500mA Low-Dropout Linear Regulator in UCSP Linear Regulator in

ABSOLUTE MAXIMUM RATINGS

IN, $\overline{SHDN}$, POK, SET to GND ....-0.3V to +6V
OUT to GND ....-0.3V to (V_{IN} + 0.3V)
Output Short-Circuit Duration 1min
Continuous Power Dissipation (T_A = +70°C) (Note 1)
6-Pin UCSP (derate 10.5mW/°C above +70°C) 840mW
Operating Temperature Range ....-40°C to +85°C
Junction Temperature...+150°C
Storage Temperature Range ....-65°C to +150°C
Soldering Temperature (10s)..+300°C

Note 1: Thermal properties are specified with product mounted on PC board with one square-inch of copper area and still air.

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} + 500mV) or V_{IN} = 2.5V, whichever is greater; $\overline{SHDN}$ = IN, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage	V_{IN}			2.5		5.5	V
Input Undervoltage Lockout	V_{UVLO}	Rising, 75mV hysteresis		2.0	2.15	2.3	V
Output Voltage Accuracy (Preset Mode)	V_{OUT}	I_{OUT} = 100mA, T_A = +25°C, V_{OUT} ≥ 2V		-1		+1	%
		I_{OUT} = 100mA, T_A = +25°C, V_{OUT} < 2V		-1.5		+1.5	
		I_{OUT} = 100mA, T_A = -40°C to +85°C		-2.5		+2.5	
		I_{OUT} = 1mA to 500mA, V_{IN} > V_{OUT} + 0.5V, T_A = -40°C to +85°C		-3		+3	
Adjustable Output Voltage Range				1.25		5.00	V
SET Voltage Threshold (Adjustable Mode)	V_{SET}	V_{IN} = 2.7V, I_{OUT} = 100mA, V_{OUT} set to 2V	T_A = 0°C to +85°C	1.225	1.250	1.275	V
			T_A = -40°C to +85°C	1.213		1.288	
Guaranteed Output Current (RMS)	I_{OUT}	V_{IN} ≥ 2.7V		500			mA
Short-Circuit Current Limit	I_{LIM}	V_{OUT} = 0, V_{IN} ≥ 2.7V		0.55	1.39	2.50	A
In-Regulation Current Limit		V_{OUT} > 96% of nominal value, V_{IN} ≥ 2.7V			2		A
SET Dual Mode™ Threshold				50	100	150	mV
SET Input Bias Current	I_{SET}	V_{SET} = 1.25V		-100		+100	nA
Ground-Pin Current	I_Q	I_{OUT} = 100µA			125	250	µA
		I_{OUT} = 500mA			150		
Dropout Voltage (Note 3)	V_{IN} - V_{OUT}	I_{OUT} = 500mA	V_{OUT} = 5V		125	220	mV
			V_{OUT} = 3.3V		133	232	
			V_{OUT} = 2.5V		165	280	
Line Regulation	ΔV_{LNR}	V_{IN} from (V_{OUT} + 100mV) to 5.5V, I_{LOAD} = 5mA		-0.15	0	+0.15	%/V

Dual Mode is a trademark of Maxim Integrated Products, Inc.

