TC1188
TC1189

MAX8863/64 Pin-Compatible, Low-Dropout, 120mA Linear Regulators

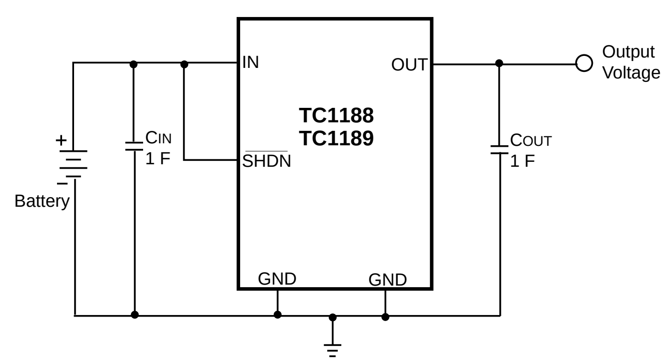
FEATURES

- **Low Cost**
- **Pin-Compatible with MAX8863/8864**
- **Stable with Any Type of Capacitors**
- **Low, 55mV Dropout Voltage @ 50mA I_{OUT}**
- **Low, 50µA Operating Supply Current (Even in Dropout)**
- **140µsec (typ.) Turn-On Response Time from SHDN**
- **Low, 350µV_{RMS} Output Noise**
- **Miniature External Components**
- **Thermal Overload Protection**
- **Output Current Limit**
- **Low-Power Shutdown Mode**

APPLICATIONS

- **Cordless, PCS, and Cellular Telephones**
- **PCMCIA Cards**
- **Modems**
- **Hand-Held Instruments**
- **Palmtop Computers**
- **Electronic Planners**

TYPICAL APPLICATION



GENERAL DESCRIPTION

Delivering up to 120mA, the TC1188 and TC1189 are fixed output, low-dropout linear regulators that operate from a +2.5V to +6.0V input range. The 50µA supply current remains independent of load, making these devices ideal for battery-operated portable equipment.

The output of the TC1188/1189 is preset at 3.15V, 2.84V, 2.80V or 1.80V. (Other output voltage options are available — contact Microchip Technology for more information.) In addition to low-power shutdown, short-circuit protection, and thermal shutdown protection, the TC1189 includes an auto-discharge function that actively discharges the output voltage to ground when the device is in shutdown mode. Both devices are pin-compatible with the Maxim MAX8863/8864 LDOs and are available in SOT-23-5 packages.

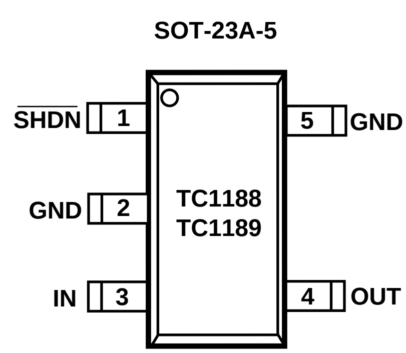
ORDERING INFORMATION

Part No.	Package	Temp. Range
TC1188xECT	SOT-23-5	–40°C to +85°C
TC1189xECT	SOT-23-5	–40°C to +85°C

NOTES: 1.The "X" denotes a suffix for output voltage - see table below
2. SOT-23A-5 is equivalent to the EIAJ (SC-74A)
3.Other output voltages available. Please contact Microchip Technology Inc. for details

Suffix	Output Voltage
Q	1.80
R	2.80
S	2.84
T	3.15

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS*

Input Voltage 6.5V
Output Short-Circuit Duration .... Infinite
SET to GND .... –0.3V to +6.5V
$\overline{SHDN}$ to GND .... –6.5V to +6.5V
$\overline{SHDN}$ to IN .... –6.5V to +0.3V
Output Voltage .... (–0.3V) to (V_{IN} + 0.3V)
Continuous Power Dissipation (T_A = +70°C)
SOT-23-5 (derate 7.1 mW/°C above +70°C)
.... 571 mW

