TC2054/2055/2186

50mA, 100mA, and 150mA CMOS LDOs with Shutdown and $\overline{\text{Error}}$ Output

Features

- Very Low Supply Current (55µA Typ.) for Longer Battery Life
- Very Low Dropout Voltage: 140mV (Typ.) @ 150mA
- High Output Voltage Accuracy: ±0.4% (Typ)
- Standard or Custom Output Voltages
- Power-Saving Shutdown Mode
- $\overline{\text{ERROR}}$ Output Can Be Used as a Low Battery Detector or Processor Reset Generator
- Fast Shutdown Reponse Time: 60µsec (Typ)
- Over-Current Protection
- Space-Saving 5-Pin SOT-23A Package
- Pin Compatible Upgrades for Bipolar Regulators

Applications

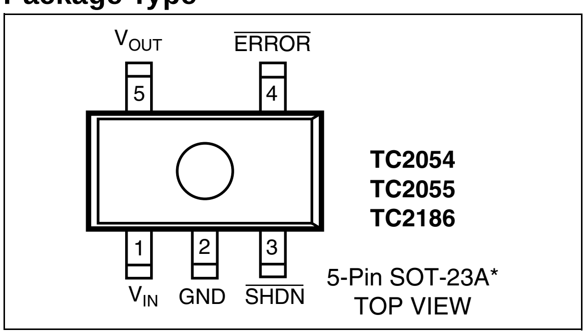
- Battery Operated Systems
- Portable Computers
- Medical Instruments
- Instrumentation
- Cellular / GSMS / PHS Phones
- Pagers

Device Selection Table

Part Number	Package	Junction Temp. Range
TC2054-xxVCT	5-Pin SOT-23A*	-40°C to +125°C
TC2055-xxVCT	5-Pin SOT-23A*	-40°C to +125°C
TC2186-xxVCT	5-Pin SOT-23A*	-40°C to +125°C

Note: *5-Pin SOT-23A is equivalent to EIAJ (SC-74A).

Package Type



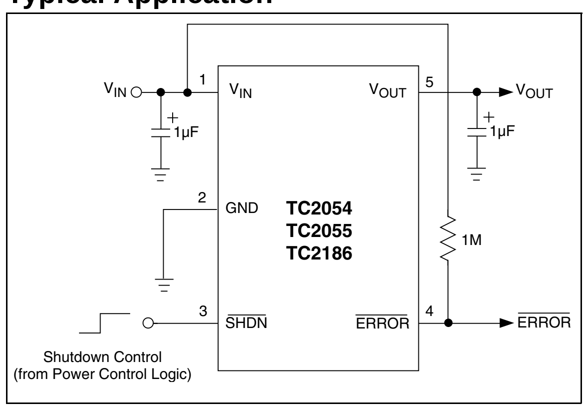
General Description

The TC2054, TC2055 and TC2186 are high accuracy (typically ±0.4%) CMOS upgrades for older (bipolar) low dropout regulators. Designed specifically for battery-operated systems, the devices' total supply current is typically 55µA 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 45mV (TC2054); 90mV (TC2055); and 140mV (TC2186) at full load - and fast response to step changes in load. An error output ($\overline{\text{ERROR}}$) is asserted when the devices are out-of-regulation (due to a low input voltage or excessive output current). Supply current is reduced to 0.5µA (max) and both V_{OUT} and $\overline{\text{ERROR}}$ are disabled when the shutdown input is low. The devices also incorporate over-current protection.

The TC2054, TC2055 and TC2186 are stable with a low esr ceramic output capacitor of 1µF and have a maximum output current of 50mA, 100mA and 150mA, respectively. This LDO Family also features a fast response time (60µsec typically) when released from shutdown.

Typical Application



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 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 my affect device reliability.

