	TC1070 TC1071 TC1187
V_{OUT}	Adjustable Output Voltage Range	V_{REF}	—	5.5	V	
V_{REF}	Reference Voltage	**1.165**	1.20	**1.235**	V	
$\Delta V_{REF}/\Delta T$	V_{REF} Temperature Coefficient	—	**40**	—	ppm/°C	**Note 1**
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	—	0.05	**0.35**	%	$(V_R + 1V) \le V_{IN} \le 6V$
$\Delta V_{OUT}/V_{OUT}$	Load Regulation TC1070; TC1071 TC1187	— —	0.5 0.5	**2** **3**	%	I_L = 0.1 mA to I_{OUTMAX} I_L = 0.1 mA to I_{OUTMAX} **(Note 2)**
$V_{IN}-V_{OUT}$	Dropout Voltage TC1071; TC1187 TC1187	— — — — —	2 65 85 180 270	— — **120** **250** **400**	mV	I_L = 0.1 mA I_L = 20 mA I_L = 50 mA I_L = 100 mA I_L = 150 mA **(Note 3)**
I_{IN}	Supply Current	—	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	$F_{RE} \le$ 1 kHz
I_{OUTSC}	Output Short Circuit Current	—	300	450	mA	V_{OUT} = 0V
$\Delta V_{OUT}/\Delta P_D$	Thermal Regulation	—	0.04	—	V/W	**Note 4**
T_{SD}	Thermal Shutdown Die Temperature	—	160	—	°C	
ΔT_{SD}	Thermal Shutdown Hysteresis	—	10	—	°C	
eN	Output Noise	—	260	—	nV/√Hz	$I_L = I_{OUTMAX}$
$\overline{SHDN}$ Input						
V_{IH}	$\overline{SHDN}$ Input High Threshold	**45**	—	—	%V_{IN}	V_{IN} = 2.5V to 6.5V

Note 1: $TC\ V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$

2: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1 mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

3: Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value.

4: 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 ms.

5: 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 5.0 "Thermal Considerations"** for more details.

6: The minimum V_{IN} has to justify the conditions: $V_{IN} \ge V_R + V_{DROPOUT}$ and $V_{IN} \ge$ 2.7V for I_L = 0.1 mA to I_{OUTMAX}.

ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: $V_{IN} = V_{OUT} + 1V$, $I_L = 0.1$ mA, $C_L = 3.3$ µF, $\overline{SHDN} > V_{IH}$, $T_A = 25°C$, unless otherwise noted. **Boldface** type specifications apply for junction temperatures of -40°C to +125°C.

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
V_{IL}	$\overline{SHDN}$ Input Low Threshold	—	—	**15**	$\%V_{IN}$	$V_{IN} = 2.5V$ to $6.5V$
ADJ Input						
I_{ADJ}	Adjust Input Leakage Current	—	50	—	pA	

Note 1: $TC\ V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$

2: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1 mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

3: Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value.

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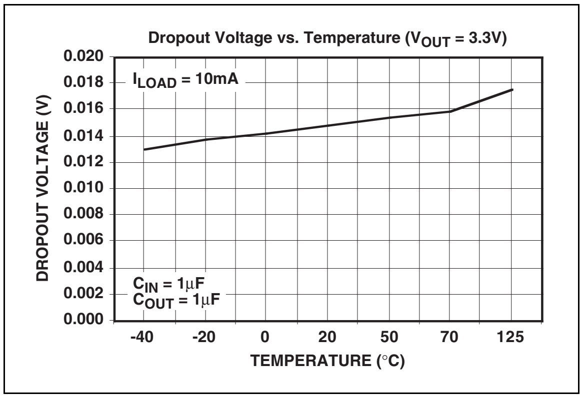
5: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction-to-air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation causes the device to initiate thermal shutdown. Please see **Section 5.0 "Thermal Considerations"** for more details.

