National Semiconductor

December 2003

LP3995
Micropower 150mA CMOS Voltage Regulator with Active Shutdown

General Description

The LP3995 regulator is designed to meet the requirements of portable wireless battery-powered applications and will provide an accurate output voltage with low noise and low quiescent current.

For battery powered applications the low dropout and low ground current provided by the device allows the lifetime of the battery to be maximized. The Enable(/Disable) control allows the system to further extend the battery lifetime by reducing the power consumption to virtually zero.

The Enable(/Disable) function on the device incorporates an active discharge circuit on the output for faster device shut-down.

The LP3995 also features internal protection against short-circuit currents and over-temperature conditions.

The LP3995 is designed to be stable with small 1.0 µF ceramic capacitors. The small outline of the LP3995 micro SMD package with the required ceramic capacitors can realize a system application within minimal board area.

Performance is specified for a −40˚C to +125˚C temperature range.

The device is available in micro SMD package and LLP package. For other package options contact your local NSC sales office.

The device is available in fixed output voltages in the ranges 1.5V to less than 1.8V and 1.8V to less than 2.5Vand 2.5V to 3.3V. For availability, please contact your local NSC sales office.

Key Specifications

- 2.5V to 6.0V Input Range
- Accurate Output Voltage; ±75mV / 2%
- 60 mV Typical Dropout with 150 mA Load
- Virtually Zero Quiescent Current when Disabled
- Low Output Voltage Noise
- Stable with a 1 µF Output Capacitor
- Guaranteed 150 mA Output Current
- Fast Turn-on; 30 µs (Typ.)
- Fast Turn-off; 175 µs (Typ.)

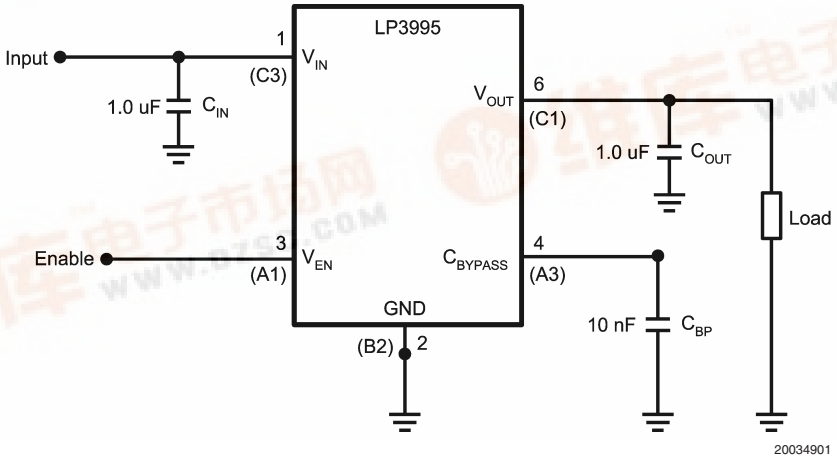
Features

- 5 pin micro SMD Package
- 6 pin LLP Package
- Stable with Ceramic Capacitor
- Logic Controlled Enable
- Fast Turn-on
- Active Disable for Fast Turn-off.
- Thermal-overload and Short-circuit Protection
- −40 to +125˚C Junction Temperature Range for Operation

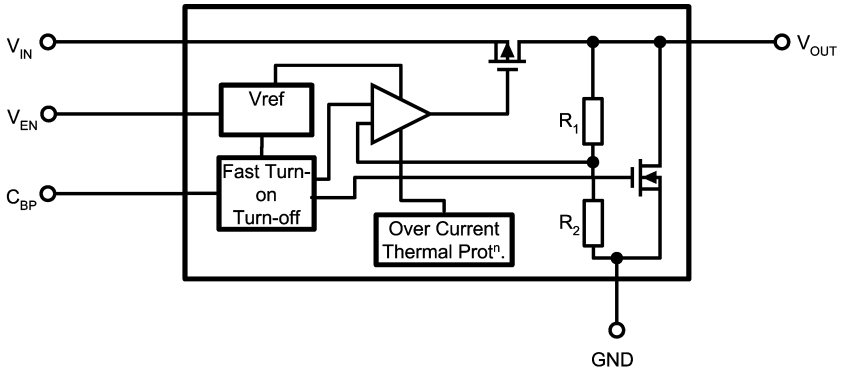
Applications

- GSM Portable Phones
- CDMA Cellular Handsets
- Wideband CDMA Cellular Handsets
- Bluetooth Devices
- Portable Information Appliances

Typical Application Circuit



Block Diagram



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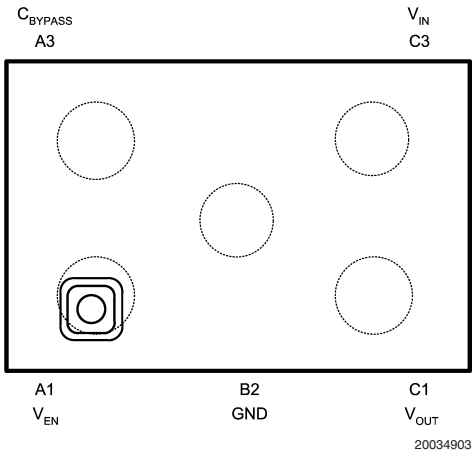
Pin Description

5 pin micro SMD and LLP - 6

Pin No.		Symbol	Name and Function
micro SMD	LLP		
A1	3	V_{EN}	Enable Input; Disables the Regulator when ≤ 0.4V. Enables the regulator when ≥ 0.9V
B2	2	GND	Common Ground
C1	6	V_{OUT}	Voltage output. Connect this output to the load circuit.
C3	1	V_{IN}	Voltage Supply Input
A3	4	C_{BYPASS}	Bypass Capacitor connection. Connect a 0.01 µF capacitor for noise reduction.
	5	N/C	No internal connection. There should not be any board connection to this pin.
	Pad	GND	Ground connection. Connect to ground plane for best thermal conduction.