TC2054/2055/2186 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 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**
$IOUT_{MAX}$	Maximum Output Current	**50** **100** **150**	— — —	— — —	mA	TC2054 TC2055 TC2186
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**	%	$(V_R + 1V) \le V_{IN} \le 6V$
$\Delta V_{OUT}/V_{OUT}$	Load Regulation	**-1.5** **-2.5**	0.5 0.5	**0.5** **0.5**	%	TC2054;TC2055 I_L = 0.1mA to $IOUT_{MAX}$ TC2186 I_L = 0.1mA to $IOUT_{MAX}$ **Note 4**
$V_{IN} - V_{OUT}$	Dropout Voltage, **Note 5**	— — — —	2 45 90 140	**—** **70** **140** **210**	mV	$I_L = 100\mu A$ I_L = 50mA TC2015; TC2185 I_L = 100mA TC2185 I_L = 150mA **Note 5**
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	—	50	—	dB	$F_{RE} \le$ 120kHz
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**
eN	Output Noise	—	600	—	nV / $\sqrt{Hz}$	$I_L = I_{OUTMAX}$, F = 10kHz
t_R	Response Time (from Shutdown Mode)	—	60	—	µsec	V_{IN} = 4V $C_{IN} = 1\mu F$, $C_{OUT} = 10\mu F$ I_L = 0.1mA, **Note 9**

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: Hysteresis voltage is referenced by V_R.

9: 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: $V_{IN} = V_R + 1V$, $I_L = 100\mu A$, $C_L = 3.3\mu F$, $\overline{SHDN} > V_{IH}$, $T_A = 25°C$, unless otherwise noted. **BOLDFACE** type specifications apply for junction 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
$\overline{ERROR}$ OUTPUT						
V_{INMIN}	Minimum V_{IN} Operating Voltage	1.0	—	—	V	$V_{OUT} \geq 2.7V$
V_{OL}	Output Logic Low Voltage	—	—	400	mV	1 mA Flows to $\overline{ERROR}$
V_{TH}	$\overline{ERROR}$ Threshold Voltage	—	0.95 x V_R	—	V	See Figure 4-2
V_{HYS}	$\overline{ERROR}$ Positive Hysteresis	—	50	—	mV	**Note 8**
t_{DELAY}	V_{OUT} to $\overline{ERROR}$ Delay	—	2	—	msec	V_{OUT} from V_R = 3V to 2.8V
$R_{\overline{ERROR}}$	Resistance from $\overline{ERROR}$ to GND	—	126	—	Ω	V_{DD} = 2.5V, V_{OUT} = 2.5V

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: Hysteresis voltage is referenced by V_R.

9: 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 listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

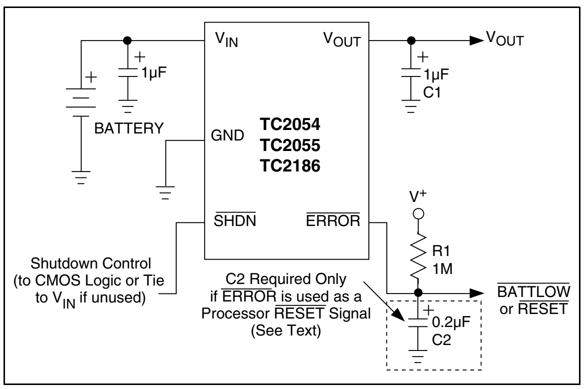
Pin Number	Symbol	Description
1	V_{IN}	Unregulated supply input.
2	GND	Ground terminal.
3	$\overline{SHDN}$	Shutdown control input. The regulator is fully enabled when a logic high is applied to this input. The regulator enters shutdown when a logic low is applied to this input. During shutdown, output voltage falls to zero, ERROR is open circuited and supply current is reduced to 0.5µA (max).
4	$\overline{ERROR}$	Out-of-Regulation Flag. (Open drain output). This output goes low when V_{OUT} is out-of-tolerance by approximately -5%.
5	V_{OUT}	Regulated voltage output.

3.0 DETAILED DESCRIPTION

The TC2054, TC2055 and TC2186 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 TC2054, TC2055 and TC2186 supply current does not increase with load current. In addition, V_{OUT} remains stable and within regulation over the entire 0mA to maximum output current operating load range.