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = (V_{OUT} + 500mV) or V_{IN} = 2.5V, whichever is greater; $\overline{SHDN}$ = IN, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Load Regulation	ΔV_{LDR}	I_{OUT} = 1mA to 500mA		0.4	1.0	%
Output Voltage Noise		10Hz to 1MHz, C_{OUT} = 3.3µF (ESR < 0.1Ω)		115		μV_{RMS}
SHUTDOWN						
Shutdown Supply Current	I_{OFF}	$\overline{SHDN}$ = GND, V_{IN} = 5.5V		0.1	15	µA
$\overline{SHDN}$ Input Threshold	V_{IH}	2.5V < V_{IN} < 5.5V	1.6			V
	V_{IL}	2.5V < V_{IN} < 5.5V			0.6	
$\overline{SHDN}$ Input Bias Current	$I_{\overline{SHDN}}$	$\overline{SHDN}$ = IN or GND, T_A = +25°C		1	70	nA
		T_A = +85°C		5		
POK OUTPUT						
POK Output Low Voltage	V_{OL}	POK sinking 1mA		0.01	0.1	V
Operating Voltage Range for Valid POK		POK sinking 100µA	1.0		5.5	V
POK Output High Leakage Current		POK = 5.5V, T_A = +25°C		1	30	nA
		T_A = +85°C		5		
POK Threshold		Rising edge, referred to $V_{OUT(NOMINAL)}$	90	93	96	%
THERMAL PROTECTION						
Thermal Shutdown Temperature	T_{SHDN}			170		°C
Thermal Shutdown Hysteresis	ΔT_{SHDN}			20		°C

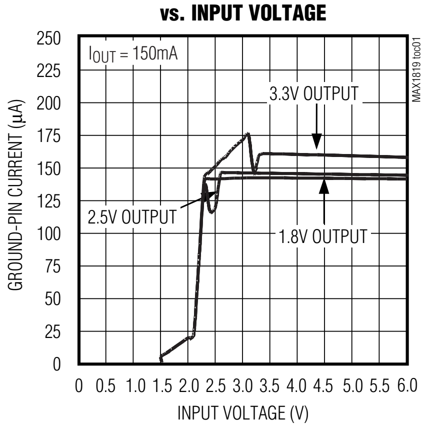
Note 2: All devices are 100% production tested at T_A = +25°C and up to 100mA. Limits over the operating temperature range and above 100mA are guaranteed by design.

Note 3: The dropout voltage is defined as V_{IN} - V_{OUT}, when V_{OUT} is 100mV below the value of V_{OUT} measured for V_{IN} = $V_{OUT(NOM)}$ + 500mV. Since the minimum input voltage is 2.5V, this specification is only meaningful when $V_{OUT(NOM)}$ > 2.5V. For $V_{OUT(NOM)}$ between 2.5V and 3.5V, use the following equations: Typical Dropout = -40mV/V × $V_{OUT(NOM)}$ + 265mV; Guaranteed Maximum Dropout = -60mV/V × $V_{OUT(NOM)}$ + 430mV. For $V_{OUT(NOM)}$ > 3.5V, Typical Dropout = 125mV; Maximum Dropout = 220mV.

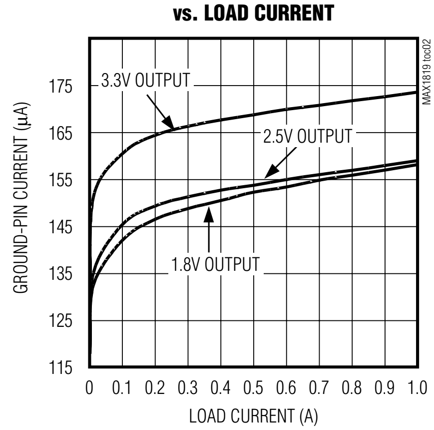
Typical Operating Characteristics

(V_{IN} = (V_{OUT} + 500mV) or 2.5V, whichever is greater; $\overline{SHDN}$ = IN, C_{IN} = 3.3µF, C_{OUT} = 3.3µF, T_A = +25°C, unless otherwise noted.)

