

50mA and 100mA CMOS LDOs with Shutdown, $\overline{\text{ERROR}}$ Output and V_{REF} Bypass

Features

- Zero Ground Current for Longer Battery Life
- Very Low Dropout Voltage
- Choice of 50mA (TC1072) and 100mA (TC1073) Output
- High Output Voltage Accuracy
- 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
- Bypass Input for Ultra Quiet Operation
- Over Current and Over Temperature Protection
- Space-Saving 6-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-Regulators for SMPS
- Pagers

Device Selection Table

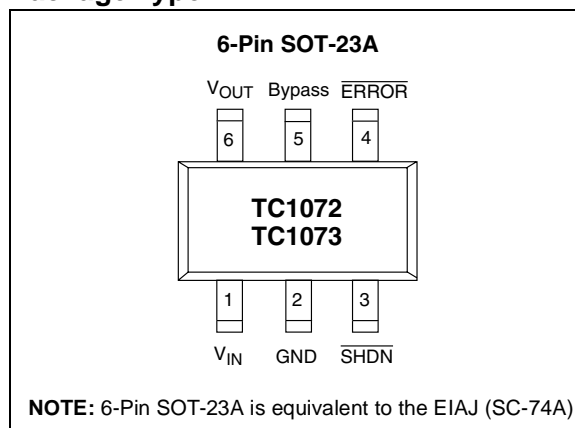
| Part Number | Package | Junction Temp. Range |
|--------------|---------------|----------------------|
| TC1072-xxVCH | 6-Pin SOT-23A | -40°C to +125°C |
| TC1073-xxVCH | 6-Pin SOT-23A | -40°C to +125°C |

NOTE: xx indicates output voltages

Available Output Voltages: 2.5, 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



TC1072/TC1073

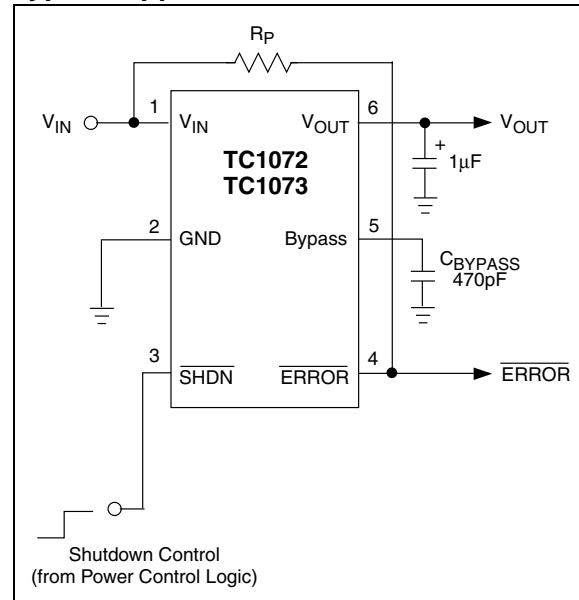
General Description

The TC1072 and TC1073 are high accuracy (typically $\pm 0.5\%$) CMOS upgrades for older (bipolar) low dropout regulators. Designed specifically for battery-operated systems, the devices' CMOS construction eliminates wasted ground current, significantly extending battery life. Total supply current is typically $50\mu\text{A}$ 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); very low dropout voltage (typically 85mV , TC1072 and 180mV , TC1073 at full load) and fast response to step changes in load. An error output (ERROR) is asserted when the devices are out-of-regulation (due to a low input voltage or excessive output current). ERROR can be used as a low battery warning or as a processor RESET signal (with the addition of an external RC network). Supply current is reduced to $0.5\mu\text{A}$ (max) and both V_{OUT} and ERROR are disabled when the shutdown input is low. The devices incorporate both over-temperature and over-current protection.

The TC1072 and TC1073 are stable with an output capacitor of only $1\mu\text{F}$ and have a maximum output current of 50mA , and 100mA respectively. For higher output current versions, please see the TC1185, TC1186, TC1187 ($I_{\text{OUT}} = 150\text{mA}$) and TC1107, TC1108 and TC1173 ($I_{\text{OUT}} = 300\text{mA}$) 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 6) |
| 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.

TC1072/TC1073 ELECTRICAL SPECIFICATIONS

| Electrical Characteristics: V _{IN} = V _{OUT} + 1V, I _L = 0.1mA, C _L = 3.3μF, $\overline{\text{SHDN}} > V_{IH}$, 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 9 |
| I _{OUTMAX} | Maximum Output Current | 50 100 | — | — | mA mA | TC1072 TC1073 |
| V _{OUT} | Output Voltage | V_R - 2.5% | V _R ±0.5% | V_R + 2.5% | V | Note 1 |
| TCV _{OUT} | V _{OUT} Temperature Coefficient | — | 20 40 | — | ppm/°C | Note 2 |
| ΔV _{OUT} /ΔV _{IN} | Line Regulation | — | 0.05 | 0.35 | % | (V _R + 1V) ≤ V _{IN} ≤ 6V |
| ΔV _{OUT} /V _{OUT} | Load Regulation | — | 0.5 | 2.0 | % | I _L = 0.1mA to I _{OUTMAX} (Note 3) |
| V _{IN} -V _{OUT} | Dropout Voltage | — | 2 65 85 180 | — | mV | I _L = 0.1mA I _L = 20mA I _L = 50mA I _L = 100mA (Note 4), TC1073 |
| I _{IN} | Supply Current | — | 50 | 80 | μA | $\overline{\text{SHDN}} = V_{IH}$, I _L = 0 (Note 8) |
| I _{INSD} | Shutdown Supply Current | — | 0.05 | 0.5 | μA | $\overline{\text{SHDN}} = 0V$ |
| PSRR | Power Supply Rejection Ratio | — | 64 | — | dB | F _{RE} ≤ 1kHz |
| I _{OUTsc} | Output Short Circuit Current | — | 300 | 450 | mA | V _{OUT} = 0V |
| ΔV _{OUT} /ΔP _D | Thermal Regulation | — | 0.04 | — | V/W | Notes 5, 6 |
| 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} 470pF from Bypass to GND |
| SHDN Input | | | | | | |
| V _{IH} | SHDN Input High Threshold | 45 | — | — | %V _{IN} | V _{IN} = 2.5V to 6.5V |
| V _{IL} | SHDN Input Low Threshold | — | — | 15 | %V _{IN} | V _{IN} = 2.5V to 6.5V |

Note 1: V_R is the regulator output voltage setting. For example: V_R = 2.5V, 2.7V, 2.85V, 3.0V, 3.3V, 3.6V, 4.0V, 5.0V.