Figure 3-1 shows a typical application circuit. The regulator is enabled any time the shutdown input ($\overline{\text{SHDN}}$) is at or above V_{IH}, and shutdown (disabled) when $\overline{\text{SHDN}}$ is at or below V_{IL}. $\overline{\text{SHDN}}$ may be controlled by a CMOS logic gate, or I/O port of a microcontroller. If the $\overline{\text{SHDN}}$ 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, and $\overline{\text{ERROR}}$ is open-circuited.

FIGURE 3-1: TYPICAL APPLICATION CIRCUIT



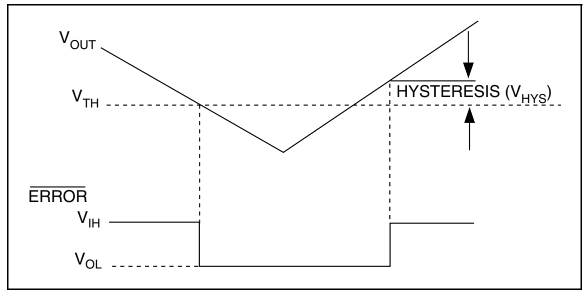
3.1 $\overline{\text{ERROR}}$ Open Drain Output

$\overline{\text{ERROR}}$ is driven low whenever V_{OUT} falls out of regulation by more than -5% (typical). This condition may be caused by low input voltage, output current limiting or thermal limiting. The $\overline{\text{ERROR}}$ threshold is 5% below rated V_{OUT} regardless of the programmed output voltage value (e.g. $\overline{\text{ERROR}}$ = V_{OL} at 4.75V (typ.) for a 5.0V regulator and 2.85V (typ.) for a 3.0V regulator). $\overline{\text{ERROR}}$ output operation is shown in Figure 4-2.

Note that $\overline{\text{ERROR}}$ is active when V_{OUT} falls to V_{TH}, and inactive when V_{OUT} rises above V_{TH} by V_{HYS}.

As shown in Figure 3-1, $\overline{\text{ERROR}}$ can be used as a battery low flag or as a processor $\overline{\text{RESET}}$ signal (with the addition of timing capacitor C2). R1 x C2 should be chosen to maintain $\overline{\text{ERROR}}$ below V_{IH} of the processor $\overline{\text{RESET}}$ input for at least 200msec to allow time for the system to stabilize. Pull-up resistor R1 can be tied to V_{OUT}, V_{IN} or any other voltage less than (V_{IN} + 0.3V). The $\overline{\text{ERROR}}$ pin sink current is self-limiting to approximately 18mA.

FIGURE 3-2: ERROR OUTPUT OPERATION



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} = 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. Ceramic, tantalum and aluminum electrolytic capacitors 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 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 power dissipation:

EQUATION 4-1:

$P_D \approx (V_{IN} - V_{OUT_{MIN}})I_{LOAD_{MAX}}$

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:

$$P_{D_{MAX}} = \frac{T_{J_{MAX}} - T_{A_{MAX}}}{\theta_{JA}}$$

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:

$V_{IN_{MAX}}$	=	3.0V ±5%
$V_{OUT_{MIN}}$	=	2.7V – 2.5%
$I_{LOAD_{MAX}}$	=	40mA
T_{AMAX}	=	55°C

Find:

1. Actual power dissapation

2. Maximum allowable dissapation

Actual power dissipation:

$$P_D \approx (V_{IN_{MAX}} - V_{OUT_{MIN}})I_{LOAD_{MAX}}$$
$$= [(3.0 \times 1.05) - (2.7 \times .975)]40 \times 10^{-3}$$
$$= 20.7\text{mW}$$

Maximum allowable power dissipation:

$$P_{D_{MAX}} = \frac{(T_{J_{MAX}} - T_{A_{MAX}})}{\theta_{JA}}$$

$$\frac{(125 - 55)}{220}$$

$$= 318\text{mW}$$

In this example, the TC2054 dissipates a maximum of only 20.7mW; far 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.

4.2 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.