Connection Diagrams

micro SMD, 5 Bump Package



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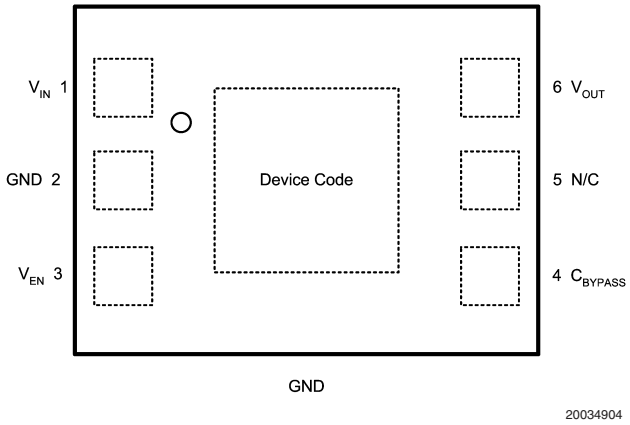
Top View
See NS Package Number TLA05

LLP- 6 Package (SOT23 Footprint)



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Top View
See NS Package Number LDE06A

Ordering Information

For micro SMD Package

Output Voltage (V)	Grade	LP3995 Supplied as 250 Units, Tape and Reel	LP3995 Supplied as 3000 Units, Tape and Reel	Package Marking
1.5	STD	LP3995ITL-1.5	LP3995ITLX-1.5	
1.6	STD	LP3995ITL-1.6	LP3995ITLX-1.6	
1.8	STD	LP3995ITL-1.8	LP3995ITLX-1.8	
1.9	STD	LP3995ITL-1.9	LP3995ITLX-1.9	
2.1	STD	LP3995ITL-2.1	LP3995ITLX-2.1	
2.5	STD	LP3995ITL-2.5	LP3995ITLX-2.5	
2.8	STD	LP3995ITL-2.8	LP3995ITLX-2.8	
3.0	STD	LP3995ITL-3.0	LP3995ITLX-3.0	

For micro SMD Package unleaded

Output Voltage (V)	Grade	LP3995 Supplied as 250 Units, Tape and Reel	LP3995 Supplied as 3000 Units, Tape and Reel	Package Marking
1.5 (Note 2)	STD	LP3995ITL-1.5	LP3995ITLX-1.5	
1.6 (Note 2)	STD	LP3995ITL-1.6	LP3995ITLX-1.6	
1.8 (Note 2)	STD	LP3995ITL-1.8	LP3995ITLX-1.8	
1.9 (Note 2)	STD	LP3995ITL-1.9	LP3995ITLX-1.9	
2.1 (Note 2)	STD	LP3995ITL-2.1	LP3995ITLX-2.1	
2.5 (Note 2)	STD	LP3995ITL-2.5	LP3995ITLX-2.5	
2.8 (Note 2)	STD	LP3995ITL-2.8	LP3995ITLX-2.8	
3.0 (Note 2)	STD	LP3995ITL-3.0	LP3995ITLX-3.0	

For LLP- 6 Package

Output Voltage (V)	Grade	LP3995 Supplied as 1000 Units, Tape and Reel	LP3995 Supplied as 4500 Units, Tape and Reel	Package Marking
1.5	STD	LP3995ILD-1.5	LP3995ILDX-1.5	LO20B
1.6	STD	LP3995ILD-1.6	LP3995ILDX-1.6	LO21B
1.8	STD	LP3995ILD-1.8	LP3995ILDX-1.8	LO22B
1.9 (Note 2)	STD	LP3995ILD-1.9	LP3995ILDX-1.9	LO23B
2.1 (Note 2)	STD	LP3995ILD-2.1	LP3995ILDX-2.1	LO24B
2.5 (Note 2)	STD	LP3995ILD-2.5	LP3995ILDX-2.5	LO25B
2.8	STD	LP3995ILD-2.8	LP3995ILDX-2.8	LO26B
3.0	STD	LP3995ILD-3.0	LP3995ILDX-3.0	LO30B
3.3 (Note 2)	STD	LP3995ILD-3.3	LP3995ILDX-3.3	LO31B

Note 1: Available in sample quantities only

Note 2: For availability contact your local sales office

Absolute Maximum Ratings

(Notes 3, 4)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Input Voltage (V_{IN})	–0.3 to 6.5V
Output Voltage	–0.3 to (V_{IN} + 0.3V) to 6.5V (max)
Enable Input Voltage	–0.3 to 6.5V
Junction Temperature	150˚C
Pad Temperature (Note 5)	
micro SMD	260˚C
LLP	235˚C
Storage Temperature	–65 to +150˚C
ESD (Note 7)	
Human Body Model	2 kV
Machine Model	200V

Operating Ratings (Note 3)

Input Voltage (V_{IN})	2.5 to 6.0V
Enable Input Voltage	0 to 6.0V
Junction Temperature	–40 to +125˚C
Thermal Resistance	
θ_{JA} (micro SMD pkg.)	255˚C/W
θ_{JA} (LLP pkg.)	88˚C/W
Power Dissipation at 25˚C (Note 6)	
micro SMD	392 mW
LLP	1.136 W

Electrical Characteristics

Unless otherwise noted, V_{EN} = 1.5, V_{IN} = V_{OUT} + 1.0V, C_{IN} = 1 µF, I_{OUT} = 1 mA, C_{OUT} = 1 µF, c_{BP} = 0.01 µF. Typical values and limits appearing in normal type apply for T_J = 25˚C. Limits appearing in **boldface** type apply over the full temperature range for operation, –40 to +125˚C. (Note 12)