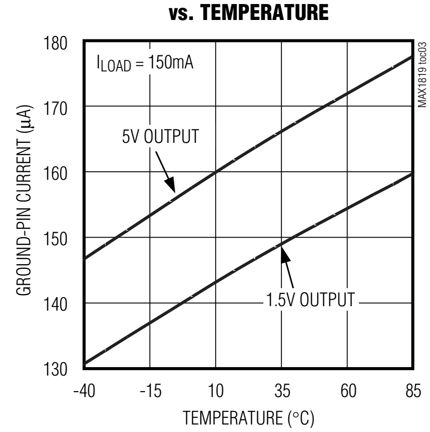
GROUND-PIN CURRENT vs. INPUT VOLTAGE



GROUND-PIN CURRENT vs. LOAD CURRENT



GROUND-PIN CURRENT vs. TEMPERATURE

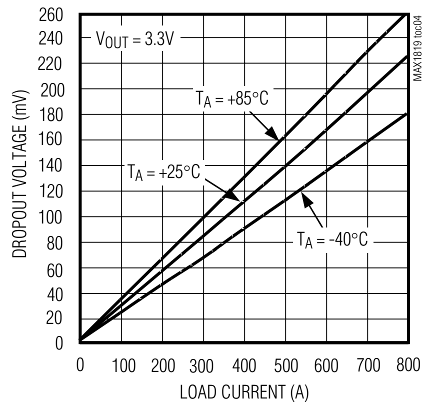


500mA Low-Dropout Linear Regulator in UCSP

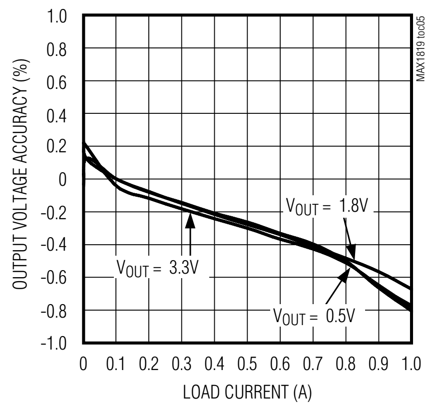
Typical Operating Characteristics (continued)

(V_{IN} = (V_{OUT} + 500mV) or 2.5V, whichever is greater; $\overline{SHDN}$ = IN, C_{IN} = 3.3µF, C_{OUT} = 3.3µF, T_A = +25°C, unless otherwise noted)

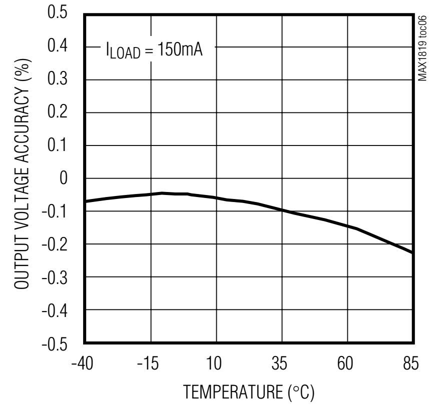
DROPOUT VOLTAGE vs. LOAD CURRENT



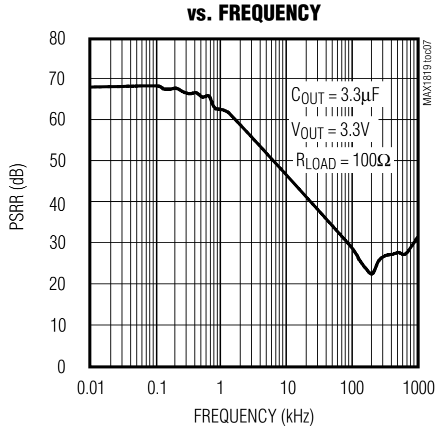
OUTPUT VOLTAGE ACCURACY vs. LOAD CURRENT