Operating Temperature Range .... –40°C to 85°C
Storage Temperature Range .... –65°C to +160°C
Lead Temperature (Soldering, 10 sec) .... +300°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 operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: (V_{IN} = +3.6V, GND = 0V, T_A = T_{MIN} to T_{MAX}, unless otherwise specified. Typical values are at T_A = +25°C.) (Note 1)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
V_{IN}	Input Voltage (Note 2)	V_{OUT} ≥ 2.5V		V_{OUT} + .5V	—	6.0	V
		V_{OUT} = 1.8V		2.7	—	6.0	
V_{OUT}	Output Voltage	0mA ≤ I_{OUT} ≤ 50mA	T	3.05	3.15	3.25	V
			S	2.75	2.84	2.93	
			R	2.70	2.80	2.88	
			Q	1.745	1.80	1.85	
I_{OUT}	Maximum Output Current			120	—	—	mA
I_{LIM}	Current Limit (Note 3)			—	280	—	mA
I_{IN}	Input Current	I_{OUT} = 0		—	50	90	µA
	Dropout Voltage (Note 4)	I_{OUT} = 1mA		—	1.1	—	mV
		I_{OUT} = 50mA		—	55	120	
		I_{OUT} = 100mA		—	110	240	
ΔV_{LNR}	Line Regulation	V_{IN} = V_{OUT} + 0.5V to 6.0V		–0.10	.001	0.10	%/V
		I_{OUT} = 1mA		—	—	—	
ΔV_{LDR}	Load Regulation	I_{OUT} = 0mA to 50mA		—	0.01	0.040	%/mA
	Output Voltage Noise	10Hz to 1MHz	C_{OUT} = 1µF	—	350	—	µV_{RMS}
			C_{OUT} = 100µF	—	220	—	
t_{WK}	Wake Up Time (from Shutdown Mode)	V_{IN} = 3.6V C_{IN} = 1µF, C_{OUT} = 1µF I_L = 30mA, (See Fig. 1)		—	10	—	µsec
t_S	Settling Time (from Shutdown Mode)	V_{IN} = 3.6V C_{IN} = 1µF, C_{OUT} = 1µF I_L = 30mA, (See Fig. 1)		—	140	—	µsec
Shutdown							
V_{IH}	$\overline{SHDN}$ Input Threshold			2.0	—	—	V
V_{IL}				—	—	0.4	
I_{SHDN}	$\overline{SHDN}$ Input Bias Current	V_{SHDN} = V_{IN}	T_A = +25°C	—	0	100	nA
			T_A = T_{MAX}	—	50	—	
I_{QSHDN}	Shutdown Supply Current	V_{OUT} = 0V	T_A = +25°C	—	.002	1	µA
			T_A = T_{MAX}	—	0.02	—	
	Shutdown to Output Discharge Delay (TC1189)	C_{OUT} = 1µF, no load To 10% of V_{OUT}		—	1	—	msec
Thermal Protection							
T_{SHDN}	Thermal Shutdown Temperature			—	170	—	°C
ΔT_{SHDN}	Thermal Shutdown Hysteresis			—	20	—	°C

NOTES: 1.Limits are 100% production tested at T_A = +25°C. Limits over the operating temperature range are ensured through correlation using Statistical Quality Control (SQC) Methods.
2.Validated by line regulation test.
3.Not tested. For design purposes, the current limit should be considered 150mA minimum to 410mA maximum.
4.The dropout voltage is defined as (V_{IN} – V_{OUT}) when V_{OUT} is 100mV below the value of V_{OUT} for V_{IN} = V_{OUT} +2V.

PIN DESCRIPTION

Pin Number	Name	Description
1	$\overline{SHDN}$	Active-Low Shutdown Input. A logic low reduces the supply current to 0.1nA. On the TC1189, a logic low also causes the output voltage to discharge to GND. Connect to IN for normal operation.
2	GND	Ground. This pin also functions as a heatsink. Solder to large pads or the circuit board ground plane to maximize thermal dissipation.
3	IN	Regulator Input. Supply voltage can range from +2.5V (+2.7V for V_{OUT} = 1.8V) to +6.0V. Bypass with 1µF to GND (see *Capacitor Selection and Regulator Stability*).
4	OUT	Regulator Output. Sources up to 120mA. Bypass with a 1µF, <1 Ω typical ESR capacitor to GND.
5	GND	Connect to GND.

DETAILED DESCRIPTION

The TC1188/1189 are fixed output, low-dropout, low-quiescent current linear regulators designed specifically for portable, battery-operated equipment such as cellular phones, cordless phones, and modems. A 1.20V reference, error amplifier, MOSFET driver, P-channel pass transistor, comparator, and internal feedback voltage divider comprise the TC1188/1189 (see Figure 2).

