19-1812; Rev 0; 1/01

500mA, Low-Dropout, Ripple-Rejecting LDO in µMAX

MAX1857

General Description

The MAX1857 low-dropout linear regulator operates from a +2.5V to +5.5V supply and delivers a guaranteed 500mA load current with low 120mV dropout. The high-accuracy (±1%) output voltage is preset at an internally trimmed 4.75V or can be adjusted from 1.25V to 5.0V with an external resistive divider.

An internal PMOS pass transistor allows the low 135µA supply current to remain independent of load, making this device ideal for portable battery-operated equipment such as personal digital assistants (PDAs), cellular phones, cordless phones, base stations, and notebook computers.

Other features include an active-low open-drain reset output with a 4.5ms timeout period that indicates when the output is out of regulation, a 0.1µA shutdown mode, short-circuit protection, and thermal shutdown protection. The device is available in a miniature 8-pin µMAX package. For higher power applications, refer to the MAX1792 and MAX1793 data sheets.

Features

- **Guaranteed 500mA Output Current**
- **Low 120mV Dropout at 500mA**
- **Up to ±1% Output Voltage Accuracy**
  - **Preset at 4.75V**
  - **Adjustable from 1.25V to 5.0V**
- **Reset Output with 4.5ms Timeout Period**
- **Low 135µA Ground Current**
- **0.1µA Shutdown Current**
- **Thermal Overload Protection**
- **Output Current Limit**
- **Tiny µMAX Package**

Applications

Notebook Computers

Cellular and Cordless Telephones

PDAs

Palmtop Computers

Base Stations

USB Hubs

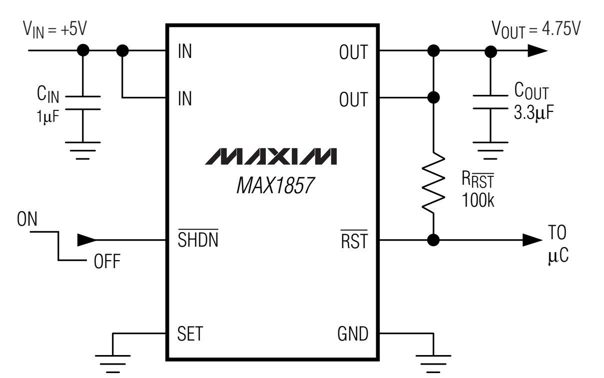
Docking Stations

Ordering Information

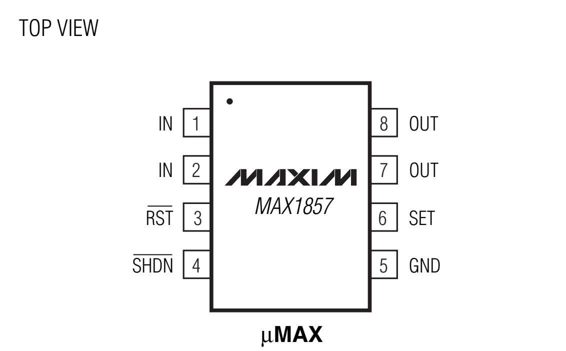
PART*	TEMP. RANGE	PIN-PACKAGE
MAX1857EUA47	-40°C to +85°C	8 µMAX

*Contact factory for other preset output voltages.

Typical Operating Circuit



Pin Configuration



500mA, Low-Dropout, Ripple-Rejecting LDO in µMAX

ABSOLUTE MAXIMUM RATINGS

IN, $\overline{SHDN}$, $\overline{RST}$, SET to GND ....-0.3V to +6V
OUT to GND ....-0.3V to (V_{IN} + 0.3V)
Output Short-Circuit Duration ....Indefinite
Continuous Power Dissipation (T_A = +70°C)
8-Pin µMAX (derate 4.5mW/°C above +70°C) 362mW

Operating Temperature Range ....-40°C to +85°C
Junction Temperature ....+150°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s) ....+300°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} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, **T_A = 0°C to +85°C**, unless otherwise noted. Typical values are at T_A = +25°C.)