Symbol	Parameter	Conditions	Typical	Limit		Units
				Min	Max	
V_{IN}	Input Voltage			2.5	6.0	V
DEVICE OUTPUT: 1.5 ≤ V_{OUT} < 1.8V						
ΔV_{OUT}	Output Voltage Tolerance	I_{OUT} = 1 mA		-50	50	mV
				-75	**75**	
	Line Regulation Error	V_{IN} = ($V_{OUT(NOM)}$+1.0V) to 6.0V, I_{OUT} = 1 mA		**-3.5**	**3.5**	mV/V
	micro SMD Load Regulation Error	I_{OUT} = 1 mA to 150 mA	10		**75**	µV/mA
	LLP Load Regulation Error	I_{OUT} = 1 mA to 150 mA	70		**125**	µV/mA
PSRR	Power Supply Rejection Ratio (Note 9)	f = 1 kHz, I_{OUT} = 1 mA	55			dB
		f = 10 kHz, I_{OUT} = 1 mA	53			
DEVICE OUTPUT: 1.8 ≤ V_{OUT} < 2.5V						
ΔV_{OUT}	Output Voltage Tolerance	I_{OUT} = 1 mA		-50	50	mV
				–75	**75**	
	microSMDLine Regulation Error	V_{IN} = ($V_{OUT(NOM)}$+1.0V) to 6.0V, I_{OUT} = 1 mA		**–2.5**	**2.5**	mV/V
	LLP Line Regulation Error	V_{IN} = ($V_{OUT(NOM)}$+1.0V) to 6.0V, I_{OUT} = 1 mA		**–3.5**	**3.5**	mV/V
	micro SMD Load Regulation Error	I_{OUT} = 1 mA to 150 mA	10		**75**	µV/mA
	LLP Load Regulation Error	I_{OUT} = 1 mA to 150 mA	80		**125**	µV/mA
PSRR	Power Supply Rejection Ratio (Note 9)	f = 1 kHz, I_{OUT} = 1 mA	55			dB
		f = 10 kHz, I_{OUT} = 1 mA	50			

Electrical Characteristics (Continued)

Unless otherwise noted, V_{EN} = 1.5, V_{IN} = V_{OUT} + 1.0V, C_{IN} = 1 µF, I_{OUT} = 1 mA, C_{OUT} = 1 µF, c_{BP} = 0.01 µF. Typical values and limits appearing in normal type apply for T_J = 25˚C. Limits appearing in **boldface** type apply over the full temperature range for operation, –40 to +125˚C. (Note 12)

Symbol	Parameter	Conditions	Typical	Limit		Units
				Min	Max	
DEVICE OUTPUT: 2.5 ≤ V_{OUT} ≤ 3.3V						
ΔV_{OUT}	Output Voltage Tolerance	I_{OUT} = 1 mA		-2	2	% of $V_{OUT(NOM)}$
				–3	**3**	
	Line Regulation Error	V_{IN} = ($V_{OUT(NOM)}$+1.0V) to 6.0V, I_{OUT} = 1 mA		**–0.1**	**0.1**	%/V
	micro SMD Load Regulation Error	I_{OUT} = 1 mA to 150 mA	0.0004		**0.002**	%/mA
	LLP Load Regulation Error	I_{OUT} = 1 mA to 150 mA	0.002		**0.005**	%/mA
	Dropout Voltage	I_{OUT} = 1 mA	0.4		**2**	mV
		I_{OUT} = 150 mA	60		**100**	
PSRR	Power Supply Rejection Ratio (Note 9)	f = 1 kHz, I_{OUT} = 1 mA	60			dB
		f = 10 kHz, I_{OUT} = 1 mA	50			
FULL V_{OUT} RANGE						
I_{LOAD}	Load Current	(Notes 8, 9)		0		µA
I_Q	Quiescent Current	V_{EN} = 1.5V, I_{OUT} = 0 mA	85		**150**	µA
		V_{EN} = 1.5V, I_{OUT} = 150 mA	140		**200**	
		V_{EN} = 0.4V	0.003		**1.5**	
I_{SC}	Short Circuit Current Limit		450			mA
E_N	Output Noise Voltage ((Note 9))	BW = 10 Hz to 100 kHz, V_{IN} = 4.2V	25			µVrms
$T_{SHUTDOWN}$	Thermal Shutdown	Temperature	160			˚C
		Hysteresis	20			
ENABLE CONTROL CHARACTERISTICS						
I_{EN}	Maximum Input Current at V_{EN} Input	V_{EN} = 0.0V and V_{IN} = 6.0V	0.001			µA
V_{IL}	Low Input Threshold				**0.4**	V
V_{IH}	High Input Threshold			**0.9**		V
TIMING CHARACTERISTICS						
T_{ON}	Turn On Time (Note 9)	To 95% Level (Note 10)	30			µs
T_{OFF}	Turn Off Time (Note 9)	To 5% Level (Note 11)	175			µs

Note 3: Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test conditions, see the Electrical Characteristics tables.

Note 4: All voltages are with respect to the potential at the GND pin.

Note 5: For information regarding micro SMD and LLP packages please refer to the following application notes;

AN-1112 Micro SMD Package Wafer Level Chip Scale Package,

AN-1187. Leadless Leadframe Package.

Note 6: The maximum power dissipation of the device is dependent on the maximum allowable junction temperature for the device and the ambient temperature. This relationship is given by the formula

$$P_D = (T_J - T_A)/\theta_{JA}$$

Where T_J is the junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

Assuming an ambient temperature of 25˚C, for the maximum operating junction temperature of 125˚C and the micro SMD package θ_{JA} of 255˚C/W, this gives a figure of 392 mW for the allowable power dissipation.

The derating factor (-1/θ_{JA}) = –3.9 mW/˚C, thus below 25˚C the power dissipation figure can be increased by 3.9 mW/˚C, and similarly decreased by this factor for temperatures above 25˚C.

