TC2014/2015/2185

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

Features

- Low Supply Current: 80 µA (Max)
- Low Dropout Voltage: 140 mV (Typ.) @ 150 mA
- 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: 60 µsec (Typ.)
- Overcurrent Protection
- Space-Saving 5-Pin SOT-23A Package
- Pin-Compatible Upgrades for Bipolar Regulators
- Wide Operating Temperature Range: -40°C to +125°C

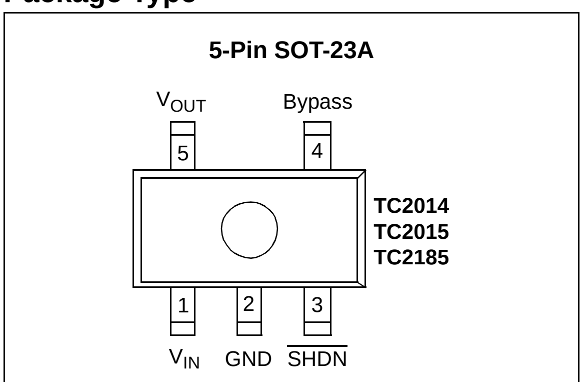
Applications

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

Related Literature

- Application Notes: AN765, AN766, AN776 and AN792

Package Type



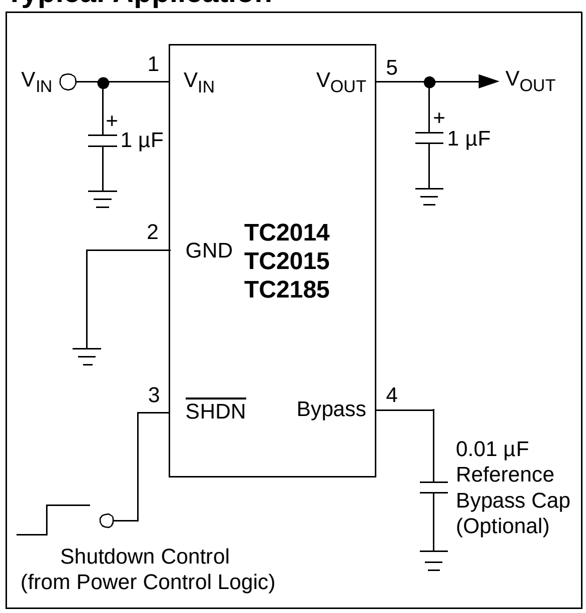
General Description

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

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

The TC2014, TC2015 and TC2185 are stable with an output capacitor of 1 µF and have maximum output currents of 50 mA, 100 mA and 150 mA, respectively. For higher-output versions, see the TC1107 (DS21356), TC1108 (DS21357) and TC1173 (DS21362) (I_{OUT} = 300 mA) data sheets.

Typical Application



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Input Voltage 7.0V
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
Maximum Junction Temperature................................. 150°C

† **Notice:** Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

PIN FUNCTION TABLE

Name	Function
V_{IN}	Unregulated Supply Input
GND	Ground Terminal
$\overline{SHDN}$	Shutdown Control Input
Bypass	Reference Bypass Input
V_{OUT}	Regulated Voltage Output

ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise specified, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$. **BOLDFACE** type specifications apply for junction temperature of -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Input Operating Voltage	V_{IN}	**2.7**	—	**6.0**	V	**Note 1**
Maximum Output Current	I_{OUTMAX}	**50**	—	—	mA	**TC2014**
		100	—	—		**TC2015**
		150	—	—		**TC2185**
Output Voltage	V_{OUT}	**V_R – 2.0%**	V_R ± 0.4%	**V_R + 2.0%**	V	**Note 2**
V_{OUT} Temperature Coefficient	TCV_{OUT}	—	20	—	ppm/°C	**Note 3**
		—	**40**	—		
Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	—	0.05	**0.5**	%	$(V_R + 1V) \le V_{IN} \le 6V$
Load Regulation **(Note 4)**	$\Delta V_{OUT}/V_{OUT}$	**-1.0**	0.33	**+1.0**	%	**TC2014**;**TC2015**: I_L = 0.1 mA to I_{OUTMAX}
		-2.0	0.43	**+2.0**		**TC2185**: I_L = 0.1 mA to I_{OUTMAX} **(Note 4)**
Dropout Voltage	$V_{IN} – V_{OUT}$	—	2	—	mV	**Note 5** I_L = 100 µA
		—	45	**70**		I_L = 50 mA
		—	90	**140**		**TC2015**; **TC2185** I_L = 100 mA
		—	140	**210**		**TC2185** I_L = 150 mA
Supply Current	I_{IN}	—	55	**80**	µA	$\overline{SHDN} = V_{IH}$, $I_L = 0$

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 1.0 mA 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.
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 = 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}).
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}.