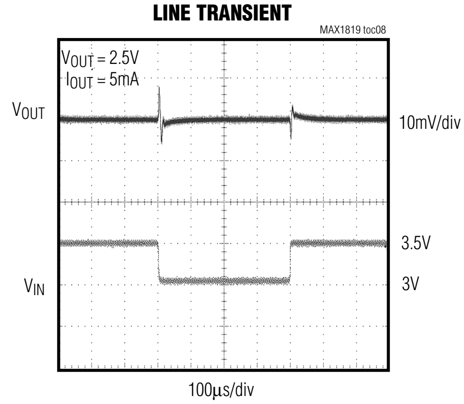
OUTPUT VOLTAGE ACCURACY vs. TEMPERATURE



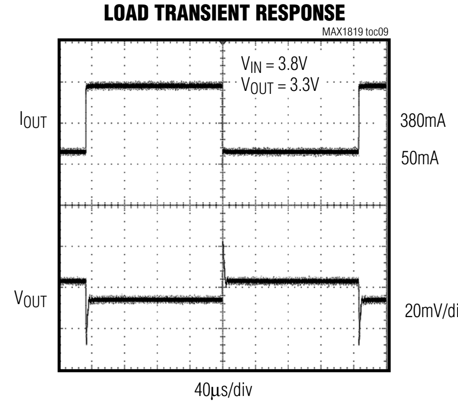
POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



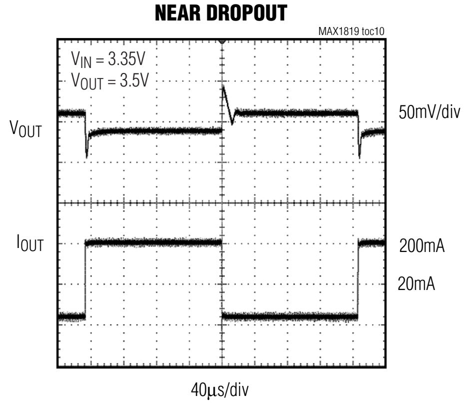
LINE TRANSIENT



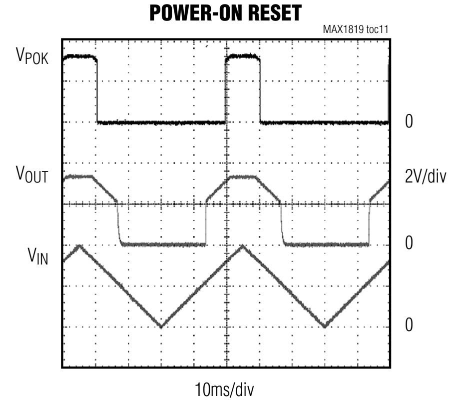
LOAD TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE NEAR DROPOUT

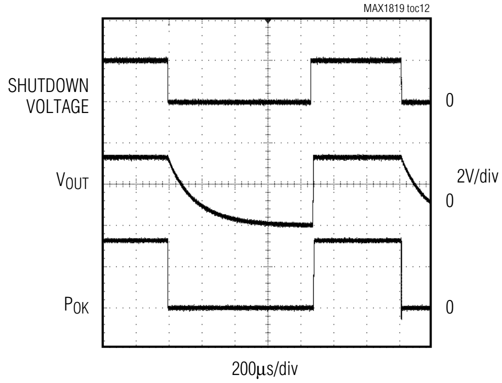


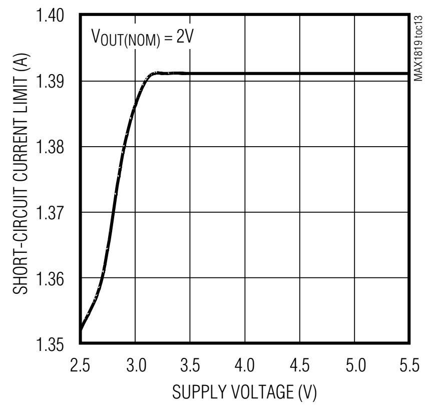
POWER-ON RESET



Typical Operating Characteristics (continued)

(V_{IN} = (V_{OUT} + 500mV) or 2.5V, whichever is greater; $\overline{SHDN}$ = IN, C_{IN} = 3.3µF, C_{OUT} = 3.3µF, T_A = +25°C, unless otherwise noted)