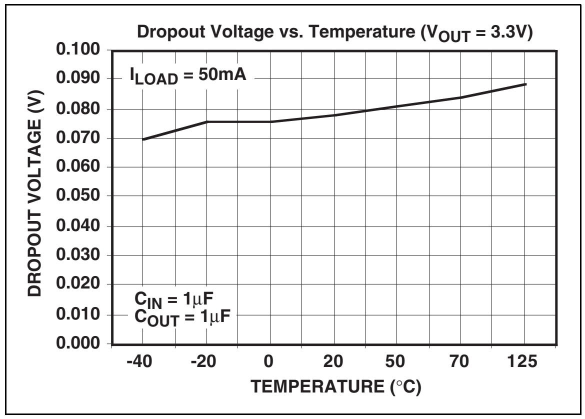
6: The minimum V_{IN} has to justify the conditions: $V_{IN} \geq V_R + V_{DROPOUT}$ and $V_{IN} \geq 2.7V$ for $I_L = 0.1$ mA to I_{OUTMAX}.

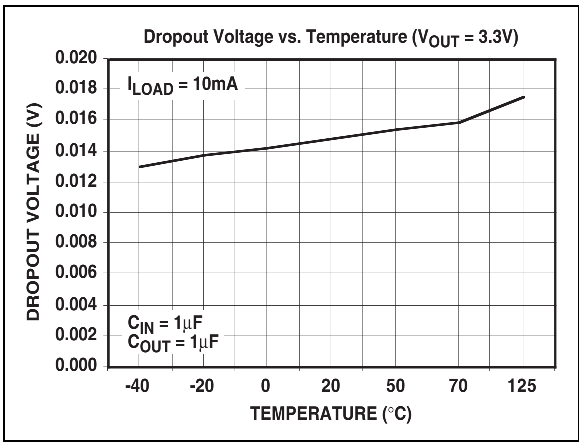
2.0 TYPICAL CHARACTERISTICS

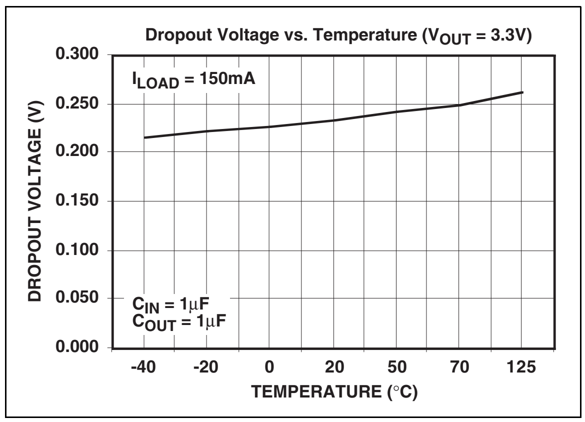
Note: Unless otherwise specified, all parts are measured at temperature = +25°C)

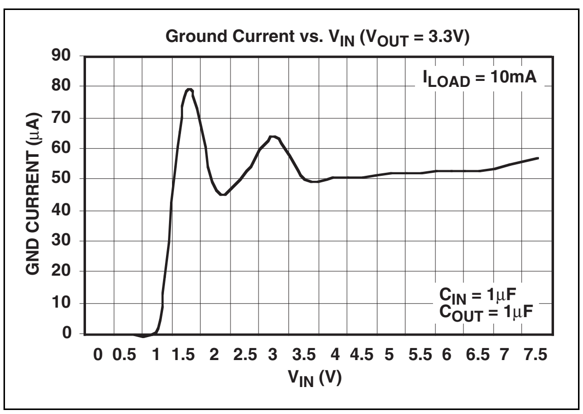
Note:	The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside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