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise specified, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$. **BOLDFACE** type specifications apply for junction temperature of -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Shutdown Supply Current	I_{INSD}	—	0.05	0.5	µA	$\overline{SHDN}$ = 0V
Power Supply Rejection Ratio	PSRR	—	55	—	dB	F ≤ 1 kHz, Cbypass = 0.01 µF
Output Short Circuit Current	I_{OUTSC}	—	160	300	mA	V_{OUT} = 0V
Thermal Regulation	$\Delta V_{OUT}/\Delta P_D$	—	0.04	—	V/W	**Note 6**, **Note 7**
Output Noise	eN	—	200	—	nV/√Hz	$I_L = I_{OUTMAX}$, F = 10 kHz 470 pF from Bypass to GND
Response Time, **(Note 8)** (from Shutdown Mode)	T_R	—	60	—	µsec	V_{IN} = 4V, I_L = 30 mA, C_{IN} = 1 µF, C_{OUT} = 10 µF
$\overline{SHDN}$ Input						
$\overline{SHDN}$ Input High Threshold	V_{IH}	**60**	—	—	$\%V_{IN}$	V_{IN} = 2.5V to 6.0V
$\overline{SHDN}$ Input Low Threshold	V_{IL}	—	—	**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:

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

4: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 1.0 mA 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.

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 = 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}).

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 TYPICAL PERFORMANCE CURVES

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.

Note: Unless otherwise indicated, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$.