Pin Description

PIN	NAME	FUNCTION
A1	IN	Regulator Input. Supply voltage can range from 2.5V to 5.5V. Bypass with a 1µF capacitor to GND (see the *Capacitor Selection and Regulator Stability* section).
A2	POK	Open-Drain POK Output. POK remains low while the output voltage (V_{OUT}) is below the POK threshold. Connect a 100kΩ pullup resistor from POK to OUT to obtain an output voltage.
A3	$\overline{SHDN}$	Active-Low Shutdown Input. A logic low reduces supply current below 15µA. In shutdown, the POK and OUT are low. Connect to IN for normal operation.
C1	OUT	Regulator Output. Sources up to 500mA. Bypass with a 3.3µF low-ESR capacitor to GND. Use a 4.7µF capacitor for output voltages below 2V.
C2	SET	Voltage-Setting Input. Connect to GND for preset output. Connect to a resistive voltage-divider between OUT and GND to set the output voltage between 1.25V and 5V.
C3	GND	Ground

Detailed Description

The MAX1819 is a low-dropout, low-quiescent-current linear regulator designed primarily for battery-powered applications. The device supplies loads up to 500mA and is available with preset output voltages. As illustrated in Figure 1, the MAX1819 consists of a 1.25V reference, error amplifier, P-channel pass transistor, and internal feedback voltage-divider.

The 1.25V reference is connected to the error amplifier, which compares this reference with the feedback voltage and amplifies the difference. If the feedback voltage is lower than the reference voltage, the pass-transistor gate is pulled lower, which allows more current to pass to the output and increases the output voltage. If the feedback voltage is too high, the pass-transistor gate is pulled up, allowing less current to pass to the output.

The output voltage is fed back through either an internal resistive-divider connected to OUT or an external resistor network connected to SET. The Dual Mode comparator examines V_{SET} and selects the feedback path. If V_{SET} is below 50mV, the internal feedback path is used and the output is regulated to the factory-preset voltage.

