TelCom Semiconductor, Inc.

EVALUATION KIT AVAILABLE

TC1072
TC1073

50mA AND 100mA CMOS LDOs WITH SHUTDOWN, ERROR OUTPUT, AND V_{REF} BYPASS

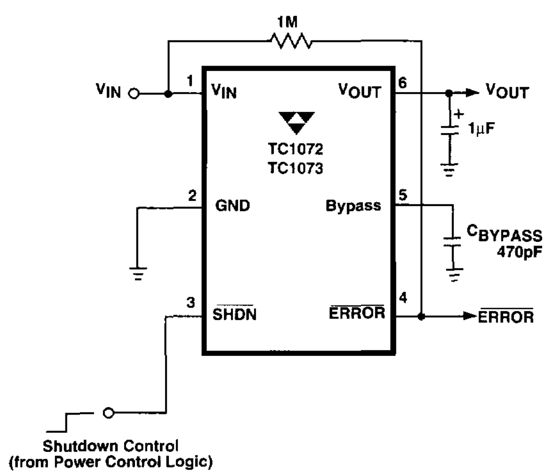
FEATURES

- Zero Ground Current for Longer Battery Life!
- Very Low Dropout Voltage
- Guaranteed 50 mA and 100 mA Output (TC1072, TC1073, Respectively
- High Output Voltage Accuracy
- Standard or Custom Output Voltages
- Power-Saving Shutdown Mode
- ERROR Ouput 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 SOT-23A-6 Package
- Pin Compatible Upgrades for Bipolar Regulators

APPLICATIONS

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

TYPICAL APPLICATION



GENERAL DESCRIPTION

The TC1072 and TC1073 are high accuracy (typically ±0.5%) CMOS upgrade 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 µA 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 85 mV,TC1072 and 180 mV,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 µA (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 µF and have a maximum output current of 50 mA. For higher output current versions, please see the TC1185, TC1186, TC1187 (I_{OUT} = 150 mA) and TC1107, TC1108, and TC1173 (I_{OUT} = 300 mA) data sheets.

ORDERING INFORMATION

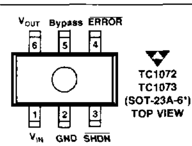
Part Number	Package	Junction Temp. Range
TC1072-xxVCH	SOT-23A-6*	– 40°C to +125°C
TC1073-xxVCH	SOT-23A-6*	– 40°C to +125°C
TC1015EV	***Evaluation Kit for CMOS LDO Family***	

NOTE: *SOT-23A-6 is equivalent to the EIAJ (SC-74A).

Available Output Voltages:
2.5, 2.7, 2.8, 2.85, 3.0, 3.3, 3.6, 4.0, 5.0
xx indicates output voltages

Other output voltages are available. Please contact TelCom Semiconductor for details.

PIN CONFIGURATION



NOTE: *SOT-23A-6 is equivalent to the EIAJ (SC-74A)

TC1072/1073-2 3/30/99

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ABSOLUTE MAXIMUM RATINGS*

Input Voltage 6.5V
Output Voltage .... (– 0.3) to (V_{IN} + 0.3)
Power Dissipation .... Internally Limited
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
Lead Temperature (Soldering, 10 Sec.) .... +260°C

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

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
V_{IN}	Input Operating Voltage		—	—	**6.0**	V
I_{OUTMAX}	Maximum Output Current	TC1072 TC1073	**50** **100**	— —	— —	mA mA
V_{OUT}	Output Voltage	Note 1	**V_R – 2.5%**	V_R ±0.5%	**V_R + 2.5%**	V
TC V_{OUT}	V_{OUT} Temperature Coefficient	Note 2	— —	20 **40**	— —	ppm/°C
$\Delta V_{OUT}/\Delta V_{IN}$	Line Regulation	(V_R + 1V) ≤ V_{IN} ≤ 6V	—	0.05	**0.35**	%/V
$\Delta V_{OUT}/V_{OUT}$	Load Regulation	I_L = 0.1 mA to I_{OUTMAX} (Note 3)	—	0.5	**2.0**	%
$V_{IN} - V_{OUT}$	Dropout Voltage (Note 4)	I_L = 0.1 mA I_L = 20 mA I_L = 50 mA I_L = 100 mA (TC1073) (Note 4)	— — — —	2 65 85 180	— — **120** **250**	mV
I_{IN}	Supply Current	$\overline{SHDN} = V_{IH}$, I_L = 0	—	50	**80**	μA
I_{INSD}	Shutdown Supply Current	$\overline{SHDN}$ = 0V	—	0.05	**0.5**	μA
PSRR	Power Supply Rejection Ratio	F_{RE} ≤ 1 KHz	—	64	—	dB
I_{OUTSC}	Output Short Circuit Current	V_{OUT} = 0V	—	300	450	mA
$\Delta V_{OUT}/\Delta P_D$	Thermal Regulation	Notes 5, 6	—	0.04	—	%/W
T_{SD}	Thermal Shutdown Die Temperature		—	160	—	°C
ΔT_{SD}	Thermal Shutdown Hysteresis		—	10	—	°C
eN	Output Noise	$I_L = I_{OUTMAX}$ 470 pF from Bypass to GND	—	260	—	nV/$\sqrt{Hz}$
$\overline{SHDN}$ Input						
V_{IH}	$\overline{SHDN}$ Input High Threshold	V_{IN} = 2.5V to 6.5V	45	—	—	%V_{IN}
V_{IL}	$\overline{SHDN}$ Input Low Threshold	V_{IN} = 2.5V to 6.5V	—	—	15	%V_{IN}