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 = +85°C, V_{OUT} ≥ 2.5V	-1		+1	%
		I_{OUT} = 100mA, T_A = +85°C, V_{OUT} < 2.5V	-1.5		+1.5	
		I_{OUT} = 100mA, T_A = 0°C to +85°C	-2		+2	%
		I_{OUT} = 1mA to 500mA, V_{IN} > V_{OUT} + 0.5V, T_A = 0°C to +85°C	-3		+3	
Adjustable Output Voltage Range		V_{SET} = 1.25V	1.25		5	V
SET Voltage Threshold (Adjustable Mode)	V_{SET}	V_{IN} = +2.7V, V_{OUT} set to 2.0V, I_{OUT} = 100mA, T_A = +85°C	1.229	1.250	1.271	V
		V_{IN} = +2.7V, V_{OUT} set to 2.0V, I_{OUT} = 100mA, T_A = 0°C to +85°C	1.219		1.281	
Maximum Output Current	I_{OUT}	V_{IN} ≥ 2.7V	500			mA_{RMS}
Short-Circuit Current Limit	I_{LIM}	V_{OUT} = 0, V_{IN} ≥ 2.7V	0.55	1.2	2.2	A
In-Regulation Current Limit		V_{OUT} > 96% of nominal value, V_{IN} ≥ 2.7V		2.0		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} = 1mA		135	250	µA
		I_{OUT} = 500mA		175		
Dropout Voltage (Note 1)	V_{IN} - V_{OUT}	I_{OUT} = 500mA		120	175	mV
Line Regulation	ΔV_{LNR}	V_{IN} from (V_{OUT} + 100mV) to 5.5V, I_{LOAD} = 5mA	-0.15	0	+0.15	%/V
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		$\overline{SHDN}$ = IN or GND		10	100	nA

Dual Mode is a trademark of Maxim Integrated Products.

ELECTRICAL CHARACTERISTICS (continued)

((V_{IN} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, **T_A = 0°C to +85°C**, unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
RESET OUTPUT						
Reset Output Low Voltage	V_{OL}	$\overline{RST}$ sinking 1mA		0.01	0.1	V
Operating Voltage Range for Valid Reset		$\overline{RST}$ sinking 100µA	1.0		5.5	V
$\overline{RST}$ Output High Leakage Current		$V_{\overline{RST}}$ = +5.5V			100	nA
$\overline{RST}$ Threshold		Rising edge, referred to $V_{OUT(NOMINAL)}$	83	86	89	%
$\overline{RST}$ Release Delay	t_{RP}	Rising edge of OUT to rising edge of $\overline{RST}$	1.4	4.5	8	ms
THERMAL PROTECTION						
Thermal Shutdown Temperature	T_{SHDN}			170		°C
Thermal Shutdown Hysteresis	ΔT_{SHDN}			20		°C

ELECTRICAL CHARACTERISTICS

(V_{IN} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
Input Voltage	V_{IN}		2.5	5.5	V
Input Undervoltage Lockout	V_{UVLO}	Rising or falling	2.0	2.3	V
Output Voltage Accuracy (Preset Mode)	V_{OUT}	I_{OUT} = 1mA to 500mA	-3	+3	%
Adjustable Output Voltage Range		V_{SET} = 1.25V	1.25	5	V
SET Voltage Threshold (Adjustable Mode)	V_{SET}	I_{OUT} = 100mA	1.212	1.288	V
Maximum Output Current	I_{OUT}		500		mA_{RMS}
Short-Circuit Current Limit	I_{LIM}	V_{OUT} = 0	0.55	2.2	A
SET Dual Mode Threshold			50	150	mV
SET Input Bias Current	I_{SET}	V_{SET} = 1.25V	-100	+100	nA
Ground-Pin Current	I_Q	I_{OUT} = 1mA		250	µA
Dropout Voltage (Note 1)	V_{IN} - V_{OUT}	I_{OUT} = 500mA		175	mV
Line Regulation	ΔV_{LNR}	V_{IN} from (V_{OUT} + 100mV) to 5.5V, I_{LOAD} = 5mA	-0.15	+0.15	%/V
Load Regulation	ΔV_{LDR}	I_{OUT} = 1mA to 500mA		1.0	%
SHUTDOWN					
Shutdown Supply Current	I_{OFF}	$\overline{SHDN}$ = GND, V_{IN} = +5.5V		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		$\overline{SHDN}$ = IN or GND		100	nA