Similarly the numbers for the absolute maximum case can be derived using a figure of 150˚C for the junction temperature.

Note 7: The human body model is an 100 pF discharge through a 1.5 kΩ resistor into each pin. The machine model is a 200 pF capacitor discharged directly into each pin.

Note 8: The device maintains a stable, regulated output voltage without load.

Note 9: This electrical specification is guaranteed by design.

Electrical Characteristics (Continued)

Note 10: Time from V_{EN} = 0.9V to V_{OUT} = 95% ($V_{OUT(NOM)}$)

Note 11: Time from V_{EN} = 0.4V to V_{OUT} = 5% ($V_{OUT(NOM)}$)

Note 12: All limits are guaranteed. All electrical characteristics having room-temperature limits are tested during production at T_J = 25˚C or correlated using Statistical Quality Control methods. Operation over the temperature specification is guaranteed by correlating the electrical characteristics to process and temperature variations and applying statistical process control.

Recommended Output Capacitor

Symbol	Parameter	Conditions	VALUE	Limit		Units
				Min	Max	
C_{OUT}	Output Capacitor	Capacitance (Note 13)	1.0	**0.70**		µF
		ESR		5	500	mΩ

Note 13: The capacitor tolerance should be ±30% or better over the temperature range. The recommended capacitor type is X7R however, dependant on the application X5R, Y5V, and Z5U can also be used.

Input Test Signals

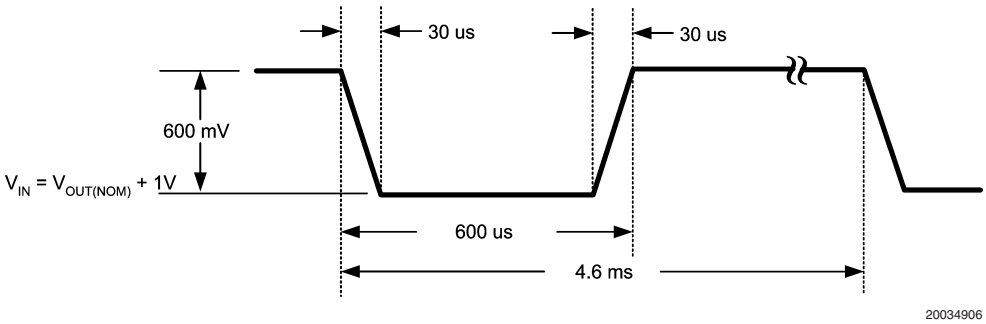


FIGURE 1. Line Transient Response Input Test Signal

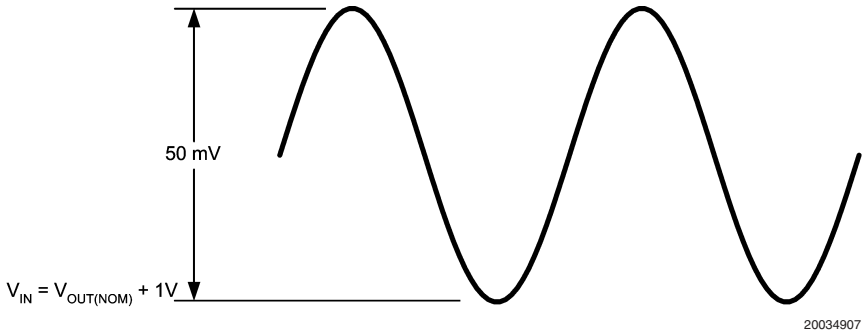
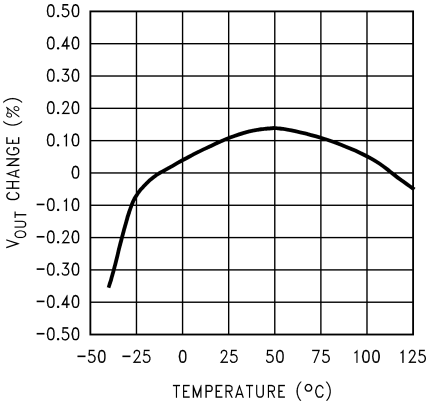


FIGURE 2. PSRR Input Test Signal

Typical Performance Characteristics

Unless otherwise specified, $C_{IN} = C_{OUT} = 1.0$ µF Ceramic, $V_{IN} = V_{OUT} + 1.0V$, $T_A = 25^{\circ}C$, Enable pin is tied to V_{IN}.

Output Voltage Change vs Temperature



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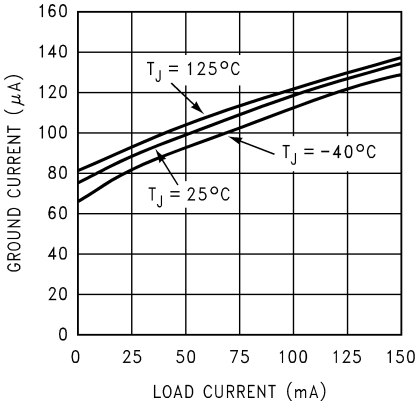
Ground Current vs Load Current (1.8V V_{OUT})



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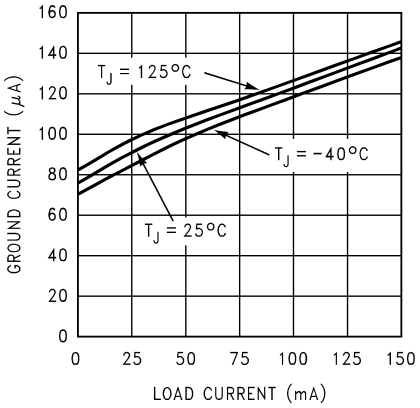
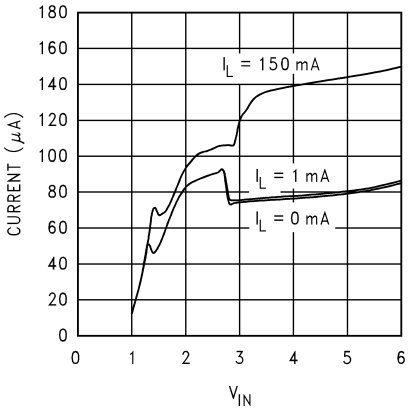
Ground Current vs Load Current (2.8V V_{OUT})