ELECTRICAL CHARACTERISTICS: $V_{IN} = V_{OUT} + 1V$, $I_L = 0.1$ mA, $C_L = 3.3$ µF, $\overline{SHDN} > V_{IH}$, $T_A = 25°C$, unless otherwise noted.

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

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

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

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

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

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.

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 *Thermal Considerations* section of this data sheet for more details.

7. Hysteresis voltage is referenced by V_R.

PIN DESCRIPTION

Pin No. (SOT-23A-6)	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 and supply current is reduced to 0.05 µA (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 – 5%.
5	Bypass	Reference bypass input. Connecting a 470 pF to this input further reduces output noise.
6	V_{OUT}	Regulated voltage output.

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 at very low load currents (an important consideration in RTC and CMOS RAM battery back-up applications).

Figure 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 µA (typical) and V_{OUT} falls to zero volts and ERROR is open-circuited.

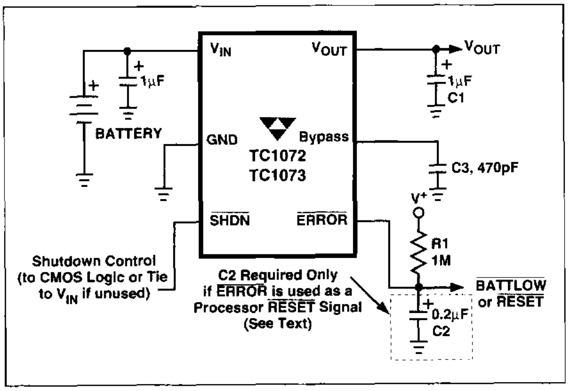


Figure 1. Typical Application Circuit

ERROR Open Drain Output

ERROR is driven low whenenver V_{OUT} falls out of regulation by more than –5% (typical). The 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). ERROR ouput operation is shown in Figure 2.

Note that 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 1, ERROR can be used as a battery low flag, or as a processor RESET signal (with the addition of timing capacitor C2). R1 x 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).

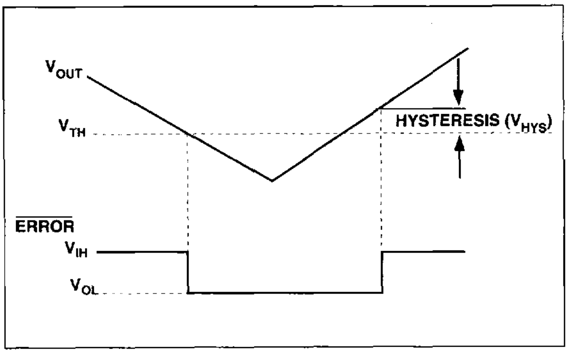


Figure 2. ERROR Output Operation

Output Capacitor

A 1 µF (min) capacitor from V_{OUT} to ground is recommended. The output capacitor should have an effective series resistance of 5Ω or less, and a resonant frequency above 1 MHz. A 1 µF capacitor should be connected from V_{IN} to GND if there is more than 10 inches of wire between the regulator and the AC filter capacitor, or if a battery is used as the power source. Aluminum electrolytic or tantalum capacitor types can be used. (Since many aluminum electrolytic capacitors freeze at approximately – 30°C, solid tantalums are recommended for applications operating below –25°C.) When operating from sources other than batteries, supply-noise rejection and transient response can be improved by increasing the value of the input and output capacitors and employing passive filtering techniques.

Bypass Input

A 470 pF 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.

Thermal Considerations

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.

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:

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

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

Equation 1.