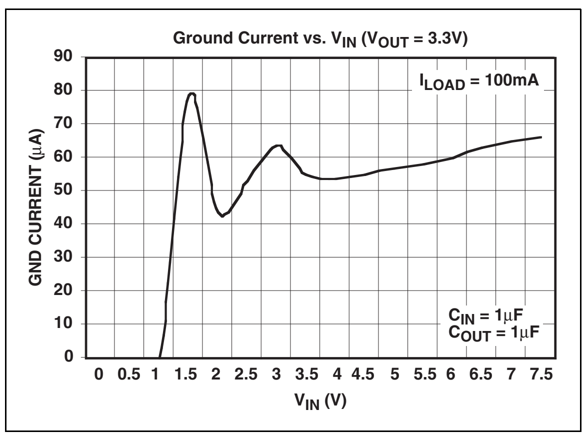






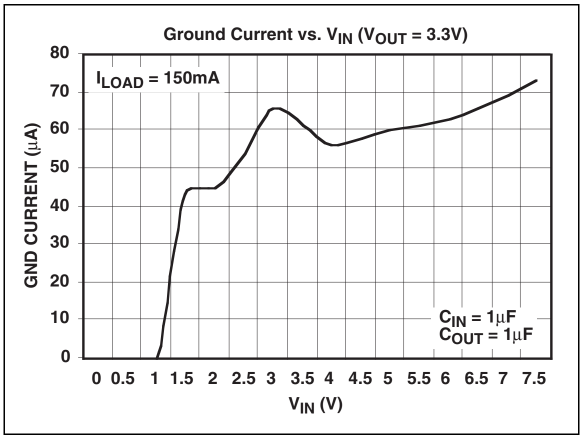


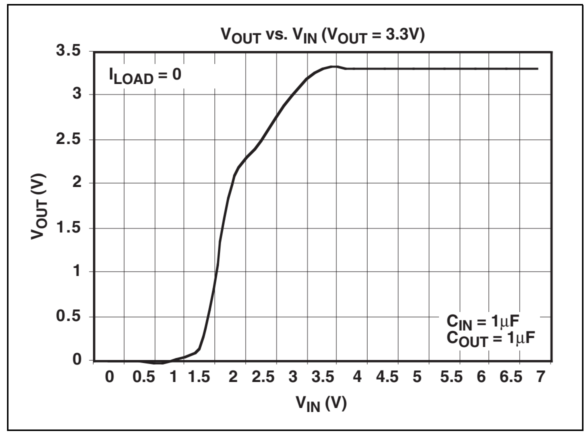


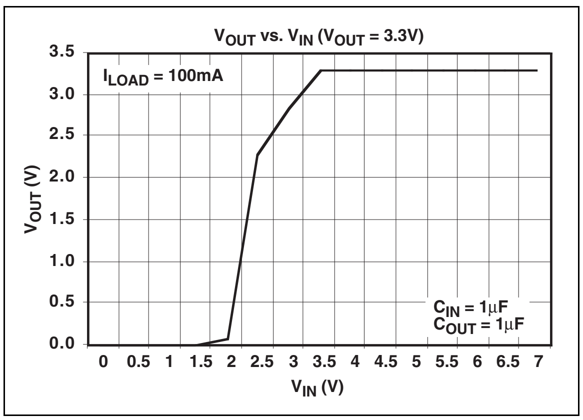


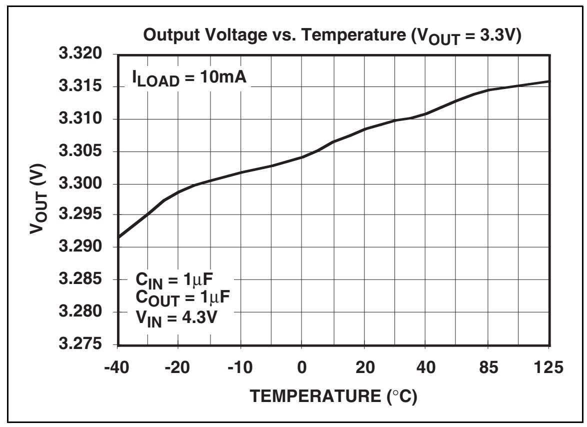
TYPICAL CHARACTERISTICS (CONTINUED)