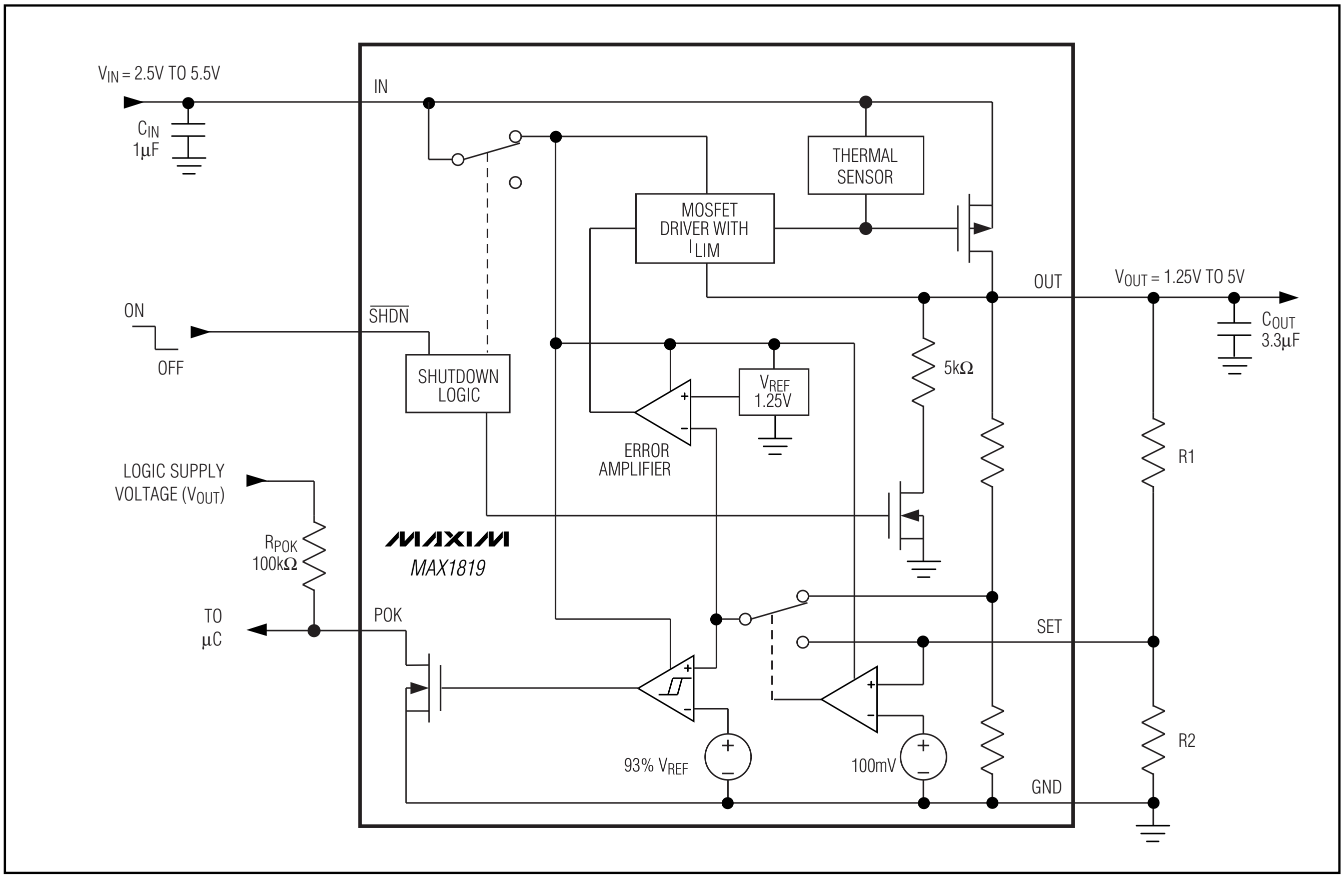


Figure 1. Functional Diagram

Additional blocks include an output current limiter, thermal sensor, and shutdown logic.

Internal P-Channel Pass Transistor

The MAX1819 features a 0.25Ω P-channel MOSFET pass transistor. Unlike similar designs using PNP pass transistors, P-channel MOSFETs require no base drive, which reduces quiescent current. PNP-based regulators also waste considerable current in dropout when the pass transistor saturates and use high base-drive currents under large loads. The MAX1819 does not suffer from these problems and consumes only 125µA of quiescent current under heavy loads as well as in dropout.

Output Voltage Selection

The MAX1819's Dual Mode allows operation in either a preset voltage mode or an adjustable mode. Connect SET to GND to select the preset output voltage. The two-digit part number suffix identifies the output voltage (see the *Selector Guide*). For example, the MAX1819EBL33 has a preset 3.3V output voltage.

The output voltage may also be adjusted by connecting a voltage-divider from OUT to SET to GND (Figure 2). Select R2 in the 25kΩ to 100kΩ range. Calculate R1 with the following equation:

$$R1 = R2\,[(V_{OUT} / V_{SET}) - 1]$$

where V_{SET} = 1.25V, and V_{OUT} may range from 1.25V to 5V.

Shutdown

Pull $\overline{SHDN}$ low to enter shutdown. During shutdown, the output is disconnected from the input and supply current drops to 0.1µA. When in shutdown, POK and OUT pull low. $\overline{SHDN}$ can be pulled as high as 6V, regardless of the input and output voltage.