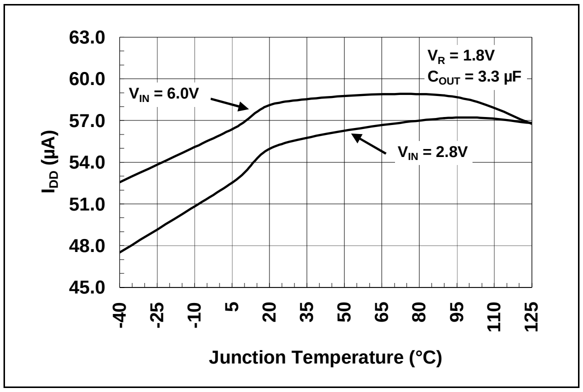


FIGURE 2-1: *Supply Current vs. Junction Temperature.*

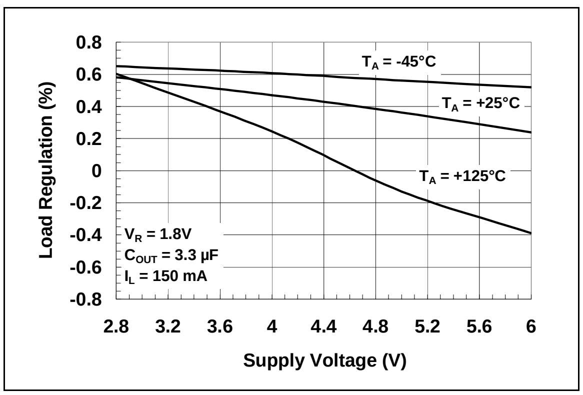


FIGURE 2-2: *Load Regulation vs. Supply Voltage.*

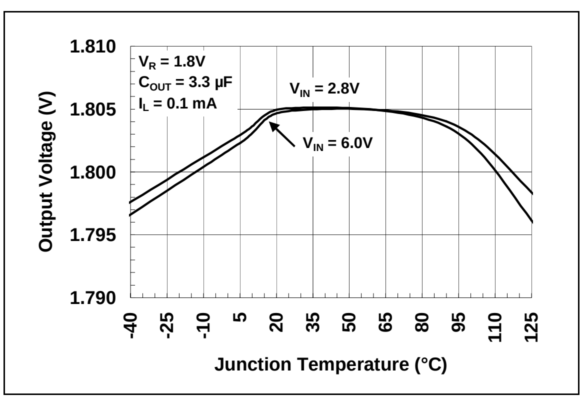


FIGURE 2-3: *Output Voltage vs. Junction Temperature.*

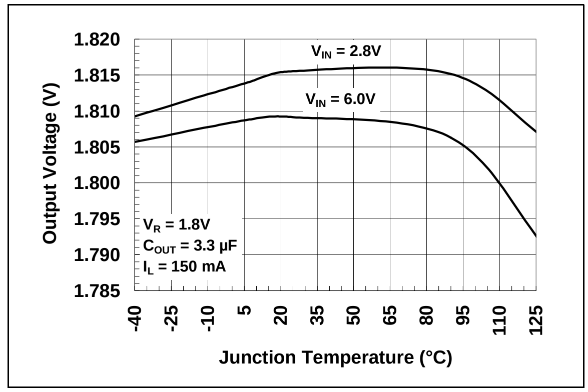


FIGURE 2-4: *Output Voltage vs. Junction Temperature.*

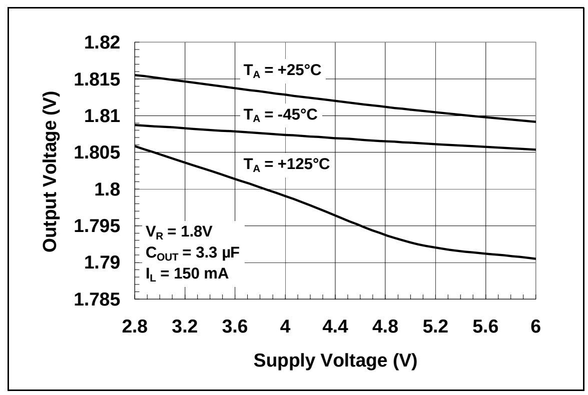


FIGURE 2-5: *Output Voltage vs. Supply Voltage.*

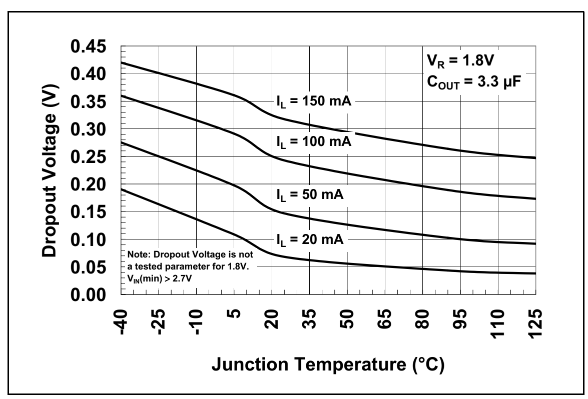


FIGURE 2-6: *Dropout Voltage vs. Junction Temperature.*

Note: Unless otherwise indicated, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$.