FIGURE 5-1: POWER SUPPLY REJECTION RATIO

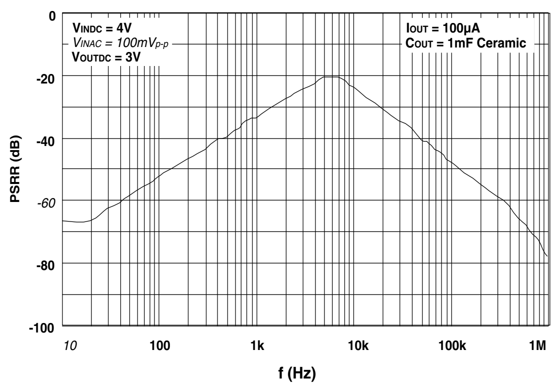


FIGURE 5-2: POWER SUPPLY REJECTION RATIO

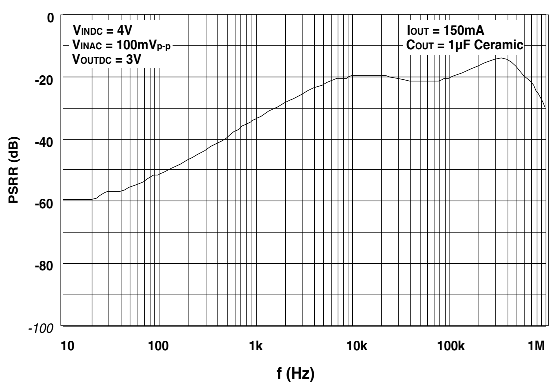


FIGURE 5-3: OUTPUT NOISE

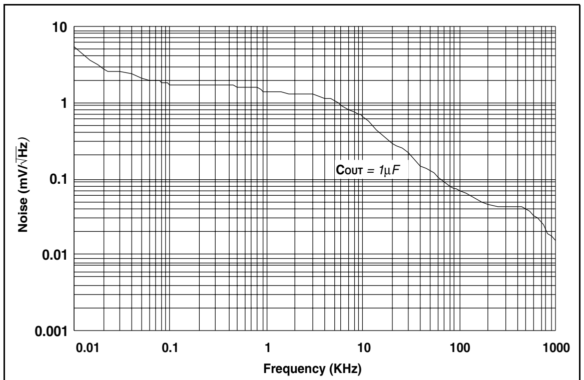


FIGURE 5-4: POWER SUPPLY REJECTION RATIO

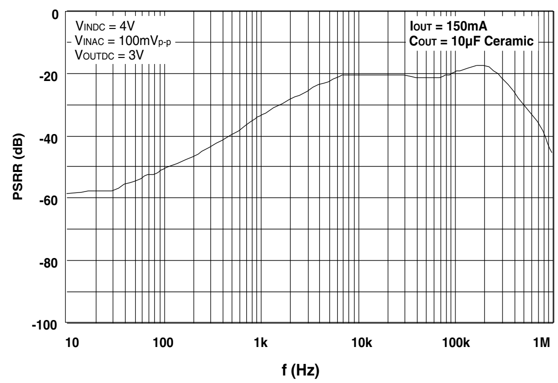


FIGURE 5-5: POWER SUPPLY REJECTION RATIO

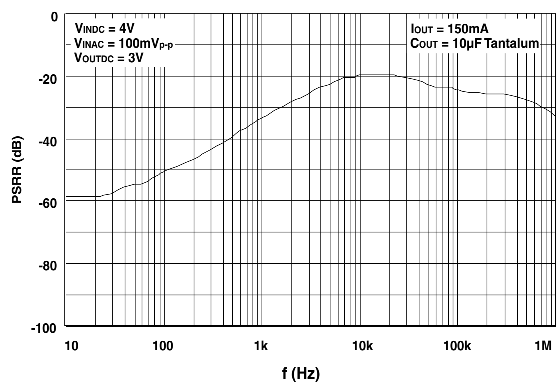
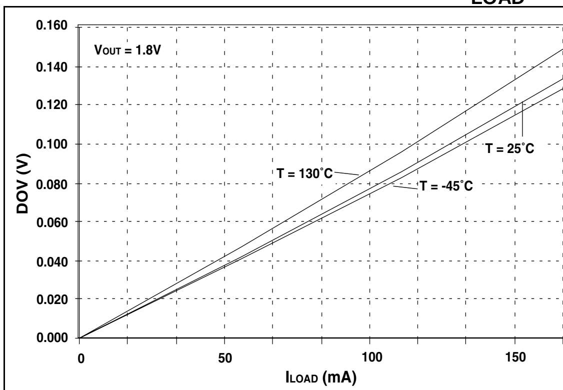