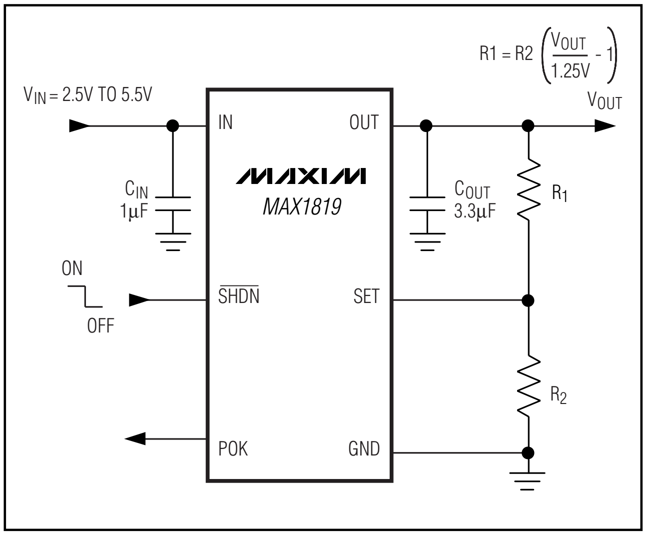


Figure 2. Adjustable Output Using External Feedback Resistors

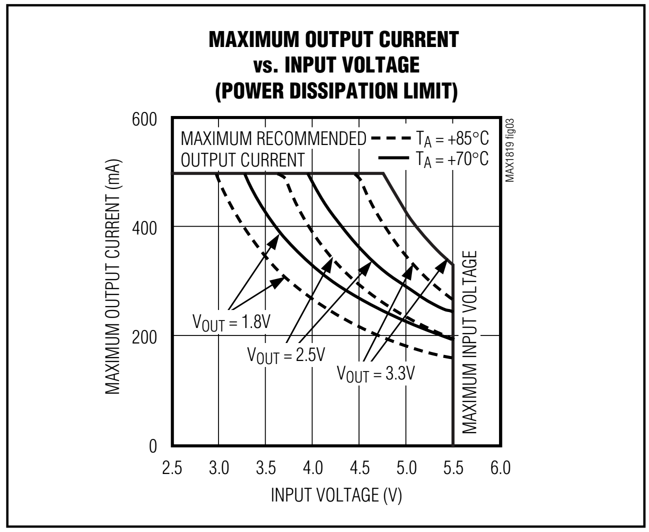


Figure 3. Power Operating Regions—Maximum Output vs. Supply Voltage

POK Output

The power-OK (POK) output pulls low when OUT is less than 93% of the nominal regulation voltage. Once OUT exceeds 93% of the nominal voltage, POK goes high impedance. POK is an open-drain N-channel output. To obtain a voltage signal, connect a pullup resistor from POK to OUT. A 100kΩ resistor works well for most applications. POK can be used as a power-OK signal to a microcontroller (µC), or drive an external LED to indicate power failure. When the MAX1819 is shut down, POK is held low independent of the output voltage. If unused, leave POK grounded or unconnected.

Current Limit

The MAX1819 monitors and controls the pass transistor's gate voltage, limiting the output current to 1.0A (typ). This current limit doubles when the output voltage is within 4% of the nominal value to improve performance with large load transients.

Thermal Overload Protection

Thermal overload protection limits total power dissipation in the MAX1819. When the junction temperature exceeds T_J = +170°C, a thermal sensor turns off the pass transistor, allowing the IC to cool. The thermal sensor turns the pass transistor on again after the junction temperature cools by 20°C, resulting in a pulsed output during continuous thermal overload conditions. Thermal overload protection protects the MAX1819 in the event of fault conditions. For continuous operation, do not exceed the absolute maximum junction-temperature rating of T_J = +150°C.

Operating Region and Power Dissipation

The MAX1819's maximum power dissipation depends on the thermal resistance of the IC package and circuit board, the temperature difference between the die junction and ambient air, and the rate of air flow. The power dissipated in the device is $P = I_{OUT} \times (V_{IN} - V_{OUT})$. The maximum allowed power dissipation is 840mW at T_A = +70°C or:

$$P_{MAX} = (T_{J(MAX)} - T_A) / (\theta_{JB} + \theta_{BA})$$

where $T_J - T_A$ is the temperature difference between the MAX1819 die junction and the surrounding air, θ_{JB} is the thermal resistance of the junction to the base, and θ_{BA} is the thermal resistance through the PC board, copper traces, and other materials to the surrounding air. For best heatsinking, the copper area should be equally shared between the IN, OUT, and GND pins.

The MAX1819 delivers up to 0.5A RMS and operates with input voltages up to 5.5V, but not simultaneously. High output currents can only be sustained when input-output differential voltages are low, as shown in Figure 3.