20034912

Ground Current vs V_{IN} @ 25˚C



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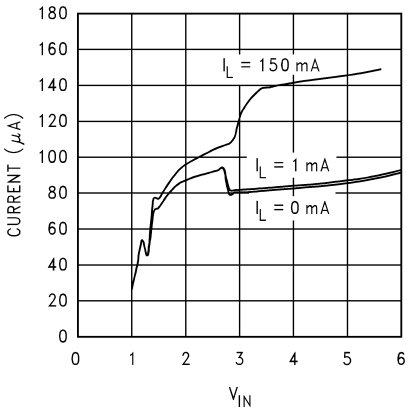
Ground Current vs V_{IN} @ 125˚C



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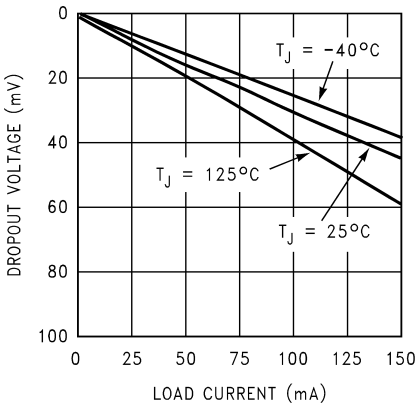
Dropout vs Load Current

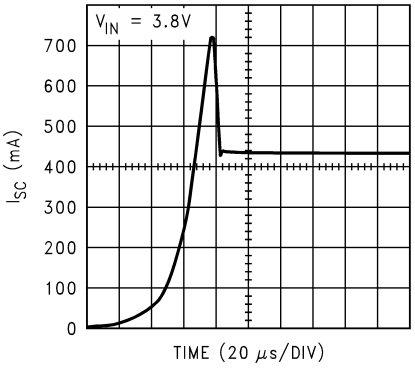


20034915

Typical Performance Characteristics

Unless otherwise specified, C_{IN} = C_{OUT} = 1.0 µF Ceramic, V_{IN} = V_{OUT} + 1.0V, T_A = 25˚C, Enable pin is tied to V_{IN}. (Continued)

Short Circuit Current



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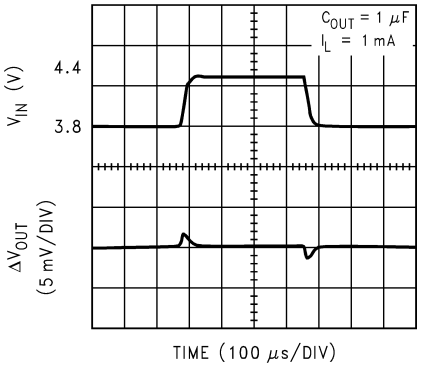
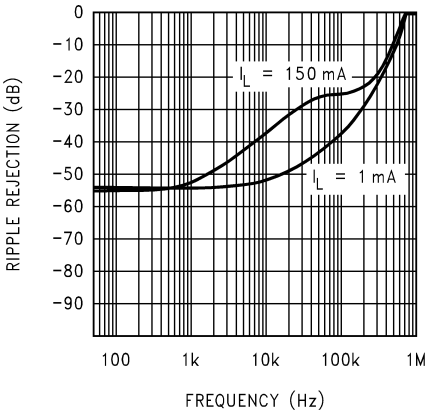
Line Transient Response (V_{OUT} = 2.8V)



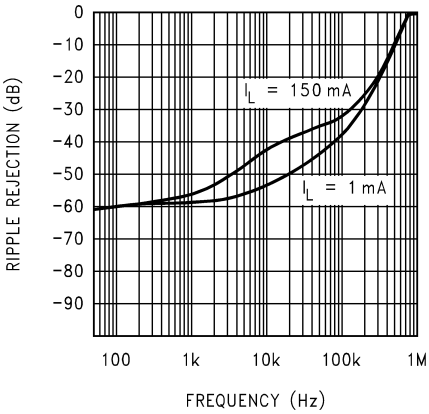
20034917

Ripple Rejection (V_{OUT} = 1.8V)



20034918

Ripple Rejection (V_{OUT} = 2.8V)



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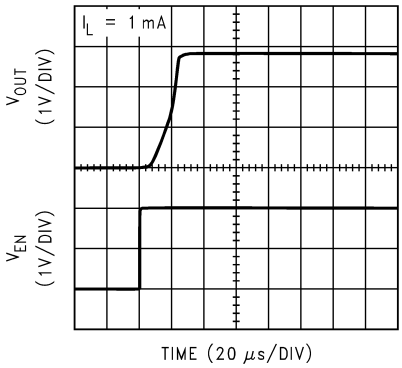
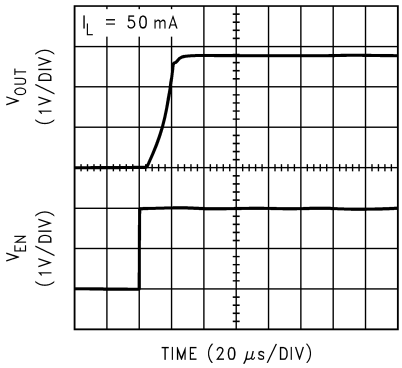
Enable Start-Up Time (V_{OUT} = 2.8V)