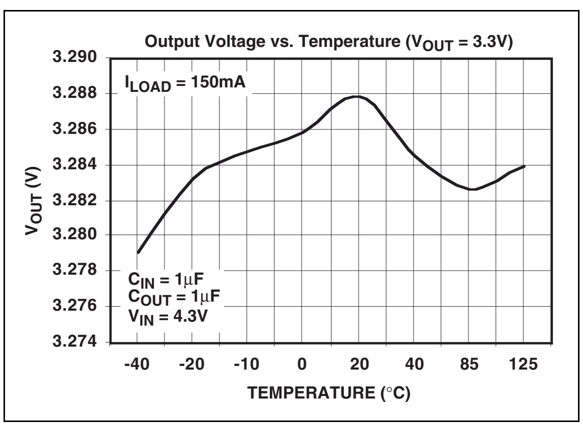
Note: Unless otherwise specified, all parts are measured at temperature = +25°C)





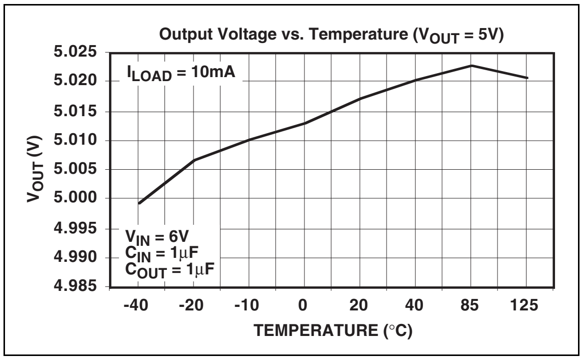


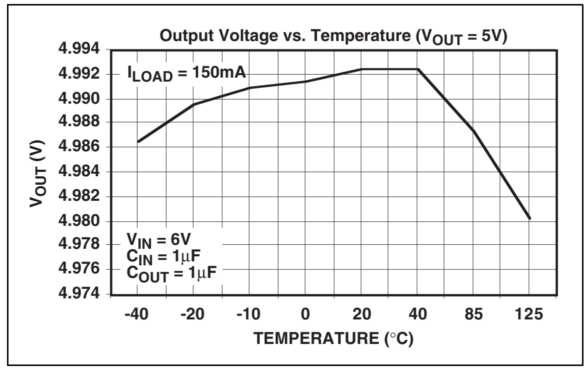


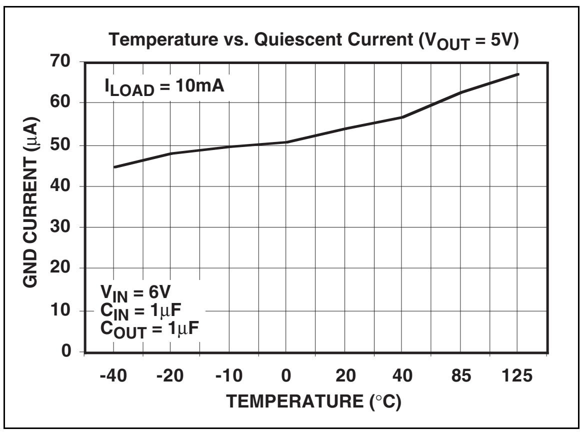


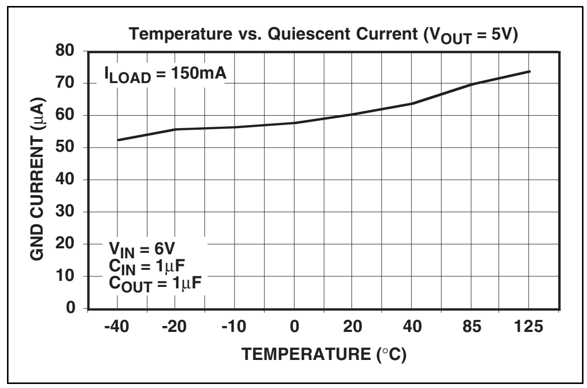
TYPICAL CHARACTERISTICS (CONTINUED)