The maximum *allowable* power dissipation (Equation 2) is a function of the maximum ambient temperature ($T_{A_{MAX}}$), the maximum allowable die temperature (125°C) and the thermal resistance from junction-to-air (θ_{JA}). SOT-23A-6 packag has a θ_{JA} of approximately *220°C/Watt* when mounted on a single layer FR4 dielectric copper clad PC board.

$$P_{D\,MAX} = \frac{(T_{JMAX} - T_{AMAX})}{\theta_{JA}}$$

Where all terms are previously defined.

Equation 2.

Equation 1 can be used in conjunction with Equation 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} = 40 mA
T_{AMAX} = 55°C

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

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:

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

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

$$= 318 \text{ mW}$$

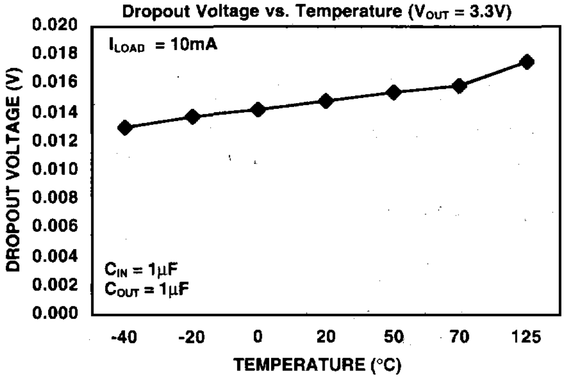
In this example, the TC1072 dissipates a maximum of only 20.7 mW; far below the allowable limit of 318 mW. In a similar manner, Equation 1 and Equation 2 can be used to calculate maximum current and/or input voltage limits.

Layout Considerations

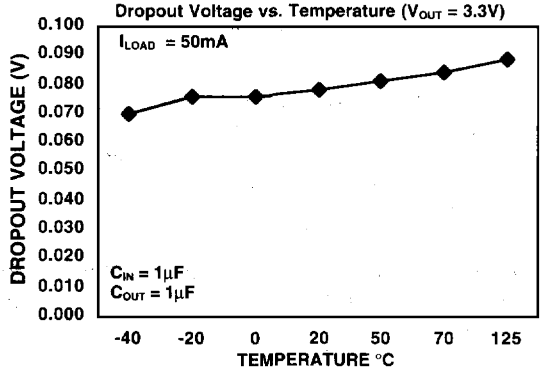
The primary path of heat conduction out of the package is via the package leads. Therefore, layouts having a ground plane, wide traces at the pads, and wide power supply bus lines combine to lower θ_{JA} and therefore increase the maximum allowable power dissipation limit.

TYPICAL CHARACTERISTICS: (Unless otherwise specified, all parts are measured at Temperature = 25°C)

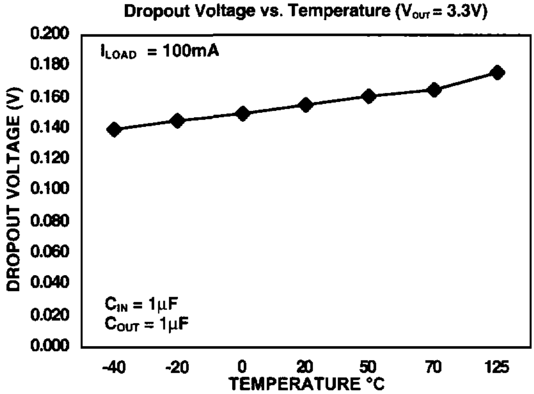
Dropout Voltage vs. Temperature (V_{OUT} = 3.3V)



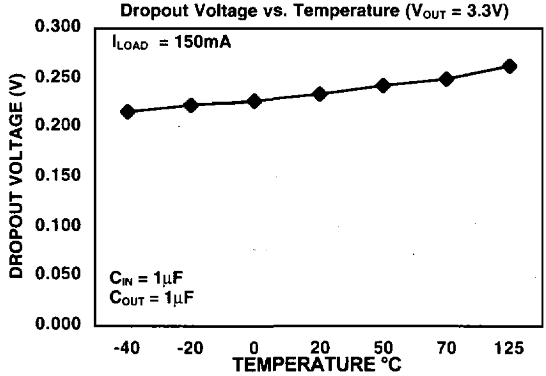
Dropout Voltage vs. Temperature (V_{OUT} = 3.3V)