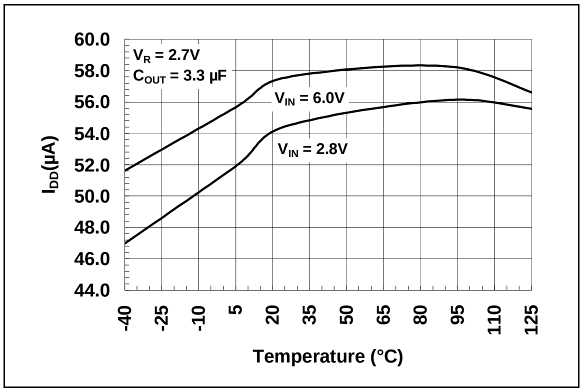


FIGURE 2-7: *Supply Current vs. Junction Temperature.*

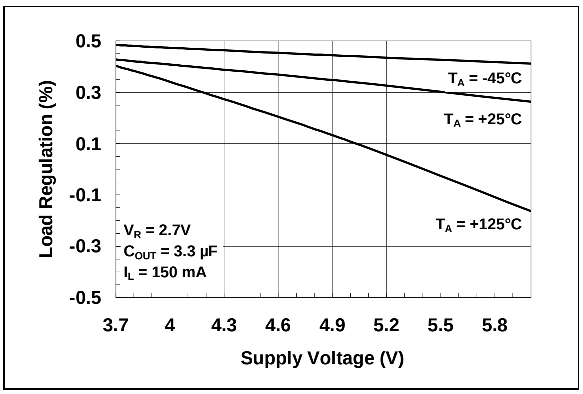


FIGURE 2-8: *Load Regulation vs. Supply Voltage.*

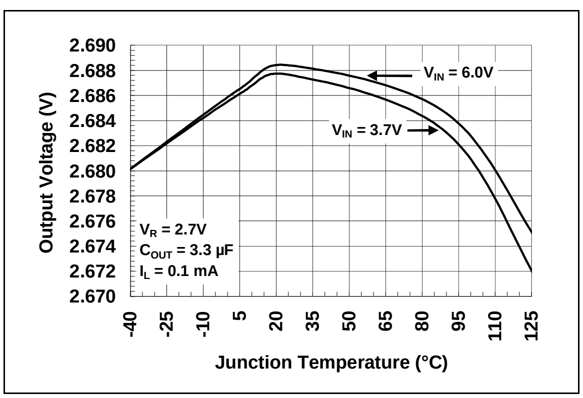


FIGURE 2-9: *Output Voltage vs. Junction Temperature.*

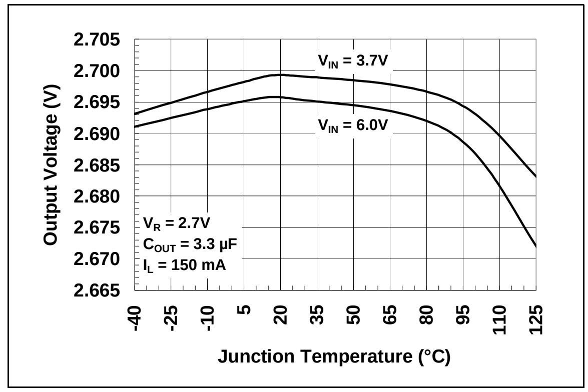


FIGURE 2-10: *Output Voltage vs. Junction Temperature.*

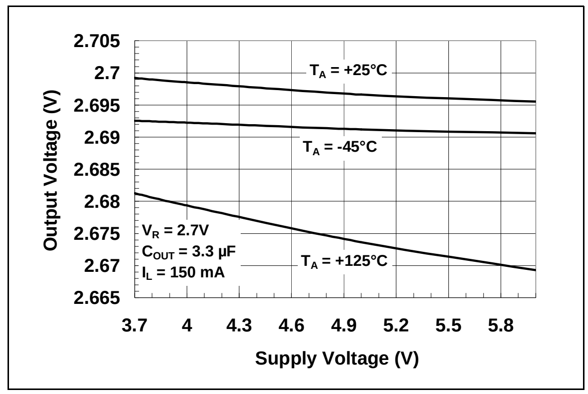


FIGURE 2-11: *Output Voltage vs. Supply Voltage.*

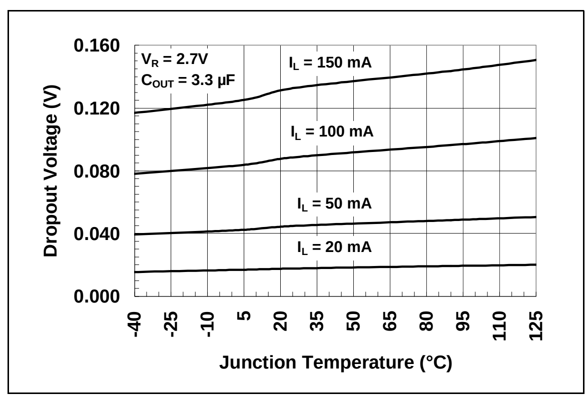


FIGURE 2-12: *Dropout Voltage vs. Junction Temperature.*

Note: Unless otherwise indicated, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$.