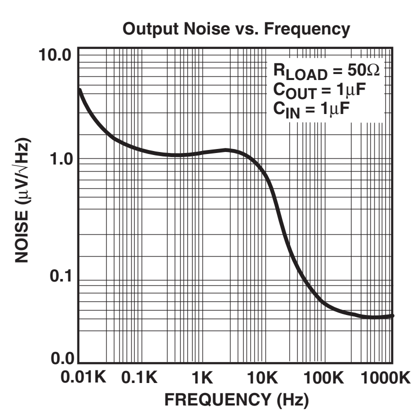
Note: Unless otherwise specified, all parts are measured at temperature = +25°C)

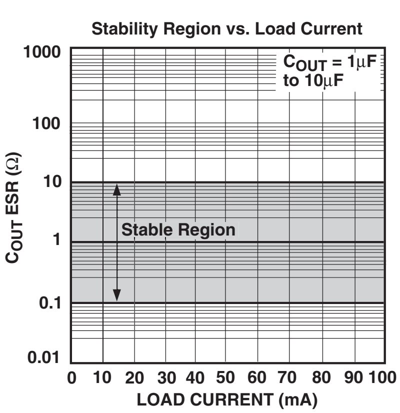


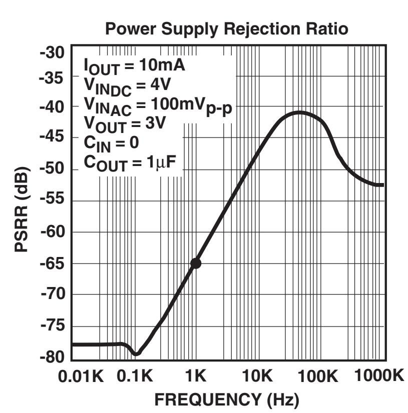










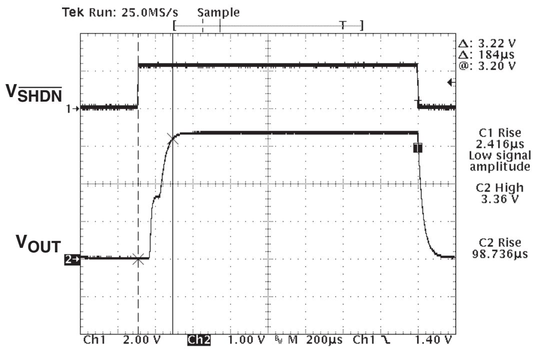


TYPICAL CHARACTERISTICS (CONTINUED)

Note: Unless otherwise specified, all parts are measured at temperature = +25°C)