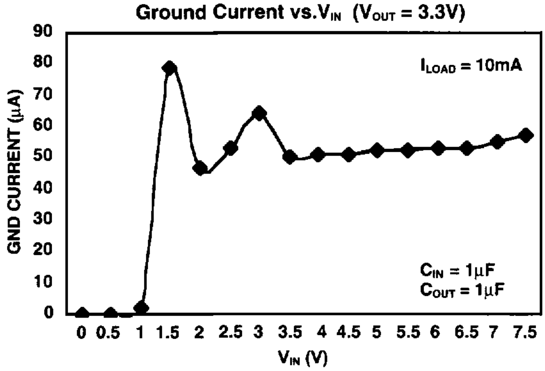
Dropout Voltage vs. Temperature (V_{OUT} = 3.3V)



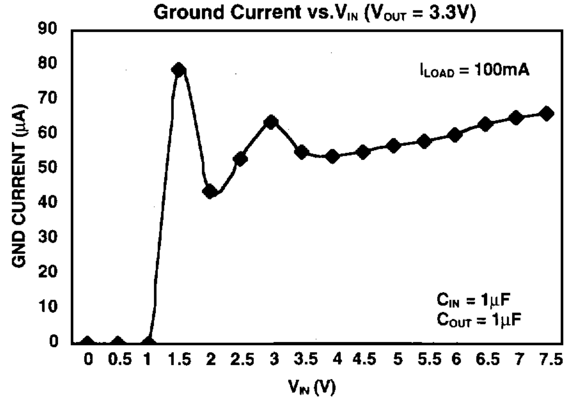
Dropout Voltage vs. Temperature (V_{OUT} = 3.3V)



Ground Current vs. V_{IN} (V_{OUT} = 3.3V)

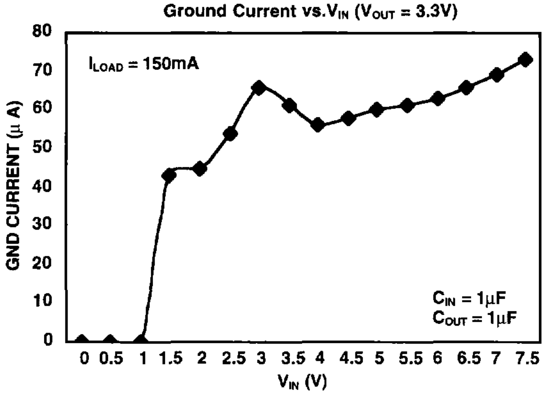


Ground Current vs. V_{IN} (V_{OUT} = 3.3V)

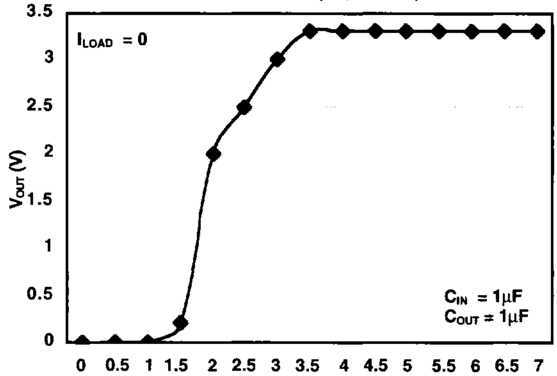


TYPICAL CHARACTERISTICS: (Unless otherwise specified, all parts are measured at Temperature = 25°C

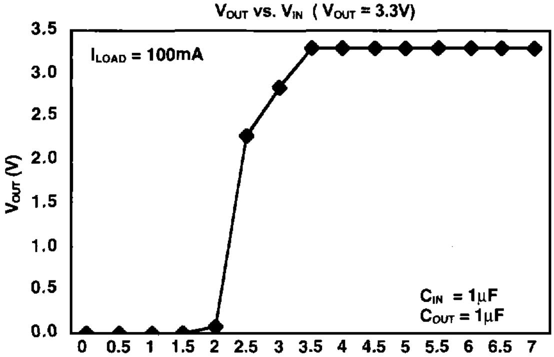
Ground Current vs.V$_{IN}$ (V$_{OUT}$ = 3.3V)



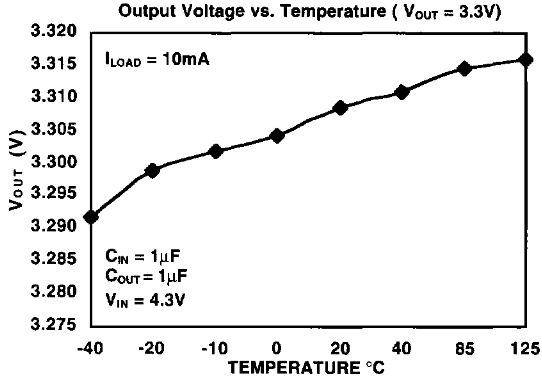
V$_{OUT}$ vs.V$_{IN}$ (V$_{OUT}$ = 3.3V)