FIGURE 5-6: DROPOUT VOLTAGE VS. I_{LOAD}



TYPICAL CHARACTERISTICS (CONT)

FIGURE 5-7: I_{DD} VS. TEMPERATURE

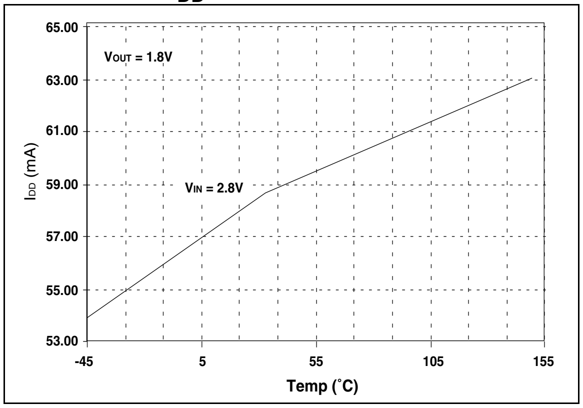


FIGURE 5-8: OUTPUT VOLTAGE VS. TEMPERATURE

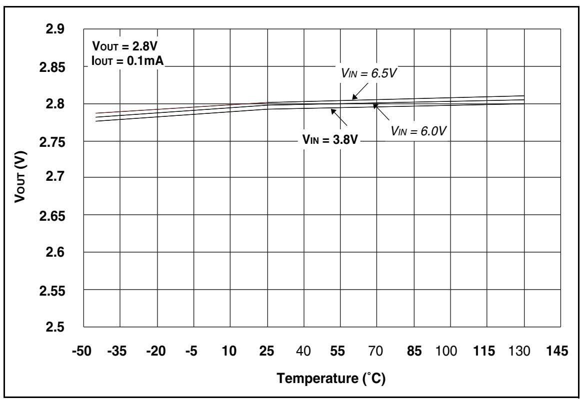


FIGURE 5-9: OUTPUT VOLTAGE VS. TEMPERATURE

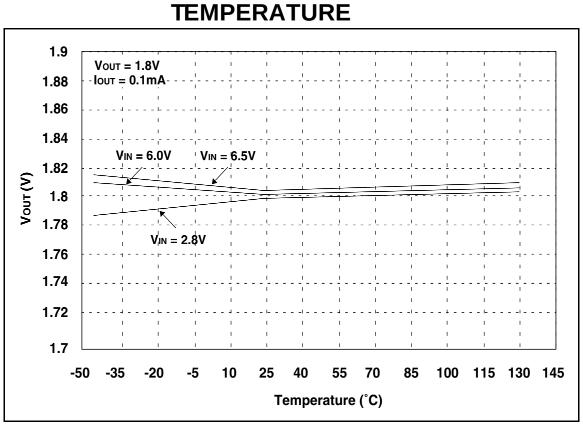


FIGURE 5-10: OUTPUT VOLTAGE VS. OUTPUT CURRENT

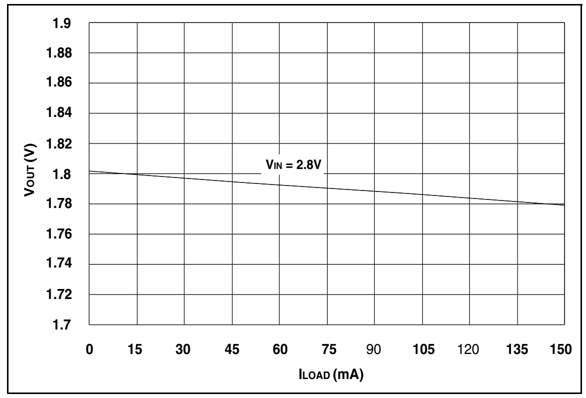


FIGURE 5-11: OUTPUT VOLTAGE VS. SUPPLY VOLTAGE

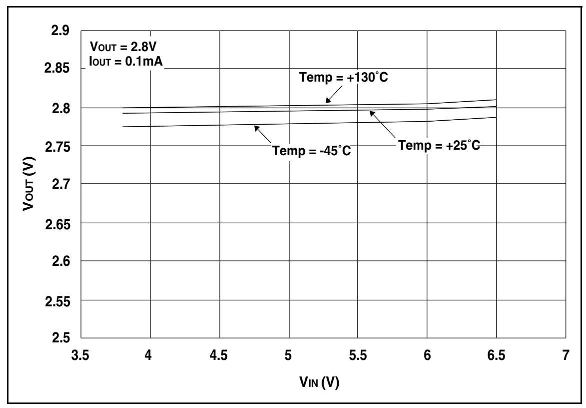
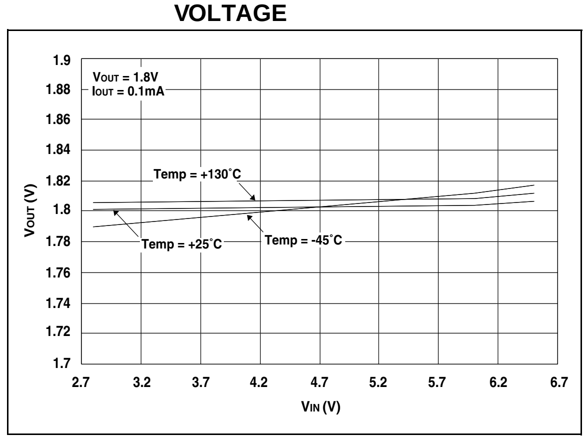


FIGURE 5-12: OUTPUT VOLTAGE VS. SUPPLY VOLTAGE



TYPICAL CHARACTERISTICS (CONT)