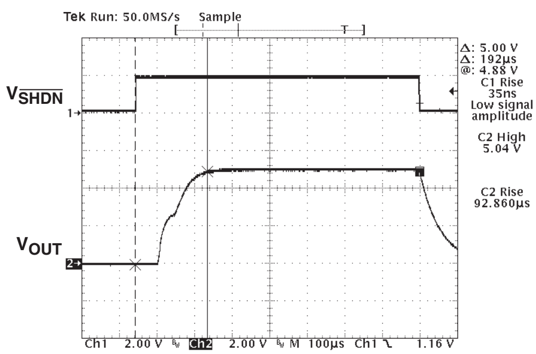
Measure Rise Time of 3.3V LDO

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



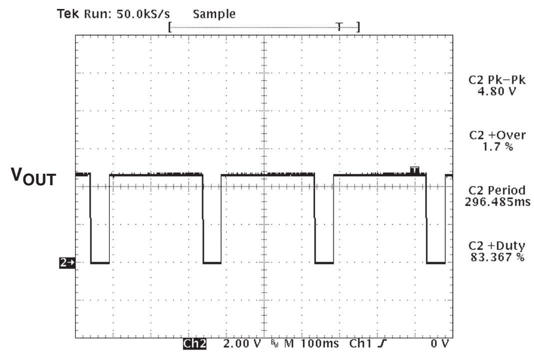
Measure Rise Time of 5.0V LDO

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



Thermal Shutdown Response of 5.0V LDO

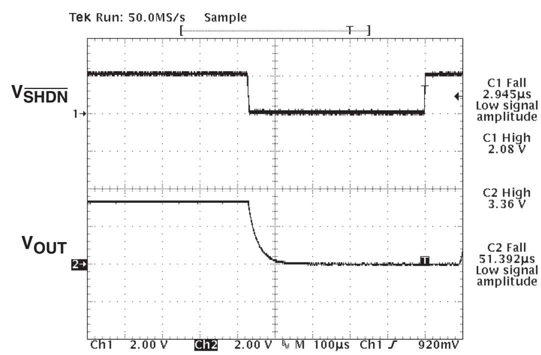
Conditions: V_{IN} = 6V, C_{IN} = 0µF, C_{OUT} = 1µF



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.

Measure Fall Time of 3.3V LDO

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

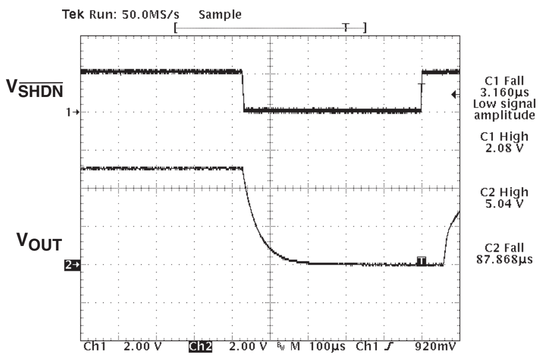


TYPICAL CHARACTERISTICS (CONTINUED)

Note: Unless otherwise specified, all parts are measured at temperature = +25°C)

Measure Fall Time of 5.0V LDO

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



3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin No. (5-Pin SOT-23)	Symbol	Description
1	V_{IN}	Unregulated supply input.
2	GND	Ground terminal.
3	$\overline{SHDN}$	Shutdown control input.
4	ADJ	Output voltage adjust terminal.
5	V_{OUT}	Regulated voltage output.

3.1 Input Voltage Supply (V_{IN})

Connect unregulated input supply to the V_{IN} pin. If there is a large distance between the input supply and the LDO regulator, some input capacitance is necessary for proper operation. A 1 µF capacitor connected from V_{IN} to ground is recommended for most applications.

3.2 Ground (GND)

Connect the unregulated input supply ground return to GND. Also connect the negative side of the 1 µF typical input decoupling capacitor close to GND and the negative side of the output capacitor C_1 to GND.

3.3 Shutdown Control Input ($\overline{SHDN}$)

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 0.5 µA (maximum).

3.4 Output Voltage Adjust (ADJ)

Output voltage setting is programmed with a resistor divider from V_{OUT} to this input. A capacitor may also be added to this input to reduce output noise (see **Section 4.2 "Output Capacitor"**).

3.5 Regulated Voltage Output (V_{out})

Connect the output load to V_{OUT} of the LDO. Also connect the positive side of the LDO output capacitor as close as possible to the V_{OUT} pin.

4.0 DETAILED DESCRIPTION

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

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

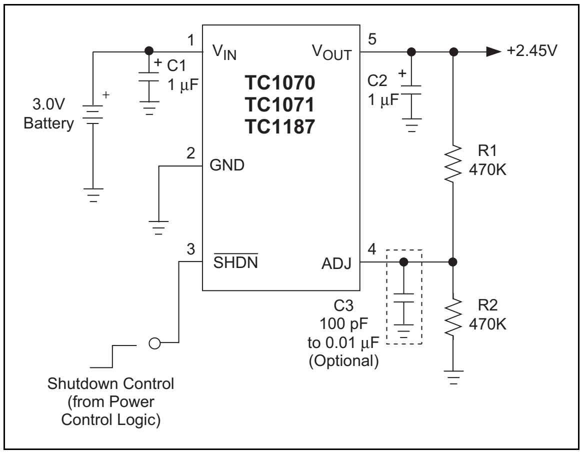


FIGURE 4-1: *Battery-Operated Supply*

4.1 Adjust Input

The output voltage setting is determined by the values of R_1 and R_2 (Equation 4-1). The ohmic values of these resistors should be between 470K and 3M to minimize bleeder current.