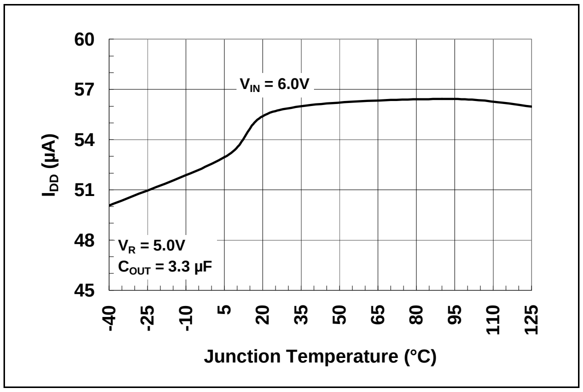


FIGURE 2-13: *Supply Current vs. Junction Temperature.*

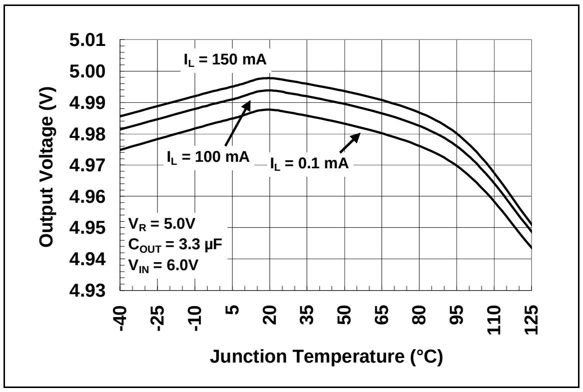


FIGURE 2-14: *Output Voltage vs. Junction Temperature.*

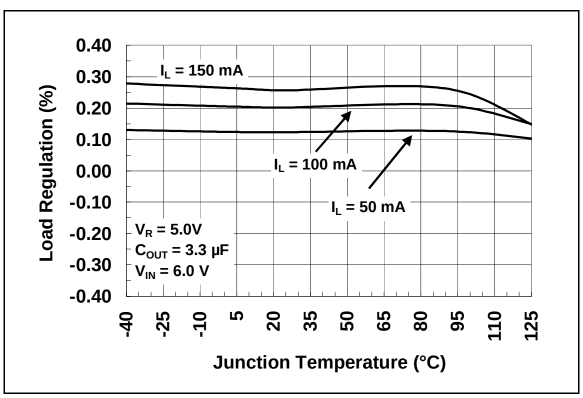


FIGURE 2-15: *Load Regulation vs. Junction Temperature.*

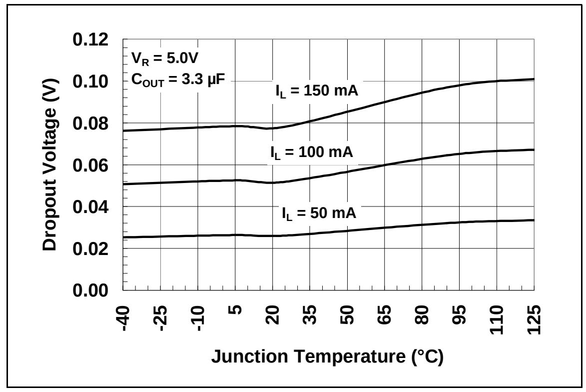


FIGURE 2-16: *Dropout Voltage vs. Junction Temperature.*

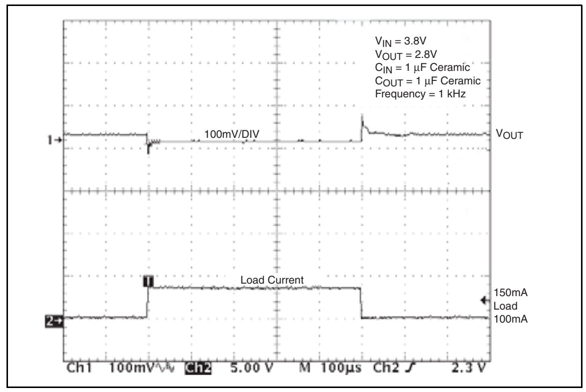


FIGURE 2-17: *Load Transient Response. (C_{OUT} = 1 µF).*

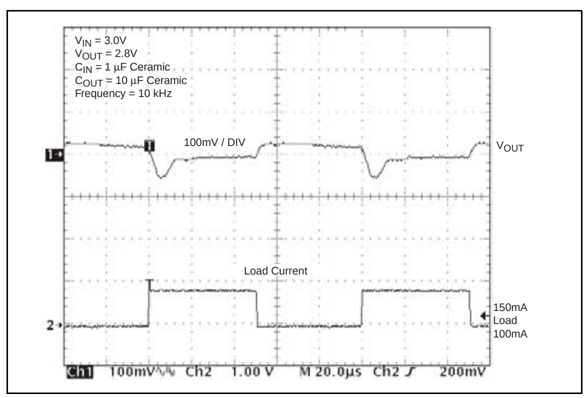


FIGURE 2-18: *Load Transient Response. (C_{OUT} = 10 µF).*

Note: Unless otherwise indicated, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$.

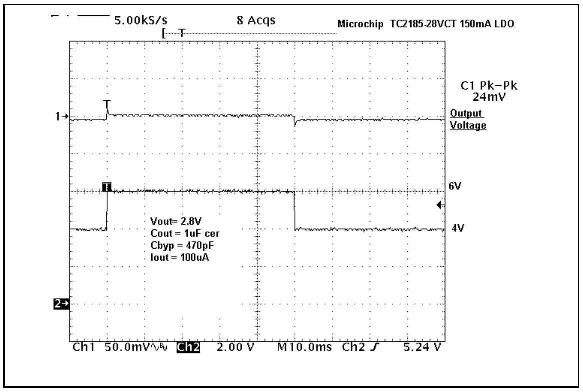


FIGURE 2-19: Line Transient Response. (C_{OUT} = 1 µF).

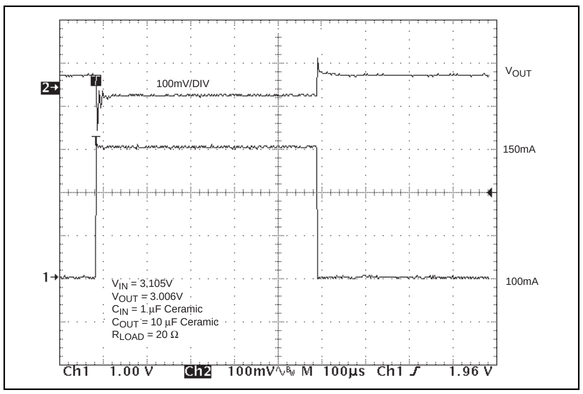


FIGURE 2-20: Load Transient Response in Dropout. (C_{OUT} = 10 µF).

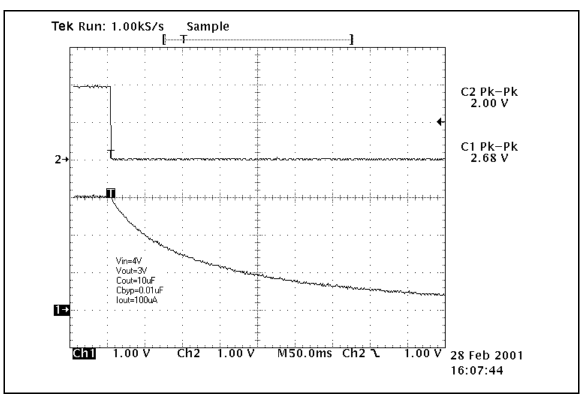


FIGURE 2-21: Shutdown Delay Time.

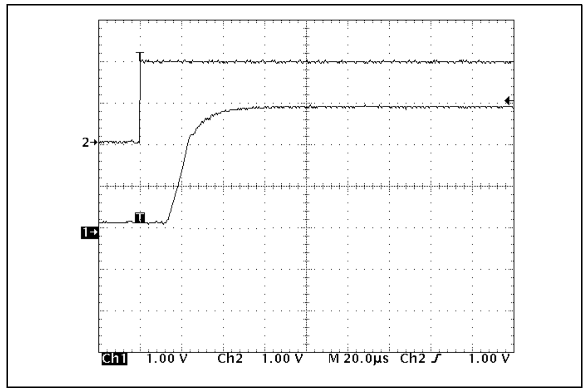


FIGURE 2-22: Wake-Up Response.