The bandgap reference is connected to the error amplifier's inverting input. The error amplifier then compares the reference with the selected feedback voltage and amplifies the difference. The MOSFET driver, reading the error signal, applies the correct drive to the P-channel pass transistor. If the feedback voltage is lower than the reference, the pass-transistor is pulled lower to allow more current through, and to increase the output voltage. Conversely, if the feedback voltage is higher than the reference, the pass-transistor is pulled up, which allows less current through to the output.

Turn On Response

The turn on response is defined as two separate response categories, **Wake Up Time (t_{WK})** and **Settling Time (t_S).**

The TC1188/89 have a fast Wake Up Time (10µsec typical) when released from shutdown. See Figure 1 for the **Wake Up Time** designated as **t_{WK}**. The **Wake Up Time** is defined as the time it takes for the output to rise to 2% of the V_{OUT} value after being released from shutdown.

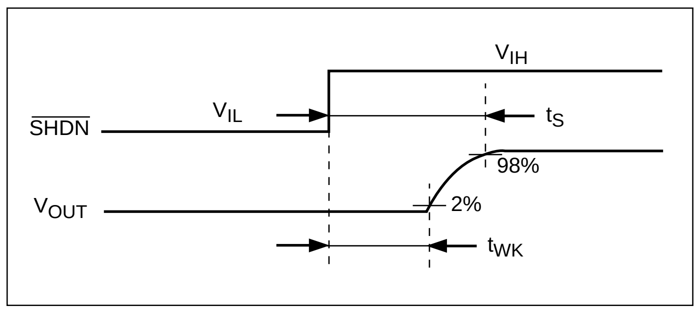


Figure 1: Wake Up Response Time

The total turn on response is defined as the **Settling Time (t_S)**, see Figure 1. **Settling Time** (inclusive with $t_{WK)}$ is defined as the condition when the output is within 2% of its fully enabled value (140µsec typical) when released from shutdown. The settling time of the output voltage is dependent on load conditions and output capacitance on V_{OUT} (RC response).

Internal P-Channel Pass Transistor

Featuring a 1.1Ω P-channel MOSFET pass transistor, the TC1188/1189 offers longer battery life than similar designs using PNP pass transistors, which waste current in dropout when the pass transistor saturates. PNP-based regulators also use high base-drive currents under large loads. The P-channel MOSFET, however, does not require a base drive current, which reduces quiescent current. The TC1188/1189 use only 50µA of quiescent current.