20034920

Enable Start-Up Time (V_{OUT} = 2.8V)

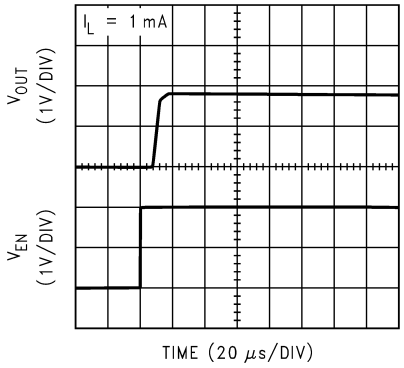


20034921

Typical Performance Characteristics

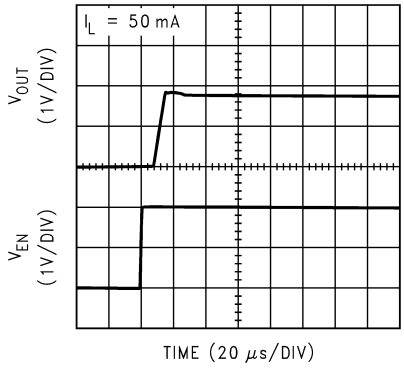
Unless otherwise specified, $C_{IN} = C_{OUT} = 1.0\ \mu F$ Ceramic, $V_{IN} = V_{OUT} + 1.0V$, $T_A = 25^{\circ}C$, Enable pin is tied to V_{IN}. (Continued)

Enable Start-Up Time (V_{OUT} = 1.8V)



20034922

Enable Start-Up Time (V_{OUT} = 1.8V)



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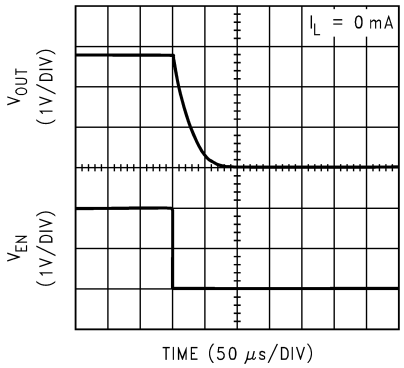
Turn-Off Time (V_{OUT} = 2.8V)



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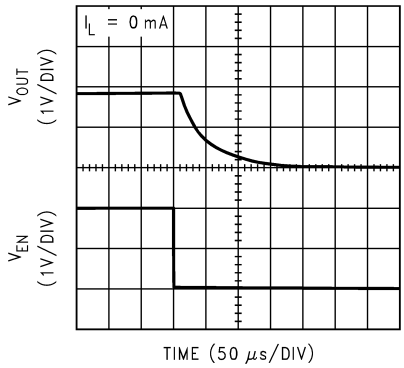
Turn-Off Time (V_{OUT} = 1.8V)



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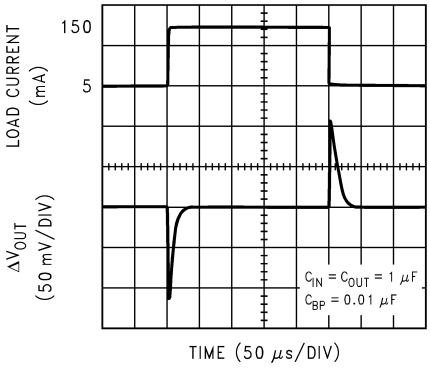
Load Transient Response (V_{OUT} = 2.8V)



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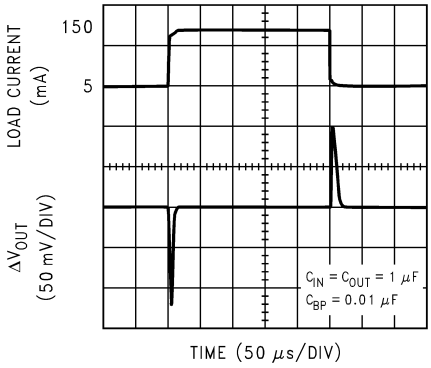
Load Transient Response (V_{OUT} = 1.8V)



20034927

Application Hints

POWER DISSIPATION AND DEVICE OPERATION

The permissible power dissipation for any package is a measure of the capability of the device to pass heat from the power source, the junctions of the IC, to the ultimate heat sink, the ambient environment. Thus the power dissipation is dependent on the ambient temperature and the thermal resistance across the various interfaces between the die and ambient air.

The Thermal Resistance figure

As stated in (Note 6) in the electrical specification section, the allowable power dissipation for the device in a given package can be calculated using the equation:

$$P_D = \frac{(T_{J(MAX)} - T_A)}{\theta_{JA}}$$

With a θ_{JA} = 255˚C/W, the device in the micro SMD package returns a value of 392 mW with a maximum junction temperature of 125˚C.

With a θ_{JA} = 88˚C/W, the device in the LLP package returns a value of 1.136 mW with a maximum junction temperature of 125˚C.

The actual power dissipation across the device can be represented by the following equation:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT}.$$

This establishes the relationship between the power dissipation allowed due to thermal consideration, the voltage drop across the device, and the continuous current capability of the device. These two equations should be used to determine the optimum operating conditions for the device in the application.

EXTERNAL CAPACITORS

In common with most regulators, the LP3995 requires external capacitors to ensure stable operation. The LP3995 is specifically designed for portable applications requiring minimum board space and smallest components. These capacitors must be correctly selected for good performance.

INPUT CAPACITOR

An input capacitor is required for stability. It is recommended that a 1.0 µF capacitor be connected between the LP3995 input pin and ground (this capacitance value may be increased without limit).

This capacitor must be located a distance of not more than 1 cm from the input pin and returned to a clean analogue ground. Any good quality ceramic, tantalum, or film capacitor may be used at the input.