500mA, Low-Dropout, Ripple-Rejecting LDO in µMAX

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
RESET OUTPUT					
Reset Output Low Voltage	V_{OL}	$\overline{RST}$ sinking 1mA		0.1	V
Operating Voltage Range for Valid Reset		$\overline{RST}$ sinking 100µA	1.0	5.5	V
$\overline{RST}$ Output High Leakage Current		$V_{\overline{RST}}$ = +5.5V		100	nA
$\overline{RST}$ Threshold		Rising edge, referred to $V_{OUT(NOMINAL)}$	83	89	%
$\overline{RST}$ Release Delay	t_{RP}	Rising edge of OUT to rising edge of $\overline{RST}$	1.4	8	ms

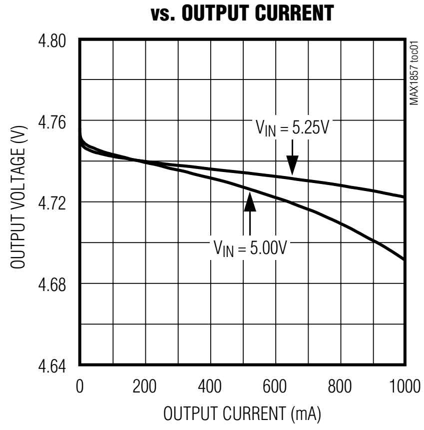
Note 1: Dropout voltage is defined as V_{IN} - V_{OUT}, when V_{OUT} is 100mV below the value of V_{OUT} measured when V_{IN} = $V_{OUT(NOM)}$ + 0.5V. Since the minimum input voltage is 2.5V, this specification is only meaningful when $V_{OUT(NOM)} \geq$ 2.5V. For $V_{OUT(NOM)}$ between 2.5V and 3.5V, use the following equations: Typical Dropout = -93mV/V × $V_{OUT(NOM)}$ + 445mV; Guaranteed Maximum Dropout = -137mV/V × $V_{OUT(NOM)}$ + 704mV. For $V_{OUT(NOM)} \geq$ 3.5V: Typical Dropout = 120mV; Guaranteed Maximum Dropout = 175mV.

Note 2: Specifications to -40°C are guaranteed by design, not production tested.

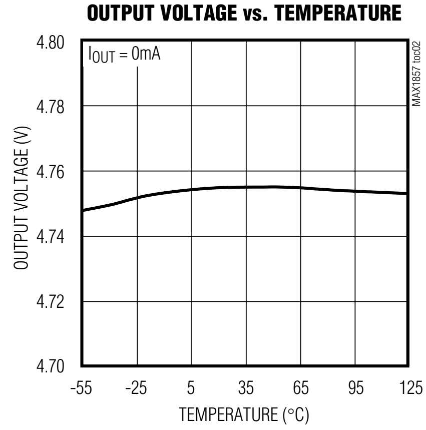
Typical Operating Characteristics

(V_{IN} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, C_{IN} = 1µF, C_{OUT} = 3.3µF, T_A = +25°C, unless otherwise noted.)