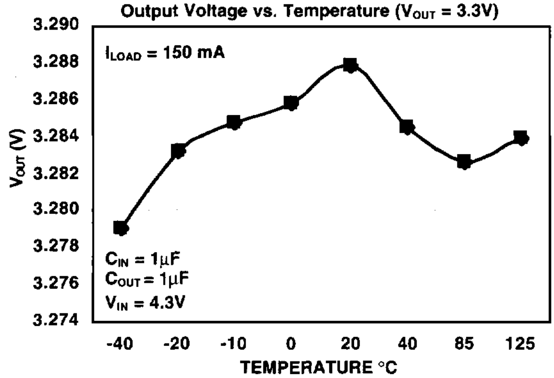
V$_{OUT}$ vs. V$_{IN}$ (V$_{OUT}$ = 3.3V)



Output Voltage vs. Temperature (V$_{OUT}$ = 3.3V)

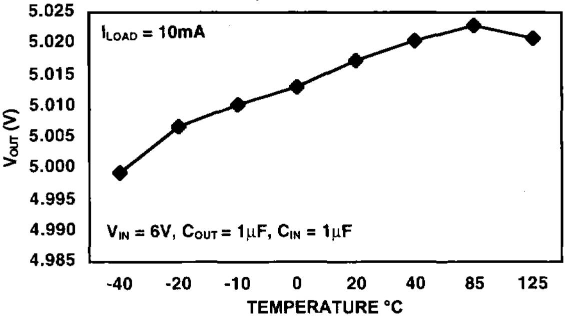


Output Voltage vs. Temperature (V$_{OUT}$ = 3.3V)

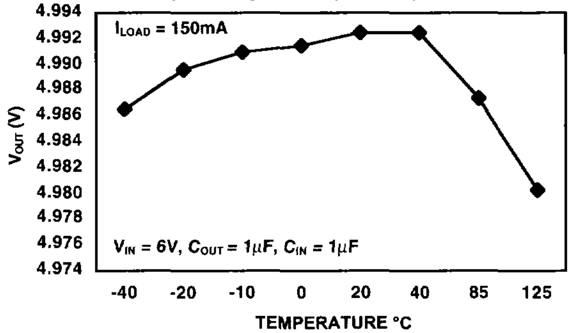


TYPICAL CHARACTERISTICS

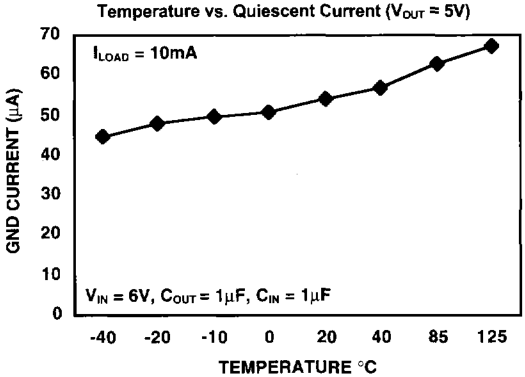
Ouput Voltage vs.Temperature (V_{OUT} = 5V)



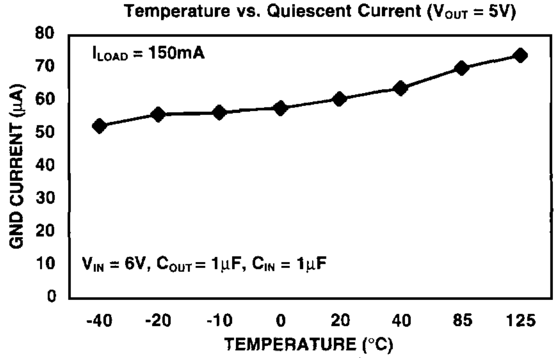
Output Voltage vs.Temperature (V_{OUT} = 5V)



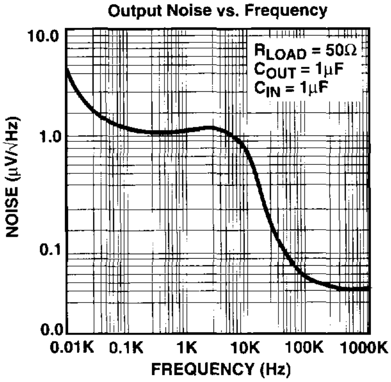
Temperature vs. Quiescent Current (V_{OUT} = 5V)



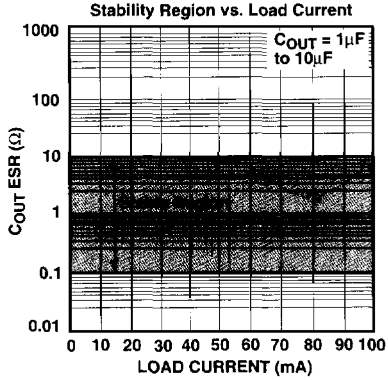
Temperature vs. Quiescent Current (V_{OUT} = 5V)