Important: Tantalum capacitors can suffer catastrophic failures due to surge current when connected to a low-impedance source of power (like a battery or a very large capacitor). If a tantalum capacitor is used at the input, it must be guaranteed by the manufacturer to have a surge current rating sufficient for the application.

There are no requirements for the **ESR** (Equivalent Series Resistance) on the input capacitor, but tolerance and temperature coefficient must be considered when selecting the capacitor to ensure the capacitance will remain ≅ 1.0 µF over the entire operating temperature range.

OUTPUT CAPACITOR

The LP3995 is designed specifically to work with very small ceramic output capacitors. A ceramic capacitor (dielectric types Z5U, Y5V or X7R) in the 1.0 [to 10 µF] range, and with ESR between 5 mΩ to 500 mΩ, is suitable in the LP3995 application circuit.

For this device the output capacitor should be connected between the V_{OUT} pin and ground.

It may also be possible to use tantalum or film capacitors at the device output, V_{OUT}, but these are not as attractive for reasons of size and cost (see the section Capacitor Characteristics).

The output capacitor must meet the requirement for the minimum value of capacitance and also have an ESR value that is within the range 5 mΩ to 500 mΩ for stability.

NO-LOAD STABILITY

The LP3995 will remain stable and in regulation with no external load. This is an important consideration in some circuits, for example CMOS RAM keep-alive applications.

CAPACITOR CHARACTERISTICS

The LP3995 is designed to work with ceramic capacitors on the output to take advantage of the benefits they offer. For capacitance values in the range of 1 µF to 4.7 µF, ceramic capacitors are the smallest, least expensive and have the lowest ESR values, thus making them best for eliminating high frequency noise. The ESR of a typical 1 µF ceramic capacitor is in the range of 20 mΩ to 40 mΩ, which easily meets the ESR requirement for stability for the LP3995.

The temperature performance of ceramic capacitors varies by type. Most large value ceramic capacitors (≥ 2.2 µF) are manufactured with Z5U or Y5V temperature characteristics, which results in the capacitance dropping by more than 50% as the temperature goes from 25˚C to 85˚C.

A better choice for temperature coefficient in a ceramic capacitor is X7R. This type of capacitor is the most stable and holds the capacitance within ±15% over the temperature range. Tantalum capacitors are less desirable than ceramic for use as output capacitors because they are more expensive when comparing equivalent capacitance and voltage ratings in the 1 µF to 4.7 µF range.

Another important consideration is that tantalum capacitors have higher ESR values than equivalent size ceramics. This means that while it may be possible to find a tantalum capacitor with an ESR value within the stable range, it would have to be larger in capacitance (which means bigger and more costly) than a ceramic capacitor with the same ESR value. It should also be noted that the ESR of a typical tantalum will increase about 2:1 as the temperature goes from 25˚C down to –40˚C, so some guard band must be allowed.

NOISE BYPASS CAPACITOR

A bypass capacitor should be connected between the C_{BP} pin and ground to significantly reduce the noise at the regulator output. This device pin connects directly to a high impedance node within the bandgap reference circuitry. Any significant loading on this node will cause a change on the regulated output voltage. For this reason, DC leakage current through this pin must be kept as low as possible for best output voltage accuracy.

The use of a 0.01uF bypass capacitor is strongly recommended to prevent overshoot on the output during start-up.

Application Hints (Continued)

The types of capacitors best suited for the noise bypass capacitor are ceramic and film. High quality ceramic capacitors with NPO or COG dielectric typically have very low leakage. Polypropolene and polycarbonate film capacitors are available in small surface-mount packages and typically have extremely low leakage current.

Unlike many other LDO's, the addition of a noise reduction capacitor does not effect the transient response of the device.

ENABLE OPERATION

The LP3995 may be switched ON or OFF by a logic input at the ENABLE pin, V_{EN}. A high voltage at this pin will turn the device on. When the enable pin is low, the regulator output is off and the device typically consumes 3 nA. If the application does not require the shutdown feature, the V_{EN} pin should be tied to V_{IN} to keep the regulator output permanently on. To ensure proper operation, the signal source used to drive the V_{EN} input must be able to swing above and below the specified turn-on/off voltage thresholds listed in the Electrical Characteristics section under V_{IL} and V_{IH}.

FAST TURN OFF AND ON

The controlled switch-off feature of the device provides a fast turn off by discharging the output capacitor via an internal FET device. This discharge is current limited by the RDSon of this switch. Fast turn-on is guaranteed by control circuitry within the reference block allowing a very fast ramp of the output voltage to reach the target voltage.

micro SMD MOUNTING

The micro SMD package requires specific mounting techniques which are detailed in National Semiconductor Application Note AN-1112.

Referring to the section *Surface Mount Technology (SMT) Assembly Considerations*, it should be noted that the pad style which must be used with the 5 pin package is NSMD (non-solder mask defined) type.