Note 2: $TC V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$

Note 3: Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

Note 4: Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value.

Note 5: 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.

Note 6: 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.

Note 7: Hysteresis voltage is referenced by V_R.

Note 8: Apply for Junction Temperatures of -40°C to +85°C.

Note 9: The minimum V_{IN} has to justify the conditions = V_{IN} ≥ V_R + V_{DROPOUT} and V_{IN} ≥ 2.7V for I_L = 0.1mA to I_{OUTMAX}.

TC1072/TC1073

TC1072/TC1073 ELECTRICAL SPECIFICATIONS (CONTINUED)

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

| Symbol | Parameter | Min | Typ | Max | Units | Test Conditions |
|--------------------------------|--|-----|-------------------|-----|-------|----------------------------------|
| ERROR Open Drain Output | | | | | | |
| V_{INMIN} | Minimum V_{IN} Operating Voltage | 1.0 | — | — | V | |
| V_{OL} | Output Logic Low Voltage | — | — | 400 | mV | 1 mA Flows to \overline{ERROR} |
| V_{TH} | \overline{ERROR} Threshold Voltage | — | $0.95 \times V_R$ | — | V | See Figure 3-2 |
| V_{HYS} | \overline{ERROR} Positive Hysteresis | — | 50 | — | mV | Note 7 |

Note 1: V_R is the regulator output voltage setting. For example: $V_R = 2.5V, 2.7V, 2.85V, 3.0V, 3.3V, 3.6V, 4.0V, 5.0V$.

Note 2: $TC V_{OUT} = \frac{(V_{OUTMAX} - V_{OUTMIN}) \times 10^6}{V_{OUT} \times \Delta T}$

- Note 3:** Regulation is measured at a constant junction temperature using low duty cycle pulse testing. Load regulation is tested over a load range from 0.1mA to the maximum specified output current. Changes in output voltage due to heating effects are covered by the thermal regulation specification.
- Note 4:** Dropout voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value.
- Note 5:** 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.
- Note 6:** 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.
- Note 7:** Hysteresis voltage is referenced by V_R .
- Note 8:** Apply for Junction Temperatures of $-40^\circ C$ to $+85^\circ C$.
- Note 9:** The minimum V_{IN} has to justify the conditions = $V_{IN} \geq V_R + V_{DROPOUT}$ and $V_{IN} \geq 2.7V$ for $I_L = 0.1mA$ to I_{OUTMAX} .

2.0 PIN DESCRIPTIONS

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

TABLE 2-1: PIN FUNCTION TABLE

| Pin No. (6-Pin SOT-23A) | Symbol | Description |
|----------------------------|---------------------------|--|
| 1 | V_{IN} | Unregulated supply input. |
| 2 | GND | Ground terminal. |
| 3 | $\overline{\text{SHDN}}$ | 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 and supply current is reduced to 0.05 μ A (typical). |
| 4 | $\overline{\text{ERROR}}$ | Out-of-Regulation Flag. (Open drain output). This output goes low when V_{OUT} is out-of-tolerance by approximately $\pm 5\%$. |
| 5 | Bypass | Reference bypass input. Connecting a 470pF to this input further reduces output noise. |
| 6 | V_{OUT} | Regulated voltage output. |

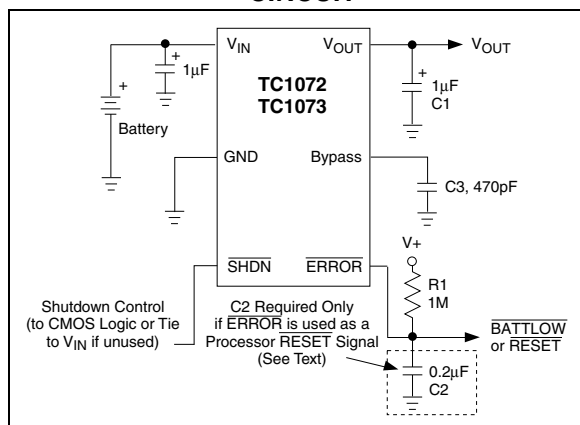
TC1072/TC1073

3.0 DETAILED DESCRIPTION

The TC1072 and TC1073 are precision fixed output voltage regulators. (If an adjustable version is desired, please see the TC1070/TC1071/TC1187 data sheet.) Unlike bipolar regulators, the TC1072 and TC1073's supply current does not increase with load current. In addition, V_{OUT} remains stable and within regulation over the entire 0mA to I_{OUTMAX} load current range, (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 (SHDN) is at or above V_{IH} , and shutdown (disabled) when SHDN is at or below V_{IL} . SHDN may be controlled by a CMOS logic gate, or I/O port of a microcontroller. If the SHDN input is not required, it should be connected directly to the input supply. While in shutdown, supply current decreases to 0.05 μ A (typical), V_{OUT} falls to zero volts, and ERROR is open-circuited.

FIGURE 3-1: TYPICAL APPLICATION CIRCUIT



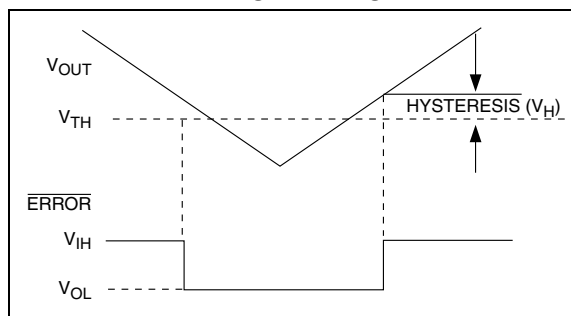
3.1 ERROR Open Drain Output

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 ERROR output voltage value (e.g. 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 3-2.