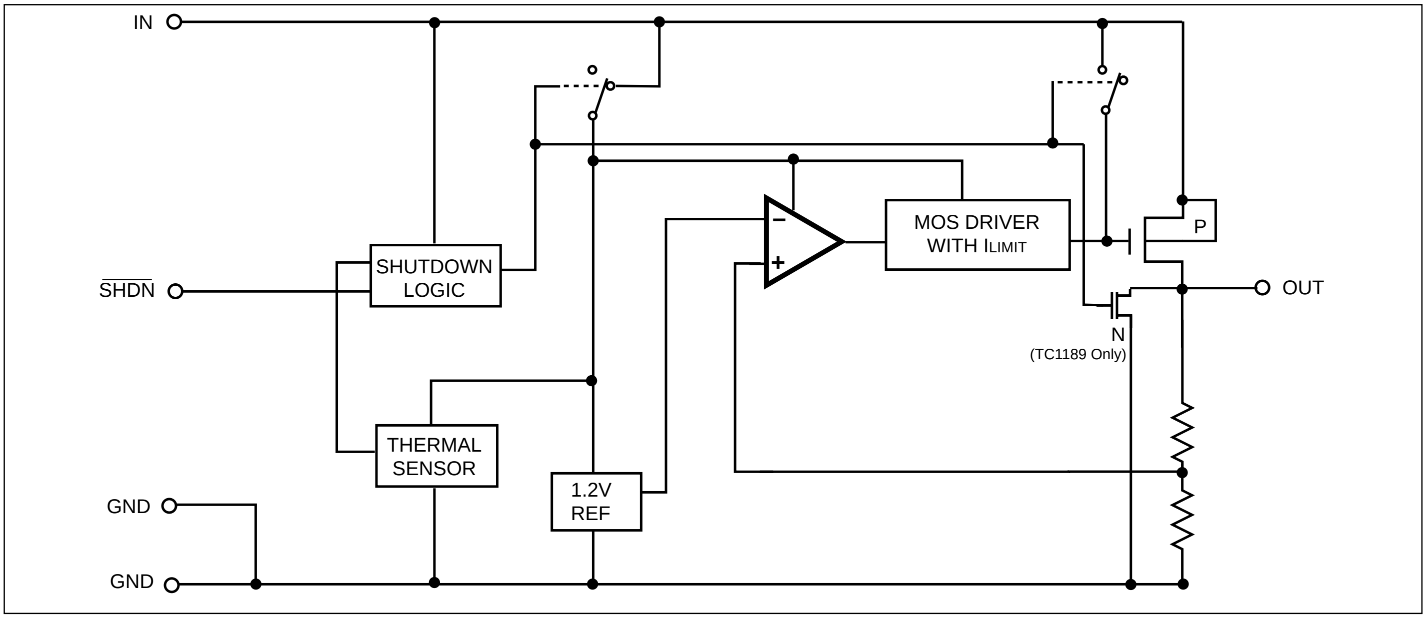


Figure 2. Functional Block Diagram

Shutdown

Low input on $\overline{SHDN}$ shuts down the TC1188/1189 by turning off the pass transistor, control circuit, reference, and all biases. This reduces the supply current to 0.1nA, typical. For normal operation, connect $\overline{SHDN}$ to IN. When theTC1189 is placed in shutdown mode, the output voltage is actively discharged to ground.

Current Limit

The current limiter on the TC1188/1189 monitors and controls the pass transistor's gate voltage. It estimates the output current, limiting it to 280mA. The current limit should be considered 150mA (min) to 410mA (max) for design purposes. The output can be shorted to ground indefinitely without damaging the device.

Thermal Overload Protection

The TC1188/1189 features thermal overload protection, which limits total power dissipation. The thermal sensor signals the shutdown logic to turn off the pass transistor when the junction temperature exceeds T_J = +170°C. This allows the IC's junction temperature to cool by 20°C before the thermal sensor turns the pass transistor back on. This results in a pulsed output during continuous thermal overload conditions.

This feature is designed to protect the TC1188/1189 during thermal events. High load currents and high input-output differential voltages may cause a momentary overshoot of 2% to 8% for 200msec when the load is removed. This can be avoided by raising the minimum load current from 0µA (+125°C) to 100µA (+150°C). The maximum junction temperature rating of +150°C should not be exceeded for continuous operation.

Operating Region and Power Dissipation

The TC1188/1189's maximum power dissipation depends on the thermal resistance of the case and circuit board, the rate of air flow, and the temperature difference between the die junction and ambient air. The devices' power dissipation is $P = I_{OUT} (V_{IN} - V_{OUT})$; resulting maximum power dissipation is :

$$P_{MAX} = (T_J - T_A)/\Theta_{JA}$$

where $(T_J - T_A)$ is the temperature difference between the devices' die junction and the surrounding air, and Θ_{JA} is the thermal resistance of the chosen package to the surrounding air.

The devices' GND pin provides an electrical connection to ground and channels heat away. The GND pin should be connected to ground with a large pad or ground plane.

APPLICATIONS INFORMATION

Capacitor Selection and Regulator Stability

A 1µF capacitor on the input, and a 1µF capacitor on the output should generally be used on the TC1188/1189. For better supply-noise rejection and transient response, larger input capacitor values and lower ESR should be used. If the device is several inches from the power source or if large, fast transients are expected, a higher-value input capacitor (10µF) may be required.

Using large output capacitors may improve load-transient response, stability, and power-supply rejection. A minimum of 1µF is recommended for stable operation over the full temperature range with load currents up to 120mA.

Noise

During normal operation, the TC1188/1189 have low (350μV_{RMS}) output noise. The ADC's power-supply rejection specifications should be considered for applications that include analog-to-digital converters of greater than 12 bits.

Power-Supply Rejection and Operation from Sources Other than Batteries

Power-supply rejection for the TC1188/1189 is 62dB at low frequencies, rolling off above 300Hz. Power supply noise rejection is primarily controlled by the output capacitor at frequencies of more than 20KHz.