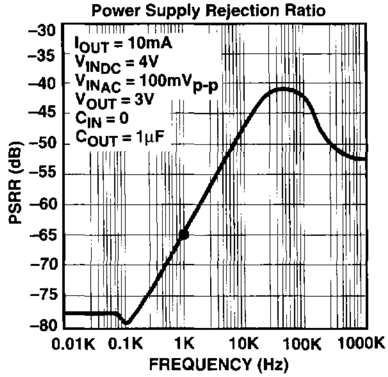
Output Noise vs. Frequency



Stability Region vs. Load Current



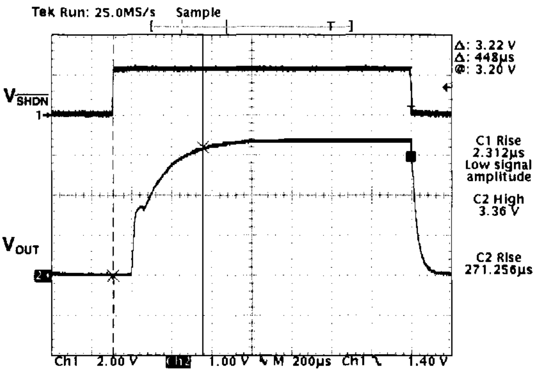
Power Supply Rejection Ratio



TYPICAL CHARACTERISTICS

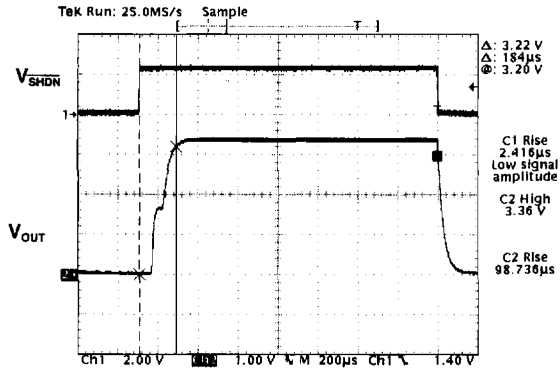
Measure Rise Time of 3.3V LDO with Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Rise Time = 448µS



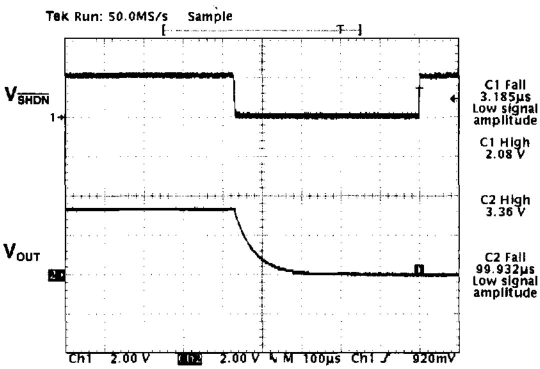
Measure Rise Time of 3.3V LDO without Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Rise Time = 184µS



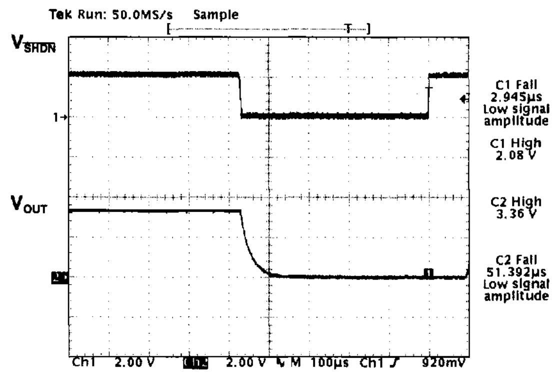
Measure Fall Time of 3.3V LDO with Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 470pF, I_{LOAD} = 50mA
V_{IN} = 4.3V, Temp = 25°C, Fall Time = 100µS



Measure Fall Time of 3.3V LDO without Bypass Capacitor

Conditions: C_{IN} = 1µF, C_{OUT} = 1µF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 4.3V, Temp = 25°C, Fall Time = 52µS