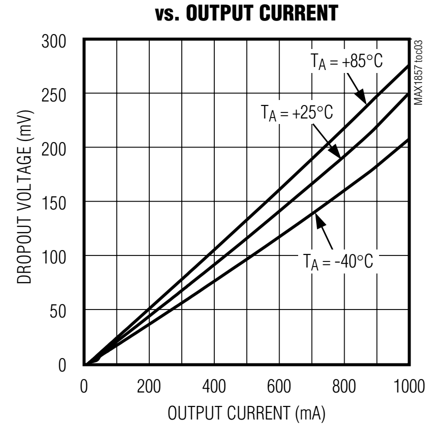
OUTPUT VOLTAGE vs. OUTPUT CURRENT



OUTPUT VOLTAGE vs. TEMPERATURE



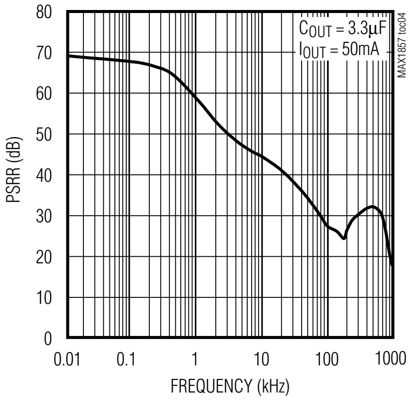
DROPOUT VOLTAGE vs. OUTPUT CURRENT



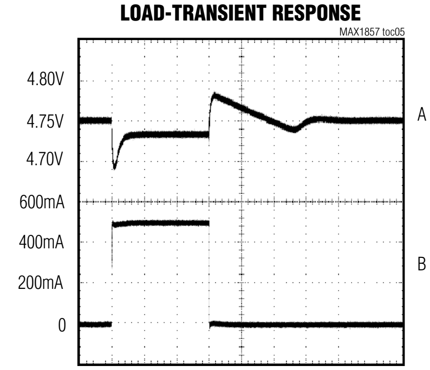
Typical Operating Characteristics (continued)

(V_{IN} = +5.25V, V_{OUT} = 4.75V, $\overline{SHDN}$ = IN, SET = GND, C_{IN} = 1µF, C_{OUT} = 3.3µF, T_A = +25°C, unless otherwise noted.)

POWER-SUPPLY REJECTION RATIO vs. FREQUENCY



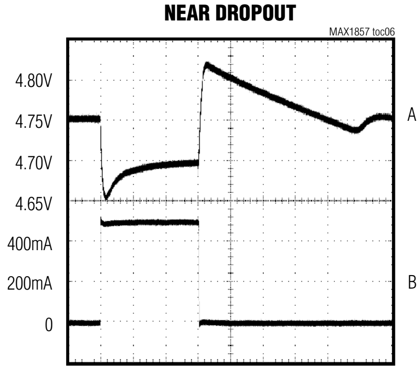
LOAD-TRANSIENT RESPONSE



10µs/div

A: V_{OUT} = 4.75V, 50mV/div
B: I_{OUT} = 5mA TO 500mA, 200mA/div
V_{IN} = 5.25V, C_{IN} = 10µF

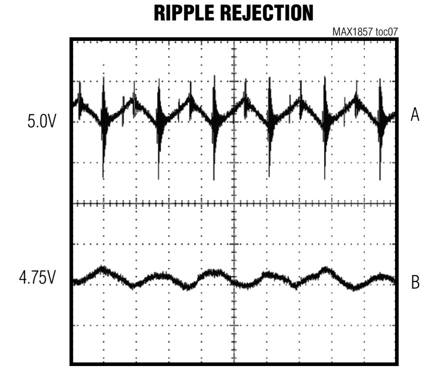
LOAD-TRANSIENT RESPONSE NEAR DROPOUT



10µs/div

A: V_{OUT} = 4.75V, 50mV/div
B: I_{OUT} = 5mA TO 500mA, 200mA/div
V_{IN} = V_{OUT} + 100mV = 4.85V, C_{IN} = 10µF

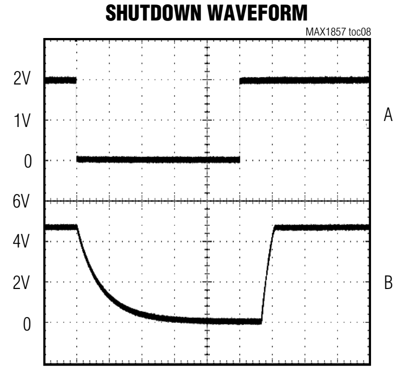
SWITCHING POWER-SUPPLY RIPPLE REJECTION



2µs/div

A: MAX1632: V_{IN} = 9V, V_{OUT} = 5.0V, 20mV/div
B: MAX1857: V_{OUT} = 4.75V, I_{OUT} = 500mA, 2mV/div
$OUT_{MAX1632} = IN_{MAX1857}$

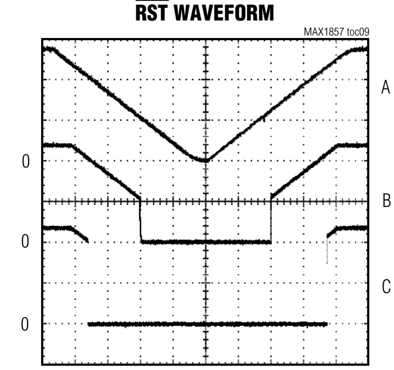
SHUTDOWN WAVEFORM



40µs/div

A: $V_{\overline{SHDN}}$ = 0 TO 2V, 1V/div
B: V_{OUT} = 4.75V, 2V/div
R_{OUT} = 9.5Ω (500mA)