Supply noise rejection and transient response can be improved when operating from sources other than batteries by increasing the values of the input and output capacitors, and using passive filtering techniques.

Load Transient Considerations

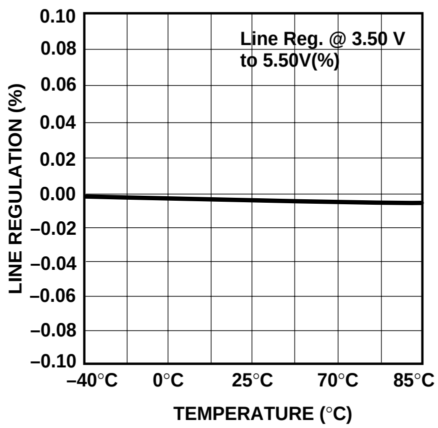
With the TC1188/1189, typical overshoot for step changes in the load current from 0mA to 50mA is 12 mV. To lessen transient spikes, increase the output capacitor's value, and decrease its ESR.

Input-Output (Dropout) Voltage

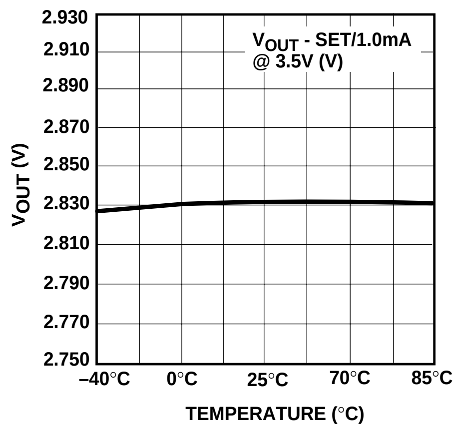
A regulator's dropout voltage determines the lowest usable supply voltage. This determines the useful end-of-life battery voltage for battery-powered systems. Since the TC1188/1189 uses a P-channel MOSFET pass transistor, the devices' dropout voltage is a function of $R_{DS(ON)}$ multiplied by the load current.