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 RESET signal (with the addition of timing capacitor C2). $R1 \times C2$ should be chosen to maintain ERROR below V_{IH} of the processor RESET input for at least 200 msec 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 $(V_{IN} + 0.3V)$.

FIGURE 3-2: ERROR OUTPUT OPERATION



3.2 Output Capacitor

A 1 μ F (min) capacitor from V_{OUT} to ground is recommended. The output capacitor should have an effective series resistance greater than 0.1 Ω and less than 5.0 Ω , and a resonant frequency above 1MHz. A 1 μ F 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 $^{\circ}$ C, solid tantalums are recommended for applications operating below -25 $^{\circ}$ 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.

3.3 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.

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 6-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:

$$V_{INMAX} = 3.0V \pm 5\%$$

$$V_{OUTMIN} = 2.7V - 2.5\%$$

$$I_{LOADMAX} = 40mA$$

$$T_{JMAX} = 125^\circ C$$

$$T_{AMAX} = 55^\circ C$$

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

Actual power dissipation:

$$\begin{aligned} P_D &\approx (V_{INMAX} - V_{OUTMIN})I_{LOADMAX} \\ &= [(3.0 \times 1.05) - (2.7 \times .975)]40 \times 10^{-3} \\ &= 20.7mW \end{aligned}$$

Maximum allowable power dissipation:

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

In this example, the TC1072 dissipates a maximum of 20.7mW; 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

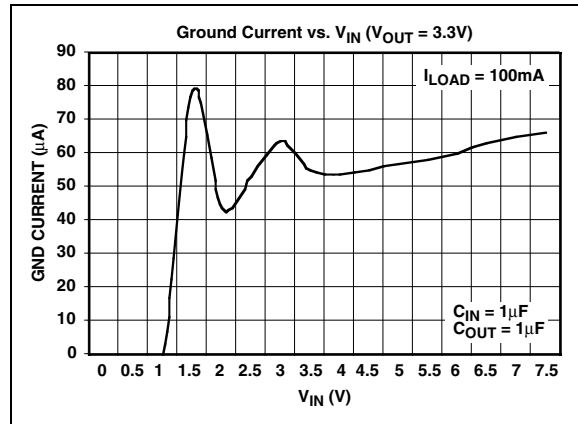
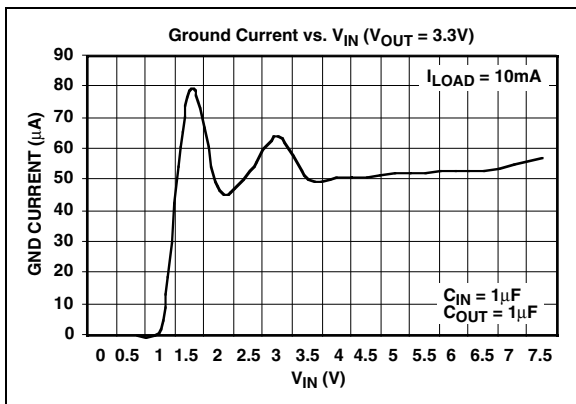
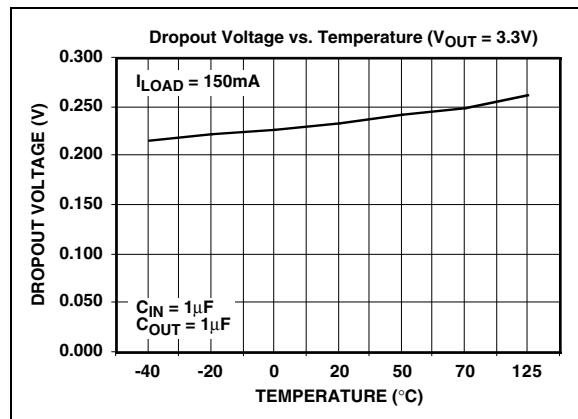
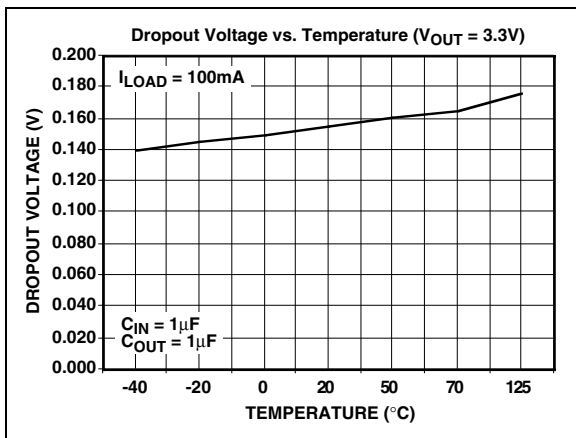
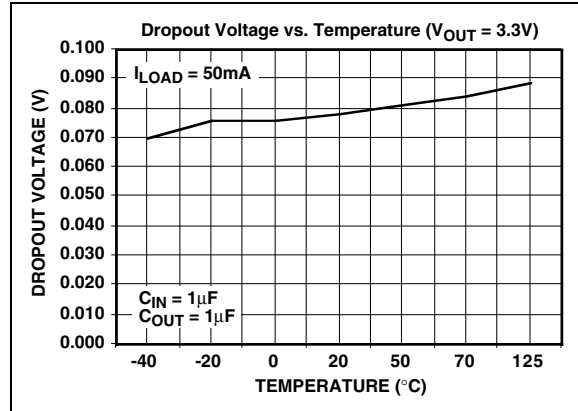
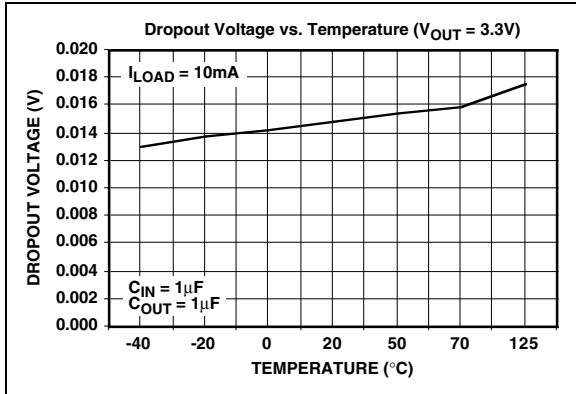
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower θ_{JA} and therefore increase the maximum allowable power dissipation limit.