$\overline{RST}$ WAVEFORM



20ms/div

A: V_{IN} = 0 TO 5.5V, 2V/div
B: V_{OUT} = 4.75V, R_{OUT} = 95Ω, 2V/div
C: $V_{\overline{RST}}$, 100kΩ TO OUT, 2V/div

500mA, Low-Dropout, Ripple-Rejecting LDO in µMAX

Pin Description

PIN	NAME	FUNCTION
1, 2	IN	Regulator Input. Supply voltage can range from +2.5V to +5.5V. Bypass with a 1µF capacitor or greater to GND (see *Capacitor Selection and Regulator Stability*). Connect both input pins together externally.
3	$\overline{RST}$	Open-Drain, Active-Low Reset Output. $\overline{RST}$ remains low while the output voltage (V_{OUT}) is below the reset threshold and for at least 4ms after V_{OUT} rises above the reset threshold. Connect a 100kΩ pullup resistor to OUT.
4	$\overline{SHDN}$	Active-Low Shutdown Input. A logic low reduces supply current to 0.1µA. In shutdown, the $\overline{RST}$ output is low and OUT is pulled low through an internal 5kΩ resistor. Connect to IN for normal operation.
5	GND	Ground
6	SET	Voltage-Setting Input. Connect to GND for preset output. Connect a resistive voltage-divider from OUT to set the output voltage between 1.25V and 5.0V.
7, 8	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. Connect both output pins together.