TYPICAL CHARACTERISTICS

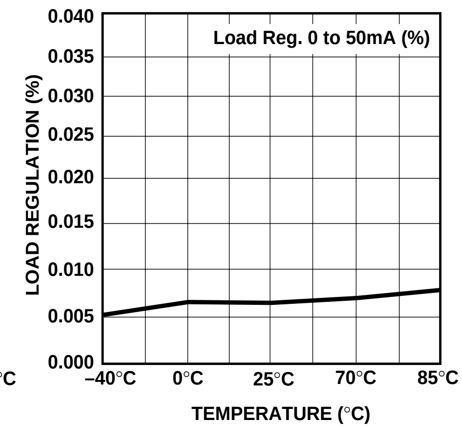
TC1188 Line Regulation



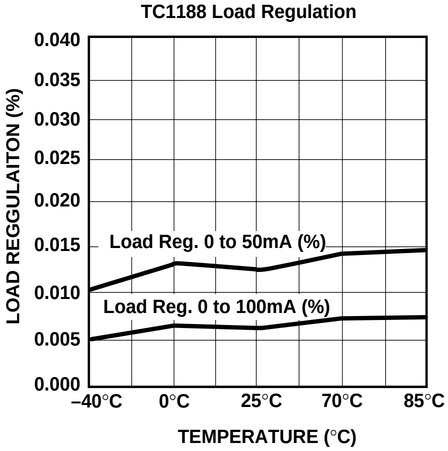
TC1188 Output Voltage



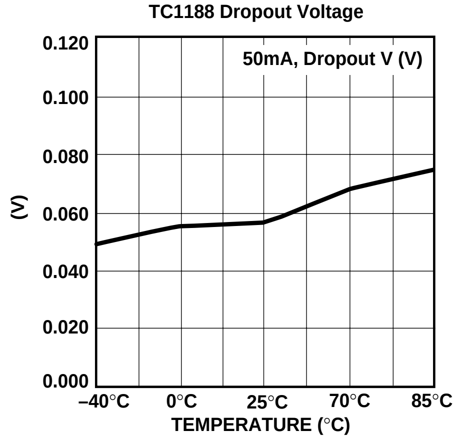
TC1188 Load Regulation



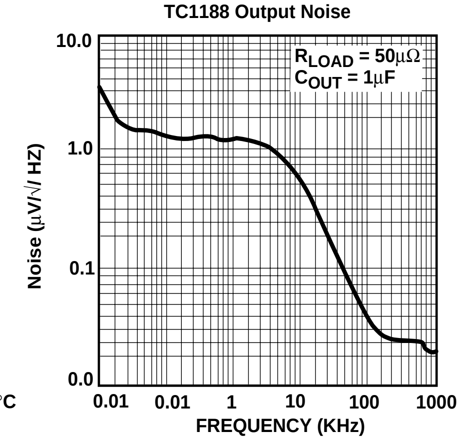
TC1188 Load Regulation



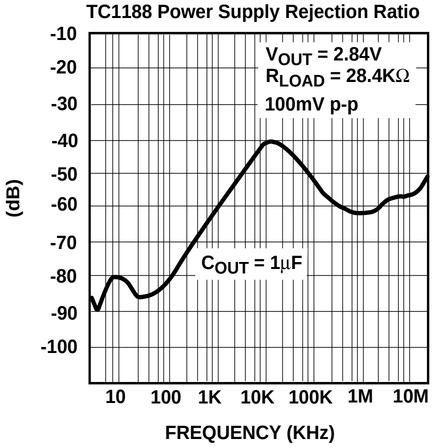
TC1188 Dropout Voltage



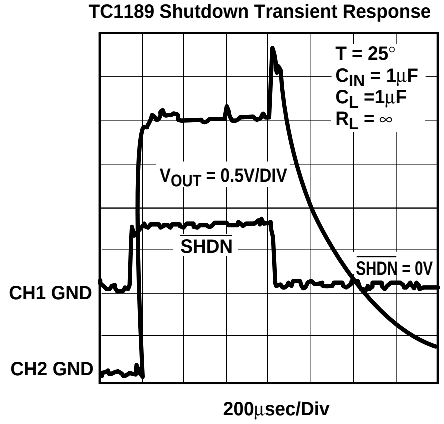
TC1188 Output Noise



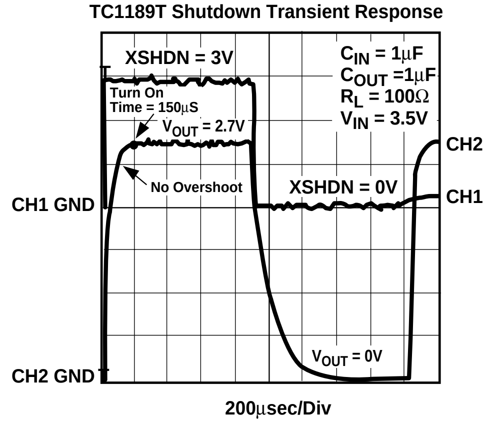
TC1188 Power Supply Rejection Ratio



TC1189 Shutdown Transient Response

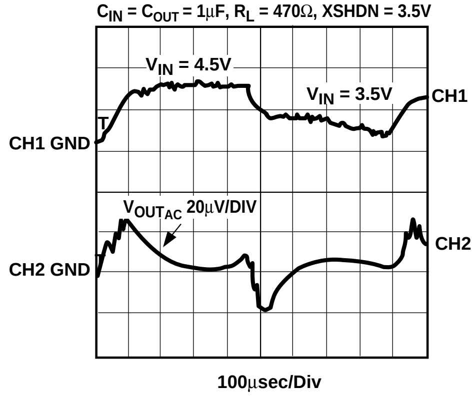


TC1189T Shutdown Transient Response

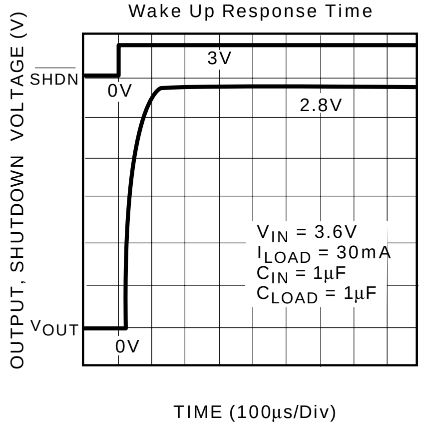


TYPICAL CHARACTERISTICS (CONT.)