TC1072/TC1073

5.0 TYPICAL CHARACTERISTICS

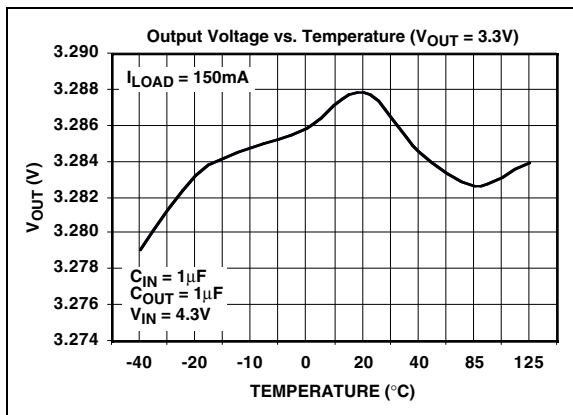
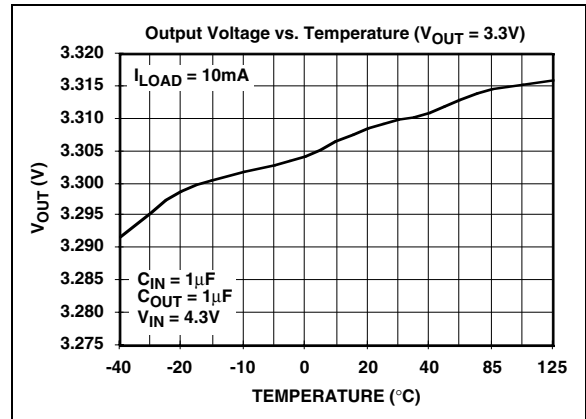
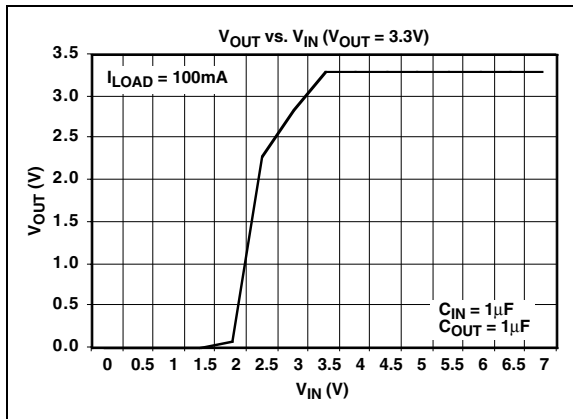
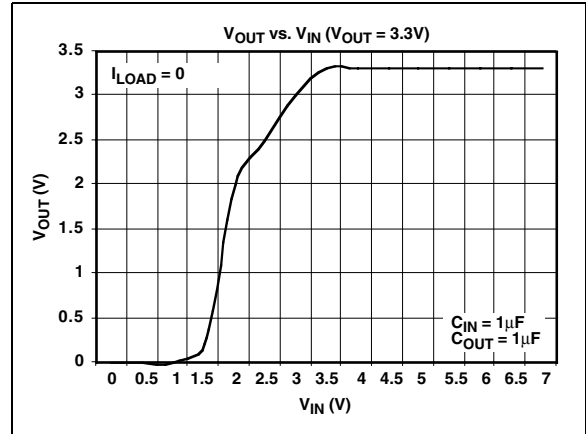
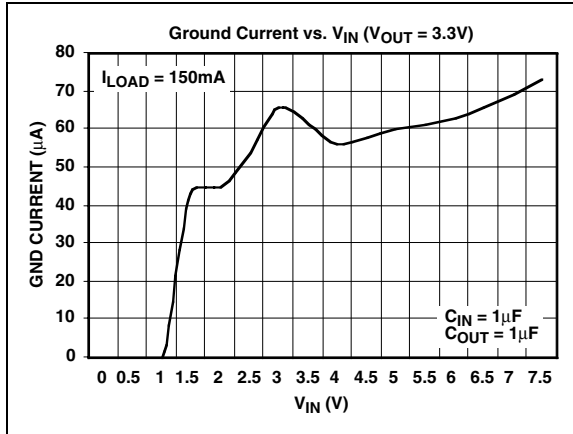
(Unless Otherwise Specified, All Parts Are Measured At Temperature = 25°C)

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)