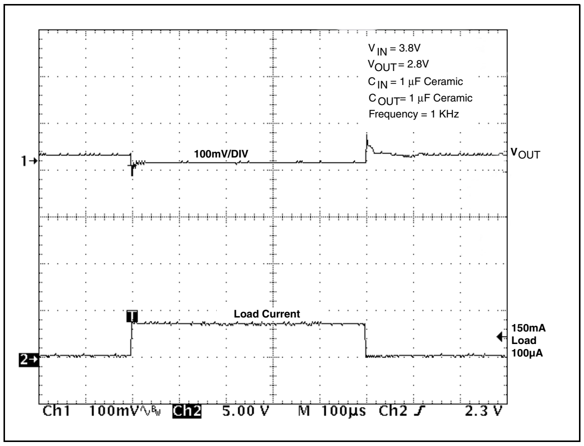


FIGURE 5-13: LOAD TRANSIENT RESPONSE

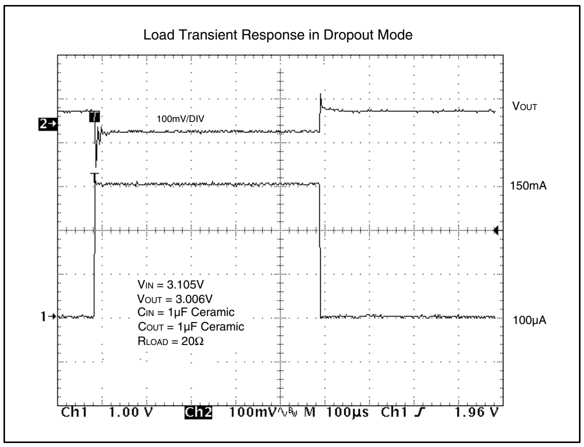


FIGURE 5-14: LOAD TRANSIENT RESPONSE IN DROPOUT MODE

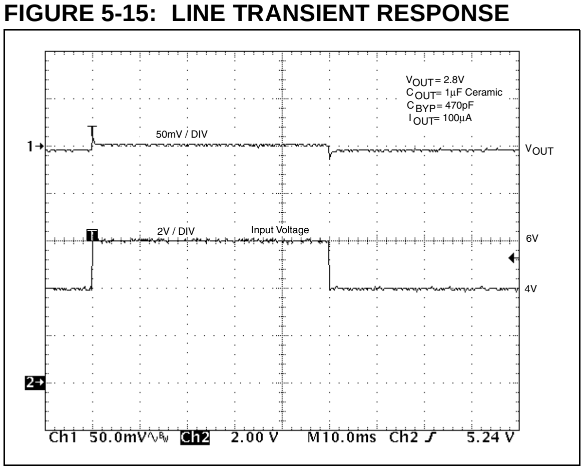


FIGURE 5-15: LINE TRANSIENT RESPONSE