Applications Information

Capacitor Selection and Regulator Stability

Capacitors are required at the MAX1819's input and output for stable operation over the full temperature range and with load currents up to 500mA. Connect a 1µF capacitor between IN and ground and a 3.3µF low-ESR capacitor between OUT and ground. For output voltages less than 2V, use a 4.7µF low-ESR output capacitor. The input capacitor (C_{IN}) lowers the source impedance of the input supply. Reduce noise and improve load-transient response, stability, and power-supply rejection by using larger output capacitors, such as 10µF.

The output capacitor's (C_{OUT}) equivalent series resistance (ESR) affects stability and output noise. Use output capacitors with an ESR of 0.1Ω or less to ensure stability and optimum transient response. Surface-mount ceramic capacitors have very low ESR and are commonly available in values up to 10µF. C_{IN} and C_{OUT} use short traces to connect to the MAX1819.

Noise, PSRR, and Transient Response

The MAX1819 is designed to operate with low dropout voltages and low quiescent currents in battery-powered systems while still maintaining good noise, transient response, and AC rejection. See the *Typical Operating Characteristics* for a plot of Power-Supply Rejection Ratio (PSRR) vs. Frequency. When operating from noisy sources, improved supply-noise rejection and transient response can be achieved by increasing the values of the input and output bypass capacitors and through passive filtering techniques.

The MAX1819 load-transient response (see the *Typical Operating Characteristics*) shows two components of the output response: a DC shift from the output impedance due to the load current change, and the transient response. Increasing the output capacitor's value and decreasing the ESR attenuates the overshoot.

Input-Output (Dropout) Voltage

A regulator's minimum input-to-output voltage differential (dropout voltage) determines the lowest usable supply voltage. In battery-powered systems, this determines the useful end-of-life battery voltage. Because the MAX1819 uses a P-channel MOSFET pass transistor, its dropout voltage is a function of drain-to-source on-resistance ($R_{DS(ON)}$) multiplied by the load current (see the *Typical Operating Characteristics*).

$$V_{DROPOUT} = V_{IN} - V_{OUT} = R_{DS(ON)} \times I_{OUT}$$

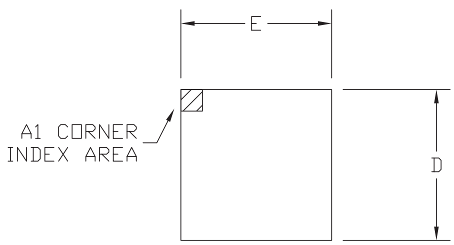
The MAX1819 ground current remains at approximately 150µA in dropout.

Chip Information

TRANSISTOR COUNT: 845

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

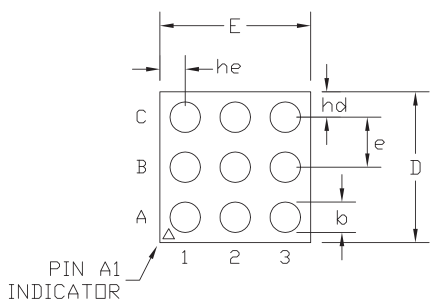


TOP VIEW

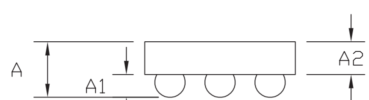
SYMBOL	DIMENSIONS
A	0.60±0.05
D	1.52±0.05
E	1.52±0.05
e	0.50 BASIC
b	ø 0.35 BASIC
A1	0.27±0.04
A2	0.33 Ref.
hd	0.26 Ref.
he	0.26 Ref.

SOLDER BALL DEPOPULATION	
PKG. CODE	DEPOPULATED BALL
B9-1	NONE
B9-2	B2
B9-3	B1, B2, B3

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MEETS JEDEC M0195.



BOTTOM VIEW



SIDE VIEW

PROPRIETARY INFORMATION

TITLE:

PACKAGE OUTLINE, 3x3 UCSP

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0093	E	1/1