TC1189 Line Reponse
$C_{IN} = C_{OUT} = 1\mu F$, $R_L = 470\Omega$, XSHDN = 3.5V

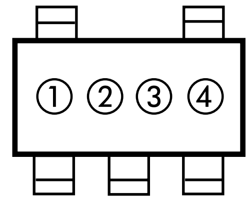


Wake Up Response Time



MARKINGS

SOT-23A-5



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

TC1188 (V)	Code
1.80	G4
2.80	G3
2.84	G2
3.15	G1

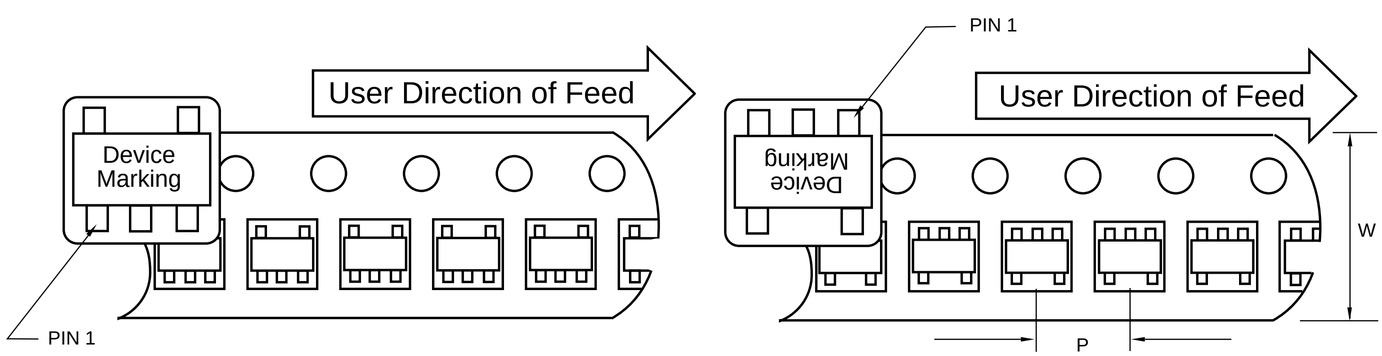
TC1189 (V)	Code
1.80	H4
2.80	H3
2.84	H2
3.15	H1

③ represents year and quarter code

④ represents lot ID number

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)

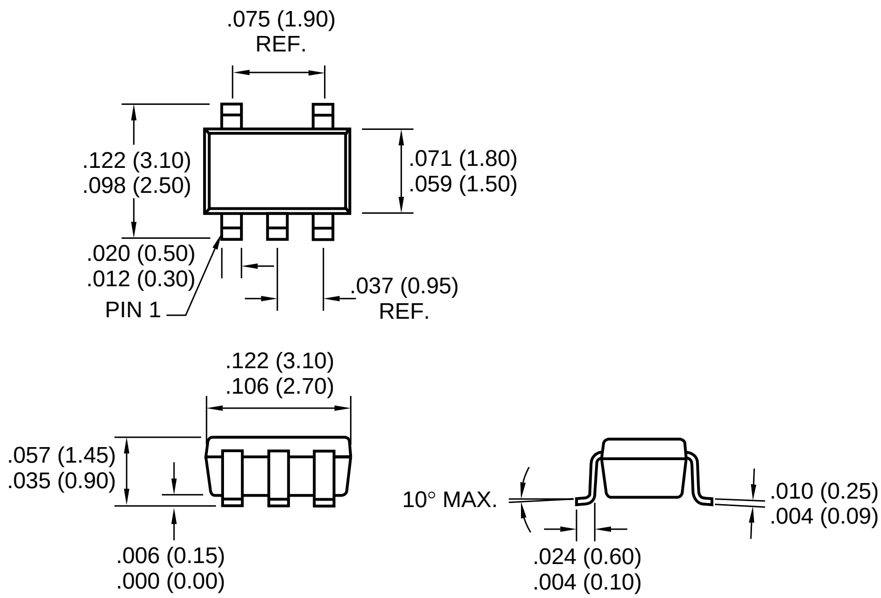
Reverse Reel Component Orientation
RT Suffix Device
(Mark Upside Down)

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

PACKAGE DESCRIPTION

5-Pin SOT-23A (EIAJ SC-74A)



Dimensions: inches (mm)

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