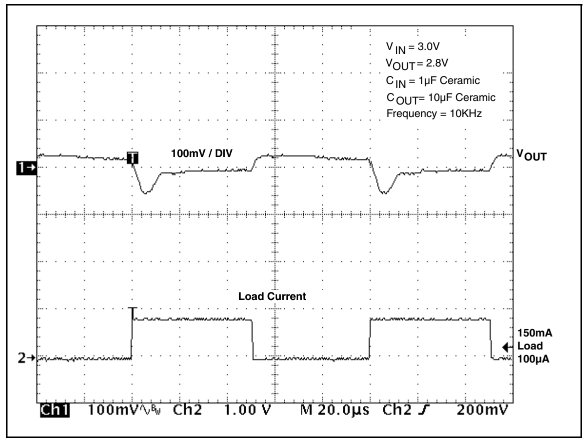


FIGURE 5-16: LOAD TRANSIENT RESPONSE

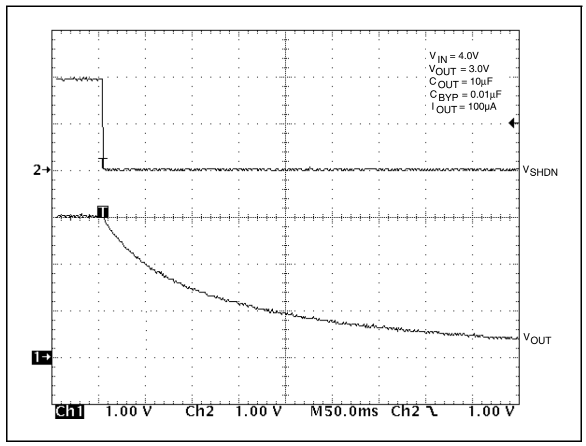


FIGURE 5-17: SHUTDOWN DELAY

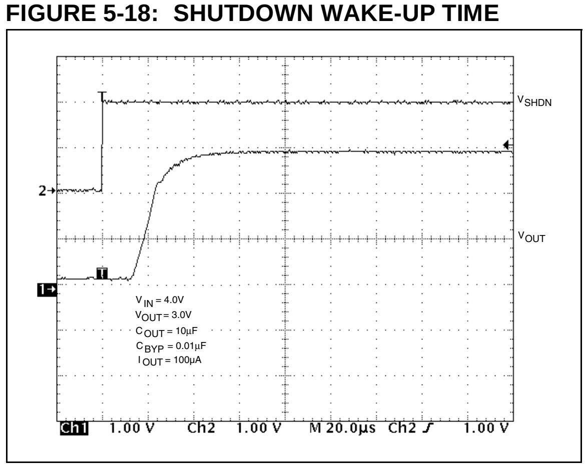
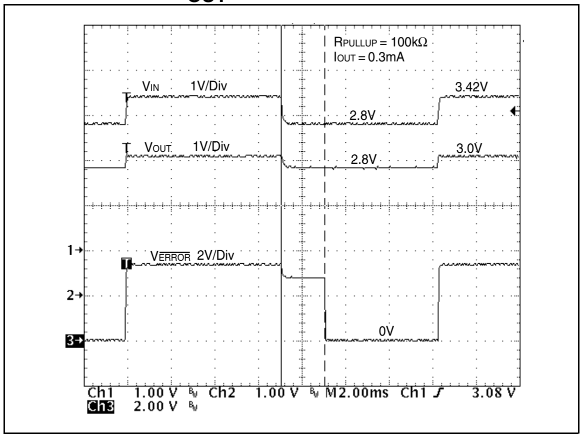