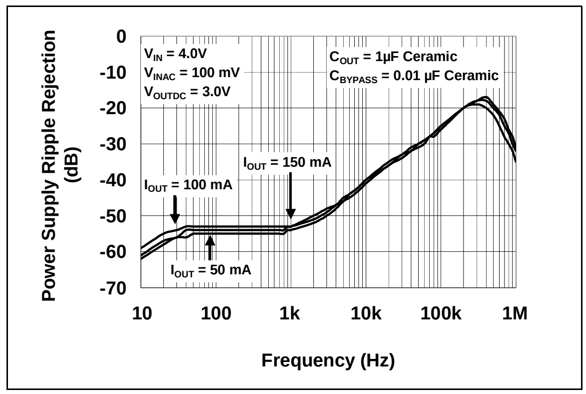


FIGURE 2-23: PSRR vs. Frequency (C_{OUT} = 1 µF Ceramic).

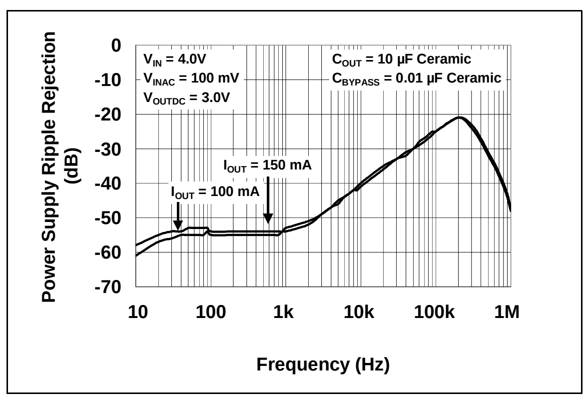


FIGURE 2-24: PSRR vs. Frequency (C_{OUT} = 10 µF Ceramic).

Note: Unless otherwise indicated, $V_{IN} = V_R + 1V$, $I_L = 100\ \mu A$, $C_{OUT} = 3.3\ \mu F$, $\overline{SHDN} > V_{IH}$, $T_A = +25°C$.

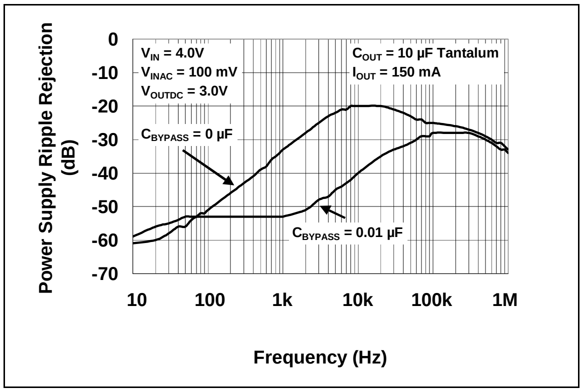


FIGURE 2-25: *PSRR vs. Frequency (C_{OUT} = 10 µF Tantalum).*

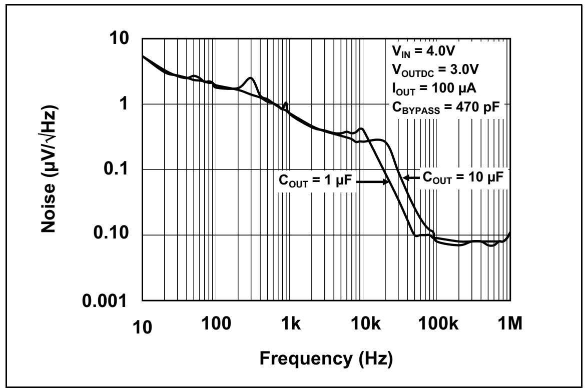


FIGURE 2-26: *Output Noise vs. Frequency.*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin No.	Symbol	Description
1	V_{IN}	Unregulated supply input
2	GND	Ground terminal
3	$\overline{SHDN}$	Shutdown control input
4	Bypass	Reference bypass input
5	V_{OUT}	Regulated voltage output

3.1 Unregulated Supply Input (V_{IN})

Connect the 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 Terminal (GND)

Connect the unregulated input supply ground return to GND. Also connect one side of the 1 µF typical input decoupling capacitor close to this pin and one side of the output capacitor C_{OUT} to this pin.

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

The regulator is fully enabled when a logic-high is applied to $\overline{SHDN}$. The regulator enters shutdown when a logic-low is applied to this input. During shutdown, the output voltage falls to zero and the supply current is reduced to 0.5 µA (max).

3.4 Reference Bypass Input (Bypass)

Connecting a low-value ceramic capacitor to Bypass will further reduce output voltage noise and improve the Power Supply Ripple Rejection (PSRR) performance of the LDO. Typical values from 470 pF to 0.01 µF are suggested. While smaller and larger values can be used, these affect the speed at which the LDO output voltage rises when input power is applied. The larger the bypass capacitor, the slower the output voltage will rise.