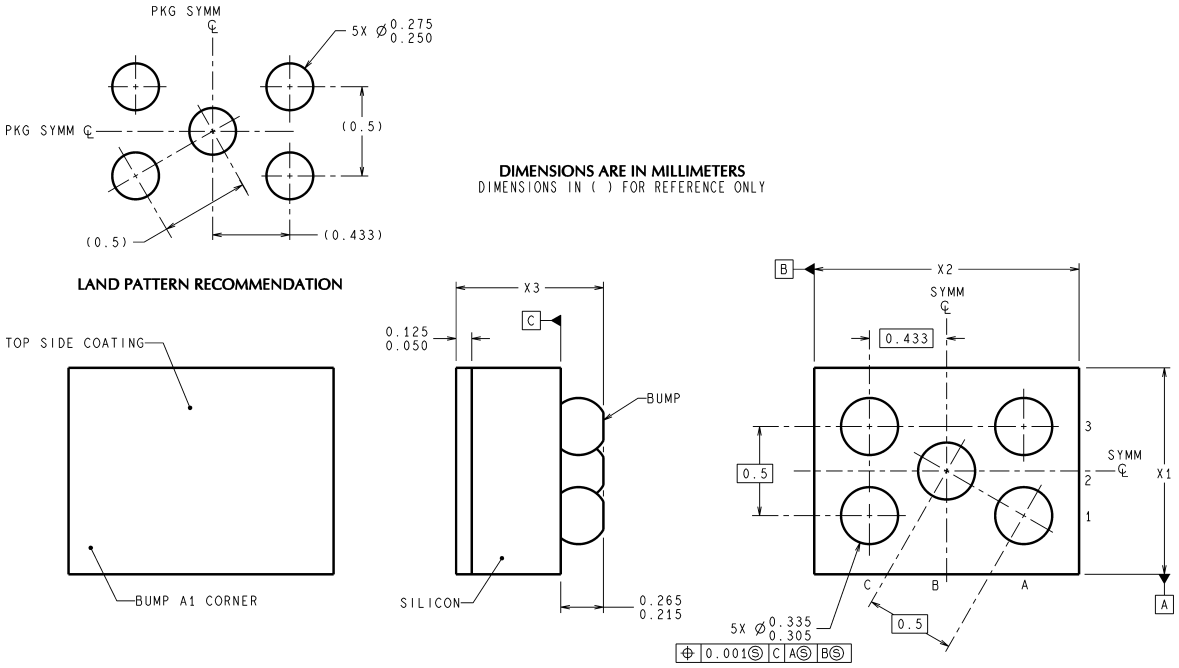
For best results during assembly, alignment ordinals on the PC board may be used to facilitate placement of the micro SMD device.

micro SMD LIGHT SENSITIVITY

Exposing the micro SMD device to direct sunlight will cause incorrect operation of the device. Light sources such as halogen lamps can affect electrical performance if they are situated in proximity to the device.

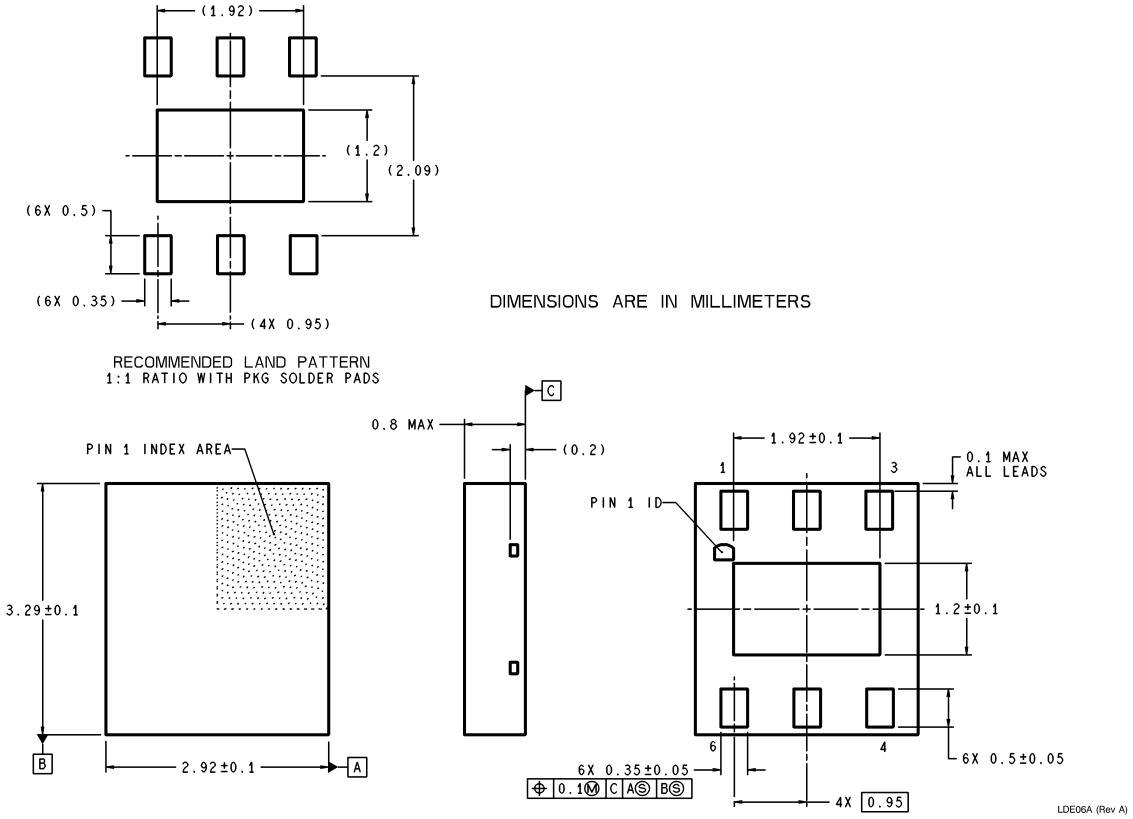
Light with wavelengths in the red and infra-red part of the spectrum have the most detrimental effect thus the fluorescent lighting used inside most buildings has very little effect on performance. Tests carried out on a micro SMD test board showed a negligible effect on the regulated output voltage when brought within 1 cm of a fluorescent lamp. A deviation of less than 0.1% from nominal output voltage was observed.

Physical Dimensions inches (millimeters) unless otherwise noted



micro SMD, 5 Bump, Package (TLA05)
NS Package Number TLA05ADA
The dimensions for X1, X2 and X3 are given as:
X1 = 1.006 +/– 0.03mm
X2 = 1.438 +/– 0.03mm
X3 = 0.600 +/– 0.075mm

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



LLP, 6 Lead, Package (SOT23 Land)
NS Package Number LDE06A

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