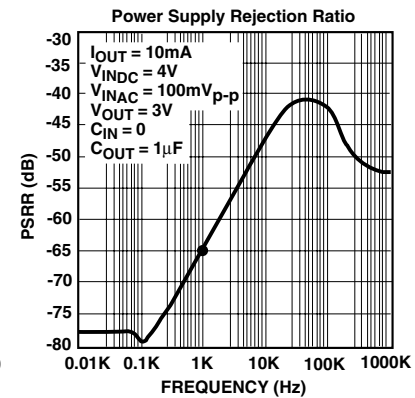
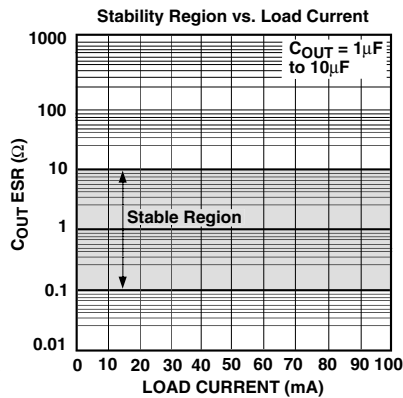
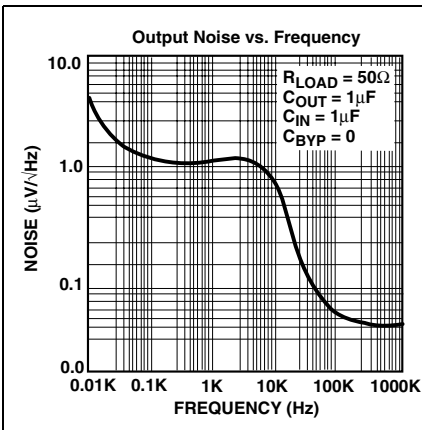
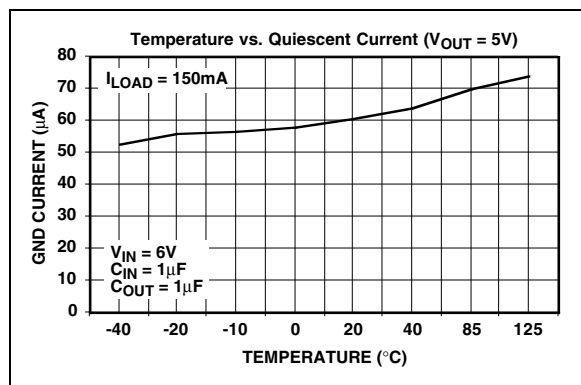
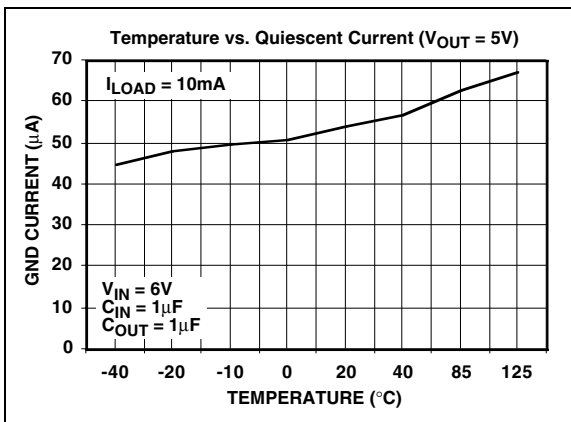
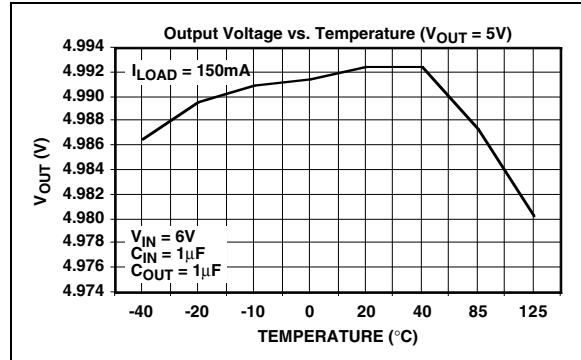
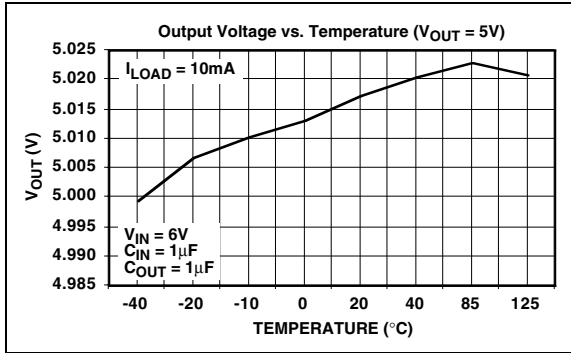
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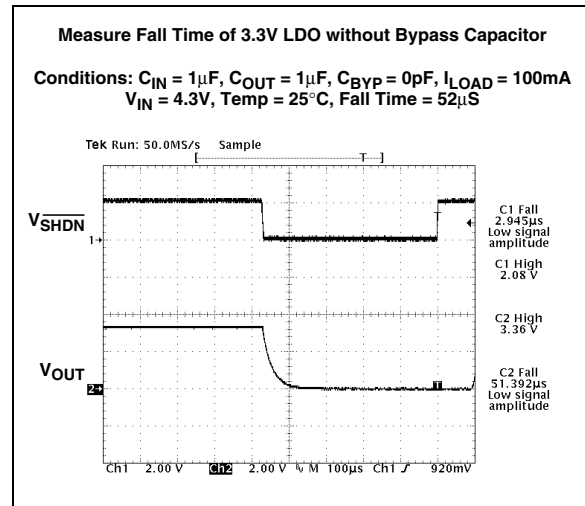
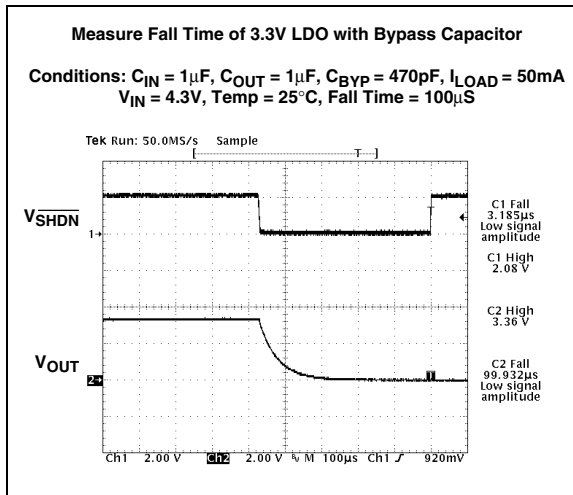
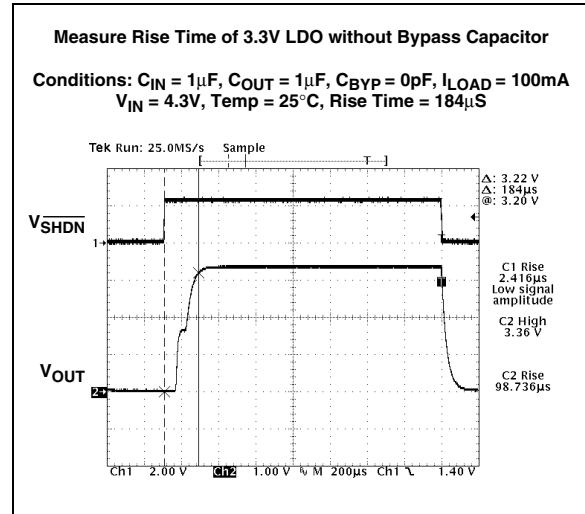
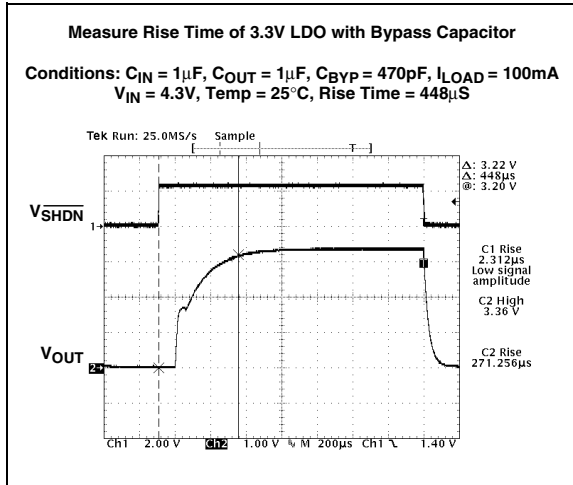
TC1072/TC1073