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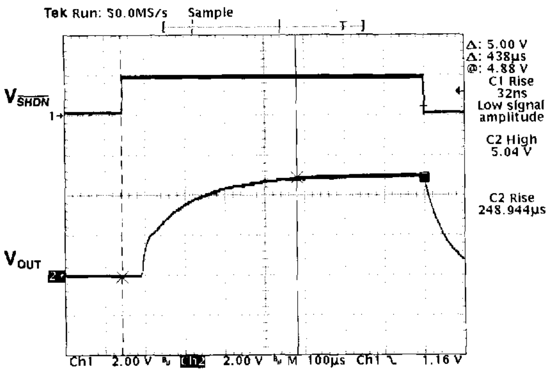
TYPICAL CHARACTERISTICS

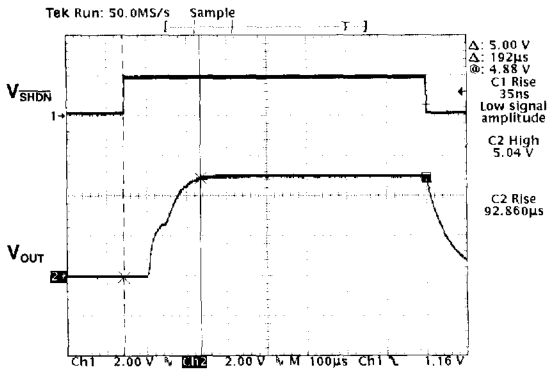
Measure Rise Time of 5.0V LDO with Bypass Capacitor

Conditions: C_{IN} = 1μF, C_{OUT} = 1μF, C_{BYP} = 470pF, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Rise Time = 390μS



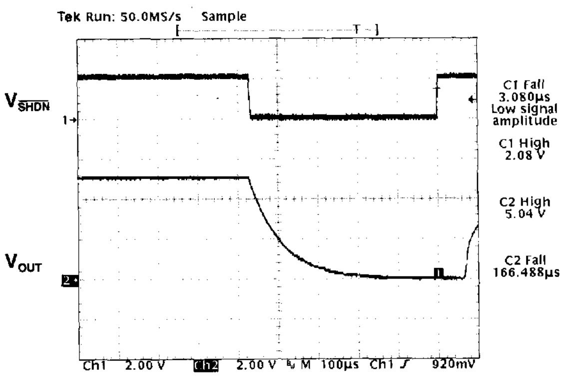
Measure Rise Time of 5.0V LDO without Bypass Capacitor

Conditions: C_{IN} = 1μF, C_{OUT} = 1μF, C_{BYP} = 0, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Rise Time = 192μS



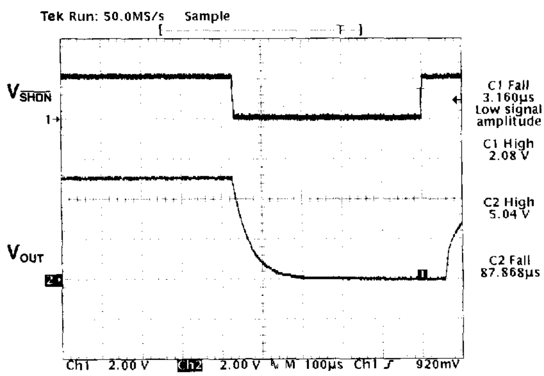
Measure Fall Time of 5.0V LDO with Bypass Capacitor

Conditions: C_{IN} = 1μF, C_{OUT} = 1μF, C_{BYP} = 470pF, I_{LOAD} = 50mA
V_{IN} = 6V, Temp = 25°C, Fall Time = 167μS



Measure Fall Time of 5.0V LDO without Bypass Capacitor

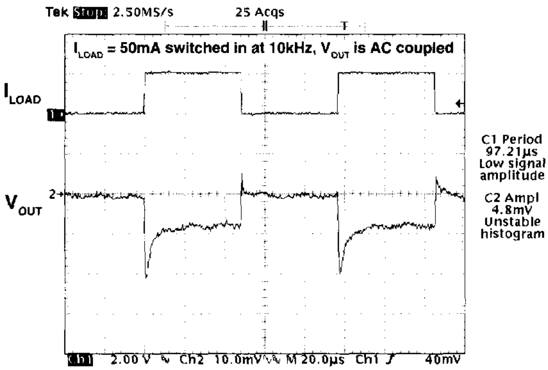
Conditions: C_{IN} = 1μF, C_{OUT} = 1μF, C_{BYP} = 0pF, I_{LOAD} = 100mA
V_{IN} = 6V, Temp = 25°C, Fall Time = 88μS