3.5 Regulated Voltage Output (V_{OUT})

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

4.0 DETAILED DESCRIPTION

The TC2014, TC2015 and TC2185 are precision fixed-output voltage regulators (if an adjustable version is needed, see the TC1070, TC1071 and TC1187 (DS21353) data sheet). Unlike bipolar regulators, the TC2014, TC2015 and TC2185 supply current does not increase with load current. In addition, the LDO's output voltage is stable using 1 µF of ceramic or tantalum capacitance over the entire specified input voltage range and output current range.

Figure 4-1 shows a typical application circuit. The regulator is enabled anytime the shutdown input ($\overline{SHDN}$) is at or above V_{IH}, and disabled (shutdown) 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, the supply current decreases to 0.05 µA (typical) and V_{OUT} falls to zero volts.

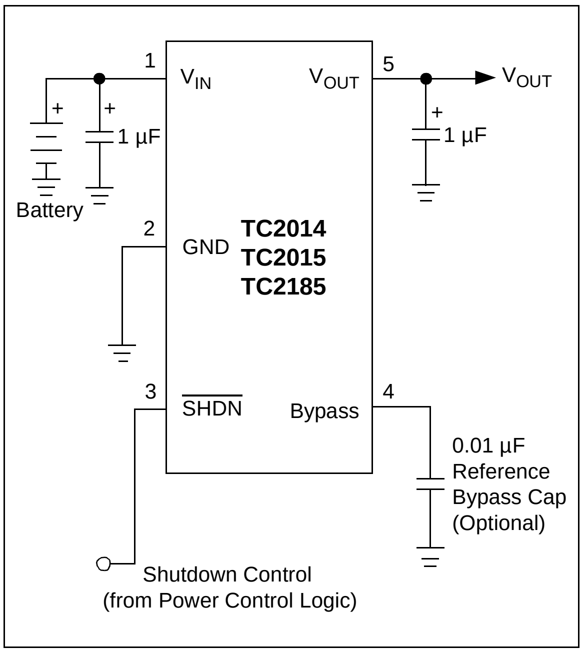


FIGURE 4-1: *Typical Application Circuit.*

4.1 Bypass Input

A 0.01 µF ceramic 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.

4.2 Output Capacitor

A 1 µF (min) capacitor from V_{OUT} to ground is required. The output capacitor should have an Effective Series Resistance (ESR) of 0.01Ω to 5Ω for $V_{OUT} \geq 2.5V$, and 0.05Ω. to 5Ω for $V_{OUT} < 2.5V$. Ceramic, tantalum or aluminum electrolytic capacitors can be used. When using ceramic capacitors, X5R and X7R dielectric material are recommended due to their stable tolerance over temperature. However, other dielectrics can be used as long as the minimum output capacitance is maintained.

4.3 Input Capacitor

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 this AC filter capacitor, or if a battery is used as the power source. Aluminum electrolytic or tantalum capacitors 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.

5.0 THERMAL CONSIDERATIONS

5.1 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 5-1:

$$P_D \approx (V_{INMAX} - V_{OUTMIN})I_{LMAX}$$

Where:

P_D	=	Worst-case actual power dissipation
V_{INMAX}	=	Maximum voltage on V_{IN}
V_{OUTMIN}	=	Minimum regulator output voltage
I_{LMAX}	=	Maximum output (load) current

The maximum allowable power dissipation (P_{DMAX}) is a function of the maximum ambient temperature (T_{AMAX}), the maximum allowable die temperature (T_{JMAX}) (+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 5-2:

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

Where all terms are previously defined.

The P_D equation can be used in conjunction with the P_{DMAX} equation to ensure that regulator thermal operation is within limits. For example:

Given:

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

Find:

1. Actual power dissipation
2. Maximum allowable dissipation

Actual power dissipation:

$$P_D = (V_{INMAX} - V_{OUTMIN})I_{LMAX}$$

$$= \frac{[(3.0 \times 1.1) - (2.7 \times 0.975)]40 \times 10^{-3}}{220}$$

$$= 26.7mW$$

Maximum allowable power dissipation:

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

$$= \frac{125 - 55}{220}$$

$$= 318mW$$

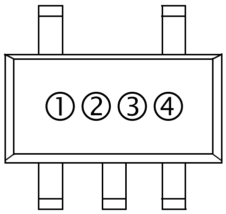
In this example, the TC2014 dissipates a maximum of only 26.7 mW; far below the allowable limit of 318 mW. In a similar manner, the P_D and P_{DMAX} equations can be used to calculate maximum current and/or input voltage limits.

5.2 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.