5.0 TYPICAL CHARACTERISTICS (CONTINUED)

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



5.0 TYPICAL CHARACTERISTICS (CONTINUED)

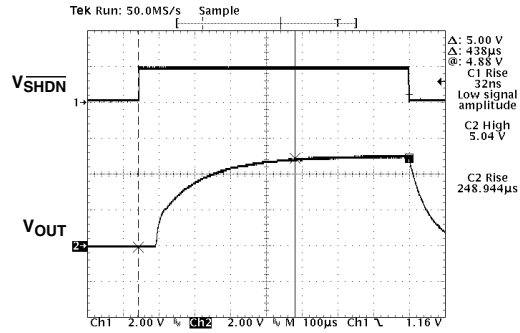


TC1072/TC1073

5.0 TYPICAL CHARACTERISTICS (CONTINUED)

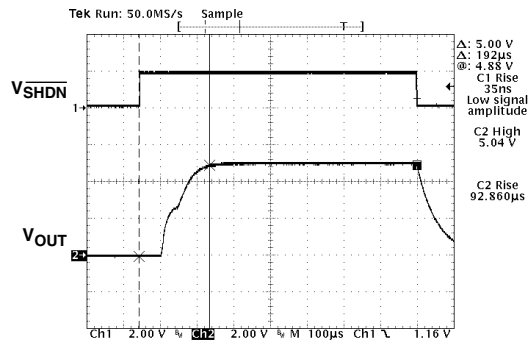
Measure Rise Time of 5.0V LDO with Bypass Capacitor

Conditions: $C_{IN} = 1\mu\text{F}$, $C_{OUT} = 1\mu\text{F}$, $C_{BYP} = 470\text{pF}$, $I_{LOAD} = 100\text{mA}$
 $V_{IN} = 6\text{V}$, Temp = 25°C, Rise Time = 390 μs



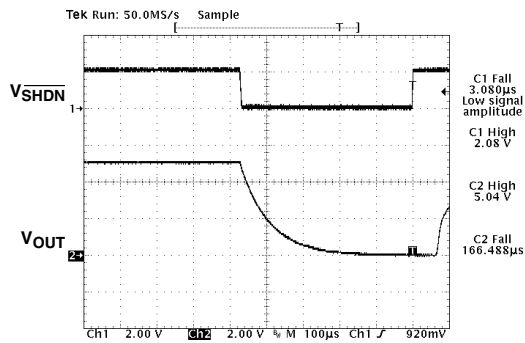
Measure Rise Time of 5.0V LDO without Bypass Capacitor

Conditions: $C_{IN} = 1\mu\text{F}$, $C_{OUT} = 1\mu\text{F}$, $C_{BYP} = 0\text{pF}$, $I_{LOAD} = 100\text{mA}$
 $V_{IN} = 6\text{V}$, Temp = 25°C, Rise Time = 192 μs



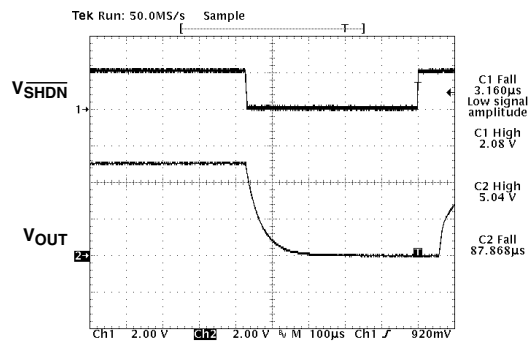
Measure Fall Time of 5.0V LDO with Bypass Capacitor

Conditions: $C_{IN} = 1\mu\text{F}$, $C_{OUT} = 1\mu\text{F}$, $C_{BYP} = 470\text{pF}$, $I_{LOAD} = 50\text{mA}$
 $V_{IN} = 6\text{V}$, Temp = 25°C, Fall Time = 167 μs