FIGURE 5-18: SHUTDOWN WAKE-UP TIME

TYPICAL CHARACTERISTICS (CONT)

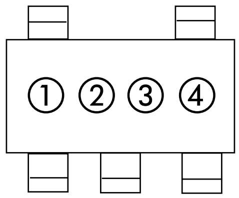
FIGURE 5-19: V_{OUT} TO $\overline{ERROR}$ DELAY



6.0 PACKAGING INFORMATION

6.1 Package Marking Information

5-Pin SOT-23A



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

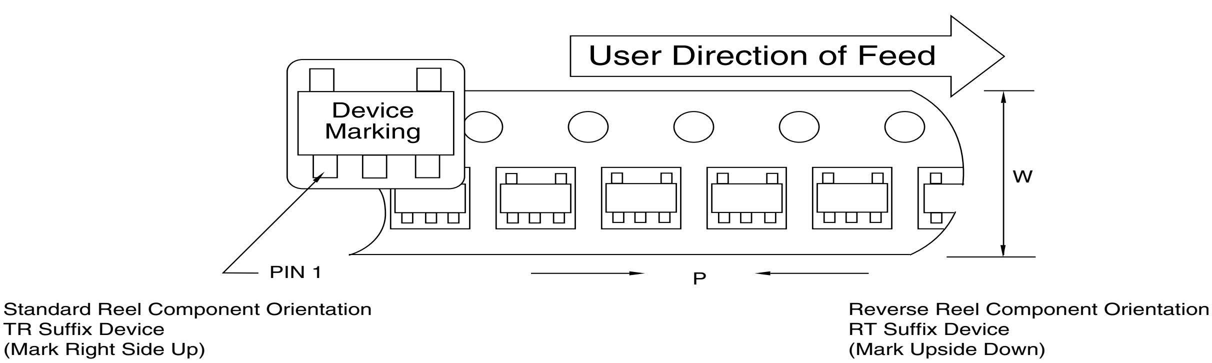
(V)	TC2054 Code	TC2055 Code	TC2186 Code
1.8	SA	TA	VA
2.5	SB	TB	VB
2.7	SC	TC	VC
2.8	SD	TD	VD
2.85	SE	TE	VE
3.0	SF	TF	VF
3.3	SG	TG	VG

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

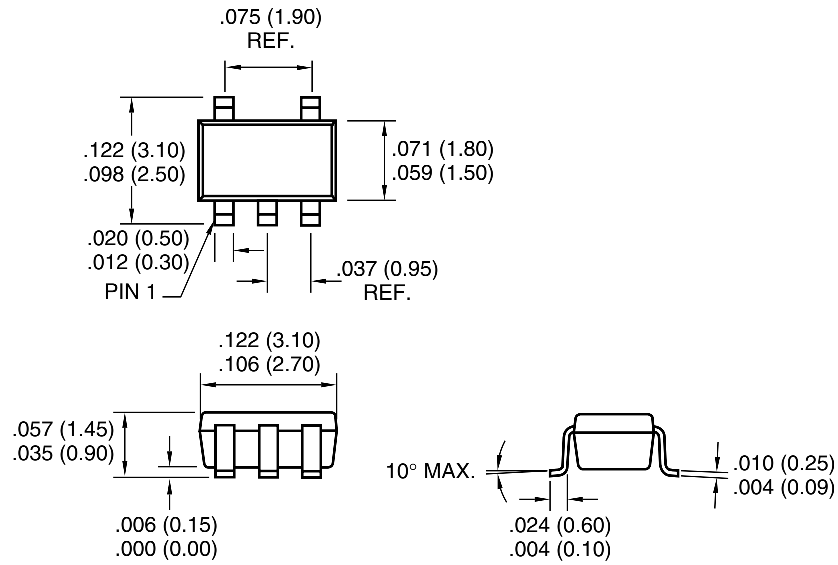


Carrier Tape, Number of Components Per Reel and Reel Size

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)

NOTES:

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
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