6.0 PACKAGING INFORMATION

6.1 Package Marking Information



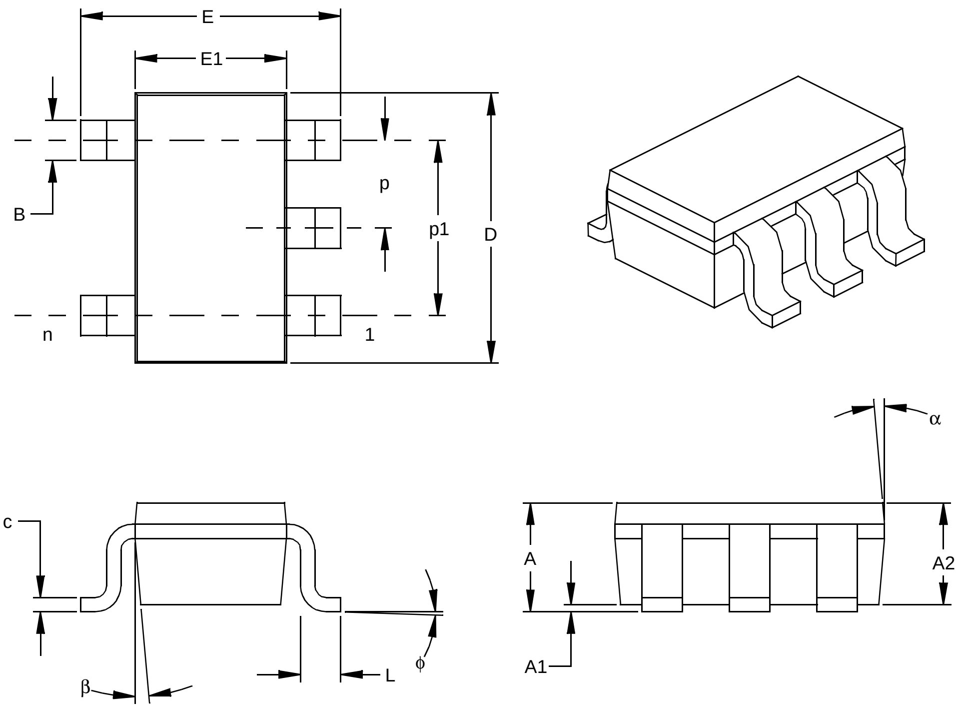
①&② represents part number code + temperature range and voltage

(V)	TC2014	TC2015	TC2185
1.8	PA	RA	UA
2.5	PB	RB	UB
2.6	PH	RH	UH
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
5.0	PJ	RJ	UJ

③ represents year and 2-month period code

④ represents lot ID number

5-Lead Plastic Small Outline Transistor (OT) (SOT23)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.038			0.95	
Outside lead pitch (basic)	p1		.075			1.90	
Overall Height	A	.035	.046	.057	0.90	1.18	1.45
Molded Package Thickness	A2	.035	.043	.051	0.90	1.10	1.30
Standoff §	A1	.000	.003	.006	0.00	0.08	0.15
Overall Width	E	.102	.110	.118	2.60	2.80	3.00
Molded Package Width	E1	.059	.064	.069	1.50	1.63	1.75
Overall Length	D	.110	.116	.122	2.80	2.95	3.10
Foot Length	L	.014	.018	.022	0.35	0.45	0.55
Foot Angle	φ	0	5	10	0	5	10
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B	.014	.017	.020	0.35	0.43	0.50
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010” (0.254mm) per side.
JEDEC Equivalent: MO-178
Drawing No. C04-091

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.	-XX	X	XXXX
Device	Output Voltage	Temperature Range	Package

Device:	TC2014:	50 mA LDO with Shutdown and VREF Bypass
	TC2015:	100 mA LDO with Shutdown and VREF Bypass
	TC2185:	150 mA LDO with Shutdown and VREF Bypass
Output Voltage:	XX =	1.8V
	XX =	2.5V
	XX =	2.6V
	XX =	2.7V
	XX =	2.8V
	XX =	2.85V
	XX =	3.0V
	XX =	3.3V
	XX =	5.0V
Temperature Range:	V =	-40°C to +125°C
Package:	CTTR =	Plastic Small Outline Transistor (SOT-23), 5-lead, Tape and Reel

Examples:

a) TC2014-1.8VCTTR: 5LD SOT-23-A, 1.8V, Tape and Reel.
b) TC2014-2.85VCTTR: 5LD SOT-23-A, 2.85V, Tape and Reel.
c) TC2014-3.3VCTTR: 5LD SOT-23-A, 3.3V, Tape and Reel.

a) TC2015-1.8VCTTR: 5LD SOT-23-A, 1.8V, Tape and Reel.
b) TC2015-2.85VCTTR: 5LD SOT-23-A, 2.85V, Tape and Reel.
c) TC2015-3.0VCTTR: 5LD SOT-23-A, 3.0V, Tape and Reel.

a) TC2185-1.8VCTTR: 5LD SOT-23-A, 1.8V, Tape and Reel.
b) TC2185-2.8VCTTR: 5LD SOT-23-A, 2.8V, Tape and Reel.

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.

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