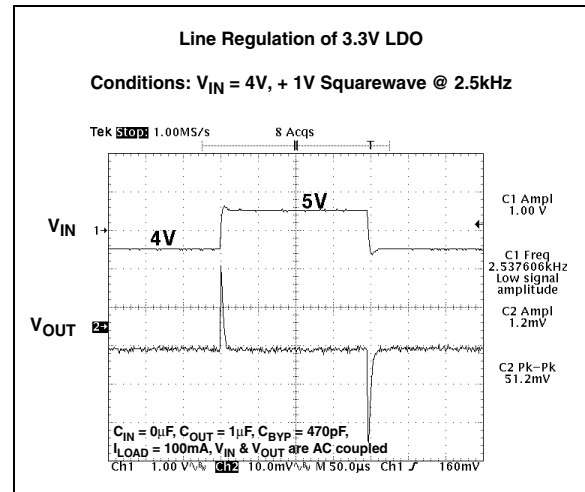
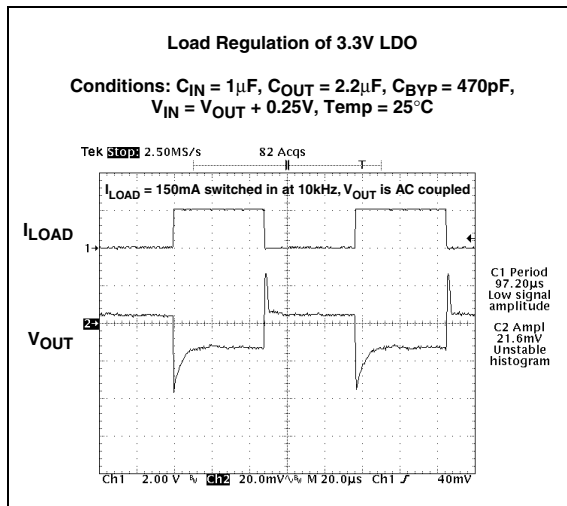
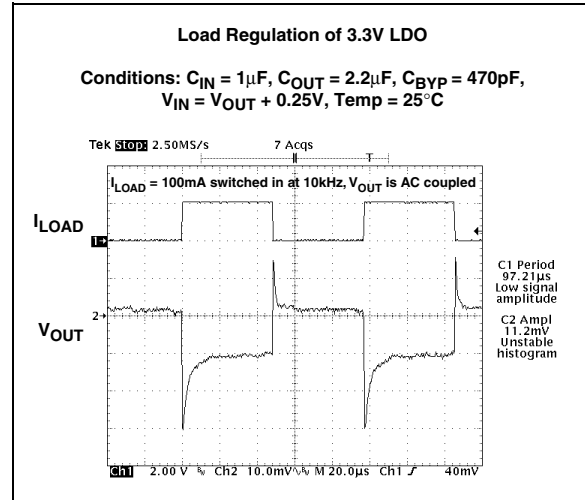
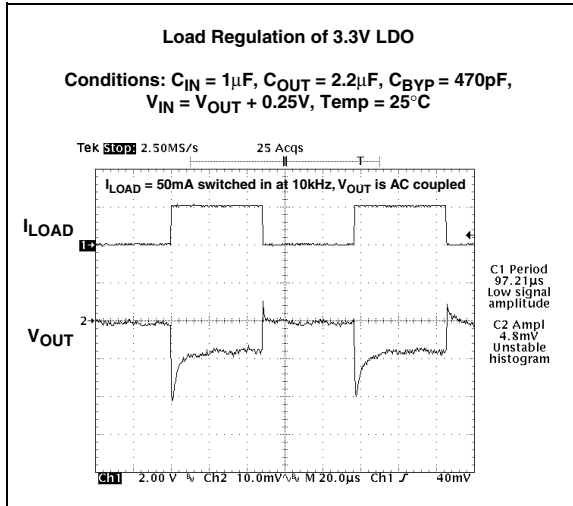


Measure Fall Time of 5.0V LDO without Bypass Capacitor

Conditions: $C_{IN} = 1\mu\text{F}$, $C_{OUT} = 1\mu\text{F}$, $C_{BYP} = 0\text{pF}$, $I_{LOAD} = 100\text{mA}$
 $V_{IN} = 6\text{V}$, Temp = 25°C, Fall Time = 88 μs

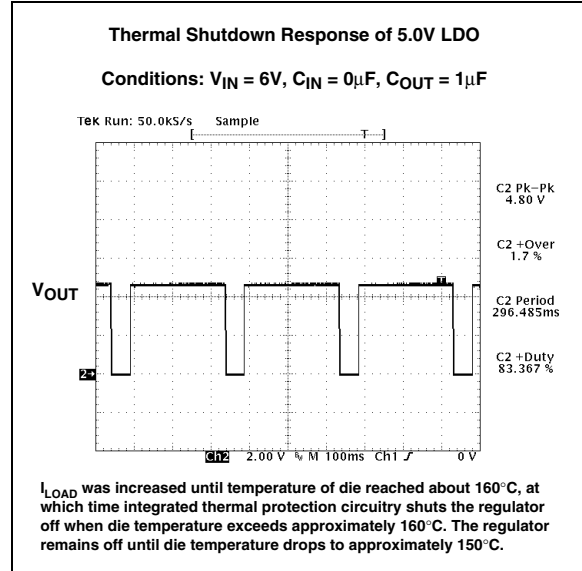
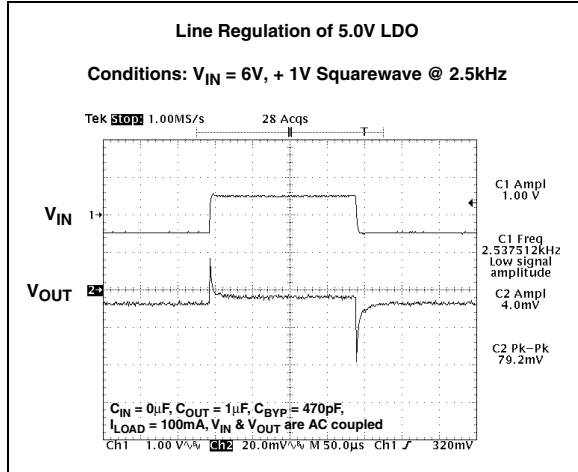