TYPICAL CHARACTERISTICS

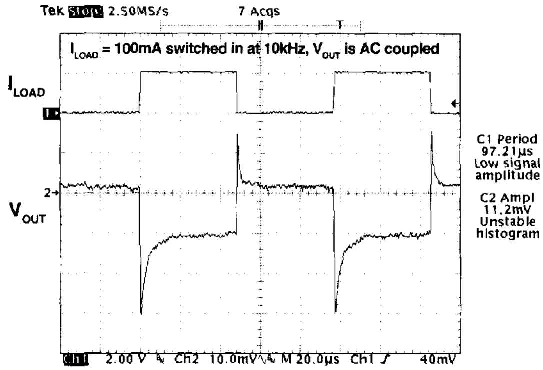
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1μF, C_{OUT} = 2.2μF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



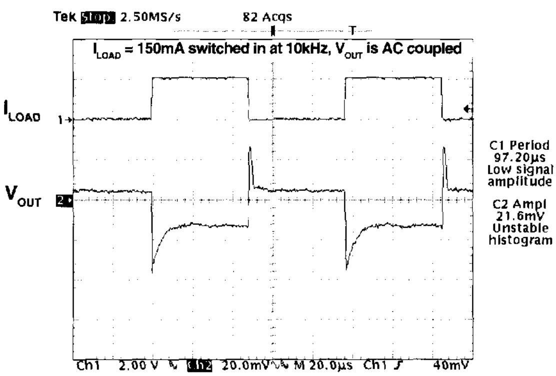
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1μF, C_{OUT} = 2.2μF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



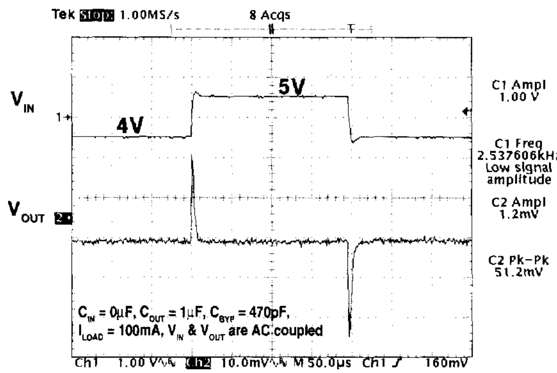
Load Regulation of 3.3V LDO

Conditions: C_{IN} = 1μF, C_{OUT} = 2.2μF, C_{BYP} = 470pF, V_{IN} = V_{OUT} + 0.25V, Temp = 25°C



Line Regulation of 3.3V LDO

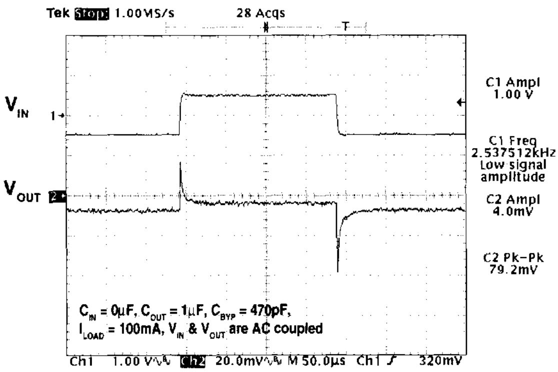
Conditions: V_{IN} = 4V,+ 1V Squarewave @ 2.5kHz,



TYPICAL CHARACTERISTICS

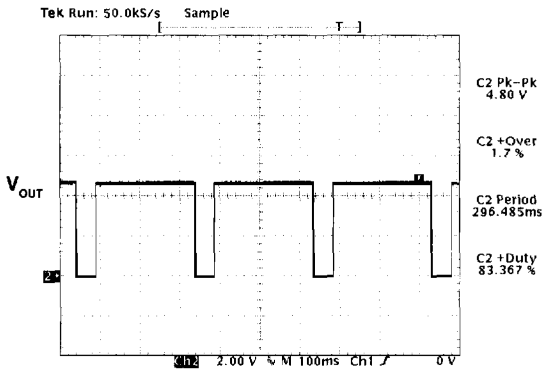
Line Regulation of 5.0V LDO

Conditions: V_{IN} = 6V,+ 1V Squarewave @ 2.5kHz,



Thermal Shutdown Response of 5.0V LDO

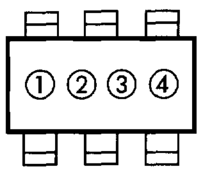
Conditions: V_{IN} = 6V,C_{IN} = 0µF, C_{OUT} = 1µF



I_{LOAD} was increased until temperature of die reached about 160°C, at which time integrated thermal protection circuitry shuts the regulator off when die temperature exceeds approximately 160°C. The regulator remains off until die temperature drops to approximately 150°C.

MARKINGS

SOT-23A-6



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

(V)	TC1072 Code	TC1073 Code
2.5	E1	F1
2.7	E2	F2
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