The output voltage setting is calculated using the following equation.

EQUATION 4-1:

$$V_{OUT} = V_{REF}\, x \left[\frac{R1}{R2} + 1 \right]$$

The voltage adjustment range of the TC1070, TC1071 and TC1187 is from V_{REF} to (V_{IN} – 0.05V). If so desired, a small capacitor (10 pF to 0.01 µF) may be added to the ADJ input to further reduce output noise.

4.2 Output Capacitor

A 1 µF (minimum) capacitor from V_{OUT} to ground is recommended. The output capacitor should have an effective series resistance greater than 0.1Ω and less than 5.0Ω, and a resonant frequency above 1 MHz. A 1 µF 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.

5.0 THERMAL CONSIDERATIONS

5.1 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.

5.2 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 5-1:

$$P_D \approx (V_{INmax} - V_{OUTmin}) I_{LOADmax}$$

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-23 package has a θ_{JA} of approximately 220° C/Watt.

EQUATION 5-2:

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

where all terms are previously defined.

Equation 5-1 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%
$I_{LOADMAX}$ = 40 mA
T_{JMAX} = 125°C
T_{AMAX} = 55°C

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

Actual power dissipation:

$P_D \approx (V_{INMAX} - V_{OUTMIN}) I_{LOADMAX}$
$= [(3.0 \times 1.10) - (2.7 \times .0.98)]40 \times 10^{-3}$
$= 26.2$ mW

Maximum allowable power dissipation:

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

In this example, the TC1070 dissipates a maximum of 26.2 mW which is below the allowable limit of 318 mW. In a similar manner, Equation 5-1 and Equation 5-2 can be used to calculate maximum current and/or input voltage limits.

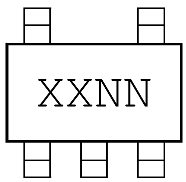
5.3 Layout Considerations

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.

6.0 PACKAGING INFORMATION

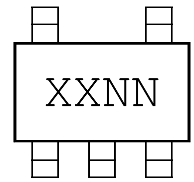
6.1 Package Marking Information

5-Lead SOT-23-5



(V)	TC1070 Code	TC1071 Code	TC1187 Code
Adjustable	BANN	BBNN	R9NN

Example:

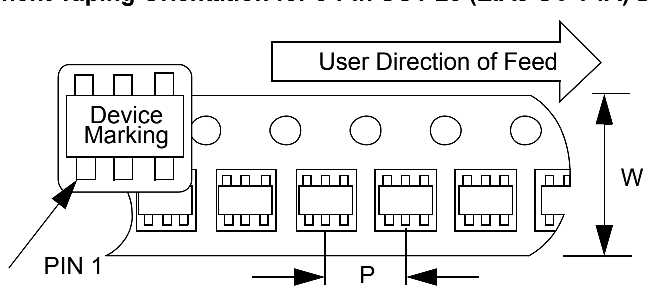


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

6.2 Taping Form

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



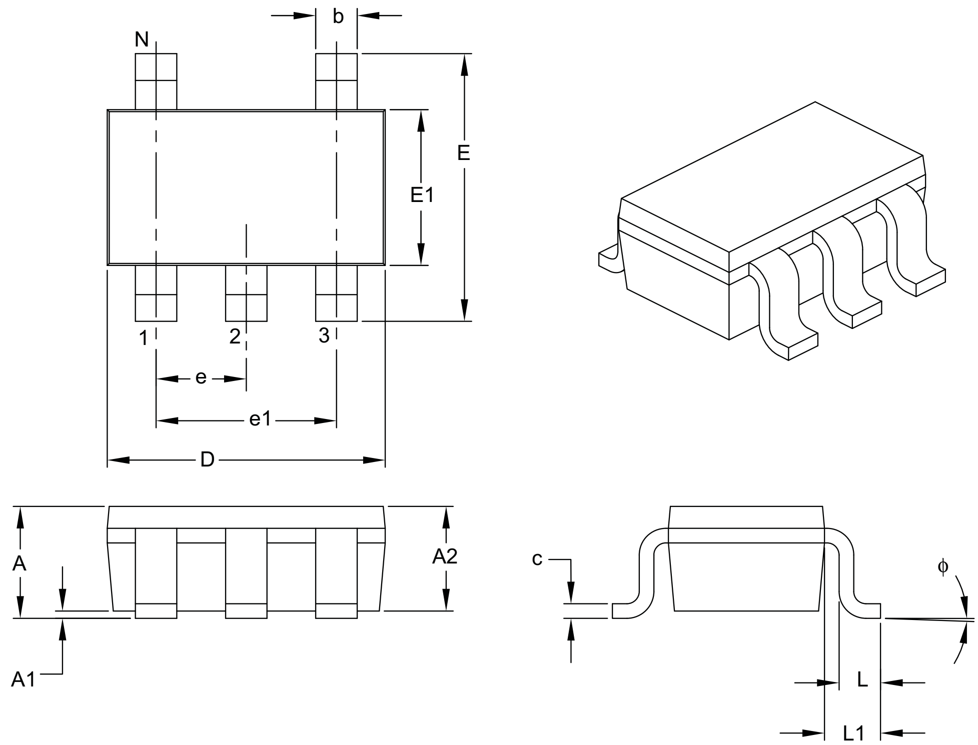
Standard Reel Component Orientation
for TR Suffix Device
(Mark Right Side Up)

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

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

5-Lead Plastic Small Outline Transistor (OT) [SOT-23]

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



	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Number of Pins	N	5		
Lead Pitch	e	0.95 BSC		
Outside Lead Pitch	e1	1.90 BSC		
Overall Height	A	0.90	–	1.45
Molded Package Thickness	A2	0.89	–	1.30
Standoff	A1	0.00	–	0.15
Overall Width	E	2.20	–	3.20
Molded Package Width	E1	1.30	–	1.80
Overall Length	D	2.70	–	3.10
Foot Length	L	0.10	–	0.60
Footprint	L1	0.35	–	0.80
Foot Angle	ϕ	0°	–	30°
Lead Thickness	c	0.08	–	0.26
Lead Width	b	0.20	–	0.51

Notes:
1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.127 mm per side.
2. Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-091B

APPENDIX A: REVISION HISTORY

Revision D (March 2007)

- Ground current changed to 50 µA.
- Package type changed to SOT-23.
- **Section 3.0 “Pin Descriptions”**: Added pin descriptions.
- **Section 6.0 “Packaging Information”**: Updated packaging information.

Revision C (January 2006)

- Undocumented changes.

Revision B (May 2002)

- Undocumented changes.

Revision A (March 2002)

- Original Release of this Document.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	X	XXXXX
Device	Temperature Range	Package

Device	TC1070: 50 mA, Adjustable CMOS LDO w/Shutdown TC1071: 100 mA, Adjustable CMOS LDO w/Shutdown TC1187: 150 mA, Adjustable CMOS LDO w/Shutdown	
Temperature Range	V	= -40°C to +125°C
Package	CT713 =	Plastic small outline transistor (OT) SOT-23, 5 lead, (tape and reel).

Examples:

a) TC1070VCT713: 50 mA, Adjustable 5LD SOT-23 package

b) TC1071VCT713: 100 mA, Adjustable, 5LD SOT-23 package

c) TC1187VCT713: 150 mA, Adjustable 5LD SOT-23 package

NOTES:

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- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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