5.0 TYPICAL CHARACTERISTICS (CONTINUED)



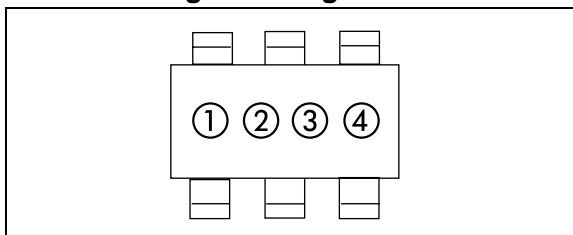
TC1072/TC1073

5.0 TYPICAL CHARACTERISTICS (CONTINUED)



6.0 PACKAGING INFORMATION

6.1 Package Marking Information



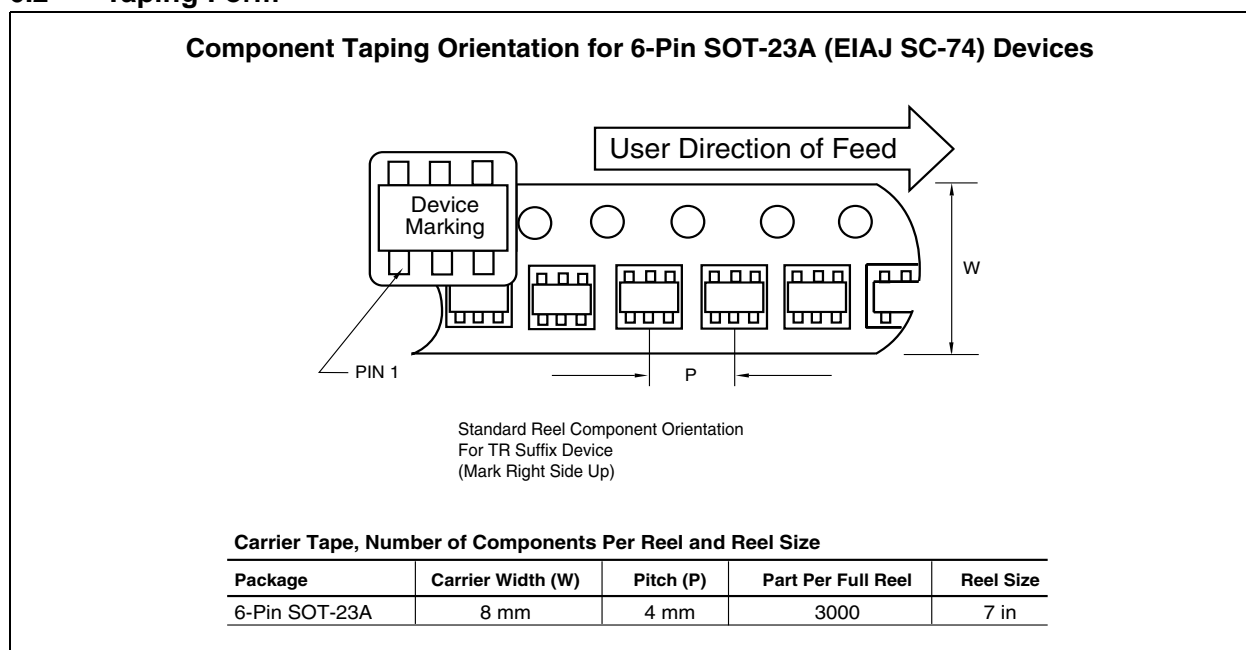
“1” & “2” = part number code + temperature range and voltage

| (V) | TC1072 Code | TC1073 Code |
|------|-------------|-------------|
| 2.5 | E1 | F1 |
| 2.7 | E2 | F2 |
| 2.8 | EZ | FZ |
| 2.85 | E8 | F8 |
| 3.0 | E3 | F3 |
| 3.3 | E5 | F5 |
| 3.6 | E9 | F9 |
| 4.0 | E0 | F0 |
| 5.0 | E7 | F7 |

“3” represents year and quarter code

“4” represents lot ID number

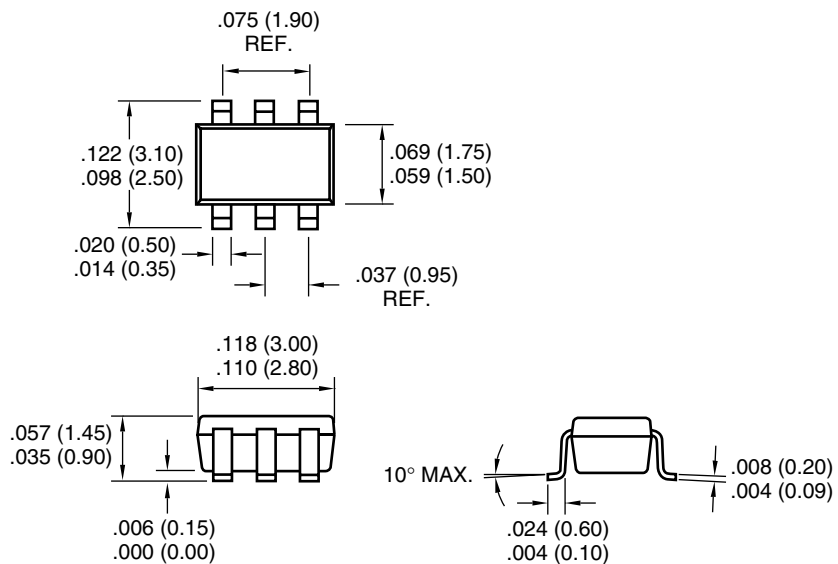
6.2 Taping Form



TC1072/TC1073

6.3 Package Dimensions

SOT-23A-6



Dimensions: inches (mm)

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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:

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TC1072/TC1073

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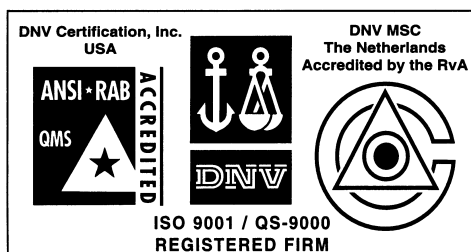
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