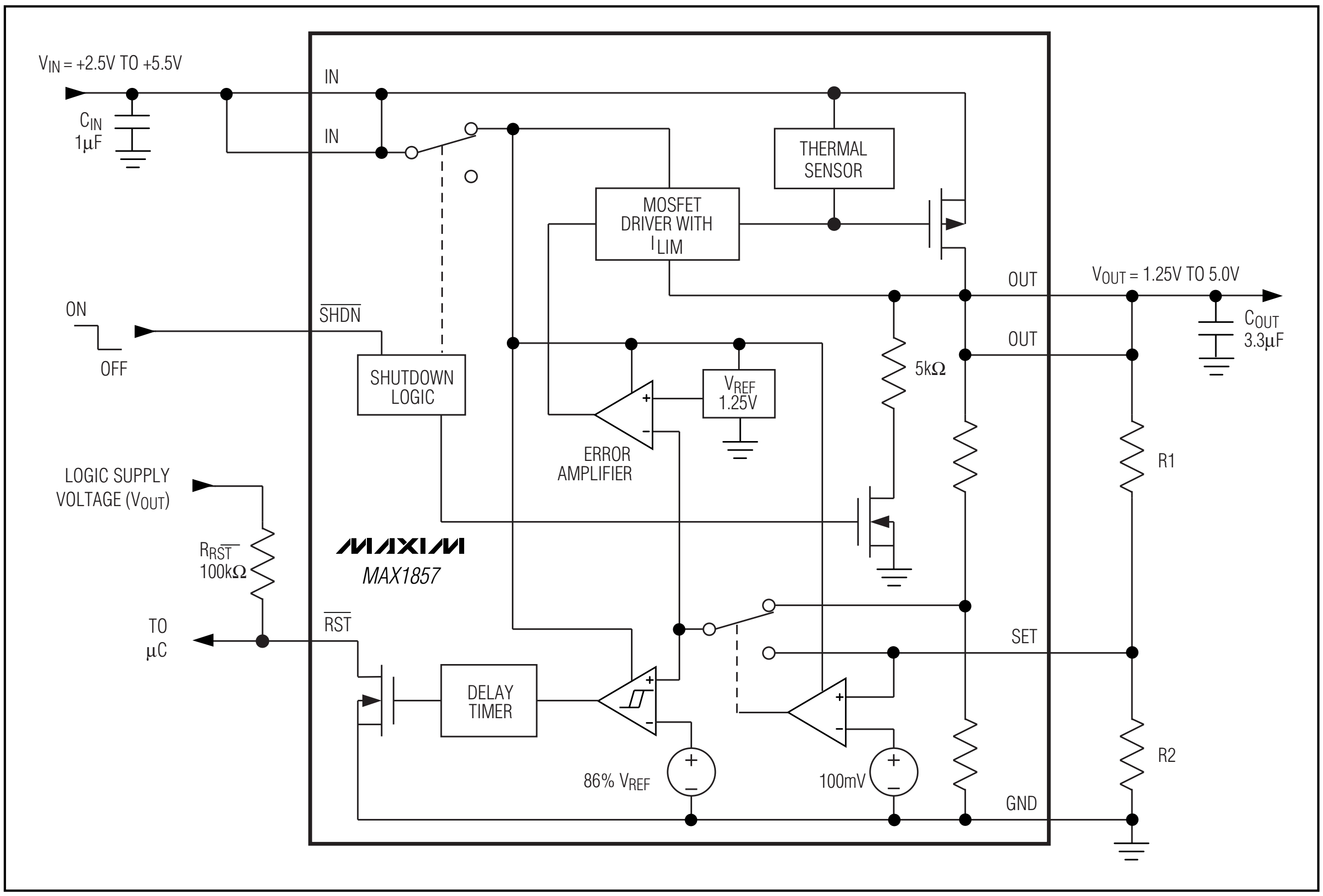


Figure 1. Functional Diagram

Detailed Description

The MAX1857 is a low-dropout, low-quiescent-current ripple rejector designed primarily for audio and video applications. The device supplies loads up to 500mA and is available with a preset output voltage of 4.75V. As shown in Figure 1, the MAX1857 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.

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

Internal P-Channel Pass Transistor

The MAX1857 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 MAX1857 does not suffer from these problems and consumes only 175µA of quiescent current under heavy loads as well as in dropout.

Output Voltage Selection

The MAX1857's dual-mode operation 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 *Selector Guide*). For example, the MAX1857EUA47 has a preset 4.75V output voltage.

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

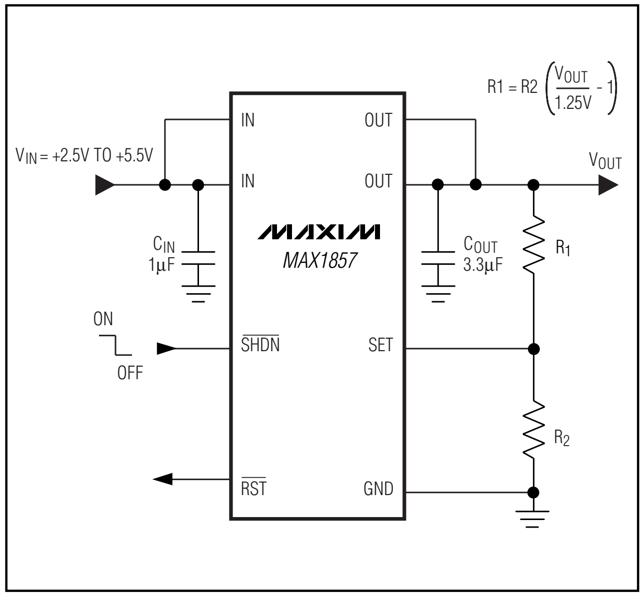


Figure 2. Adjustable Output Using External Feedback Resistors

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

where V_{SET} = 1.25V, and V_{OUT} may range from 1.25V to 5.0V.

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, $\overline{RST}$ pulls low and OUT is discharged through an internal 5kΩ resistor. The capacitance and load at OUT determine the rate at which V_{OUT} decays. $\overline{SHDN}$ can be pulled as high as 6V, regardless of the input and output voltage.

Reset Output

The reset output ($\overline{RST}$) pulls low when OUT is less than 86% of the nominal regulation voltage. Once OUT exceeds 86% of the nominal voltage, $\overline{RST}$ goes high impedance after 4.5ms. $\overline{RST}$ is an open-drain N-channel output. To obtain a voltage at $\overline{RST}$, connect a pullup resistor from $\overline{RST}$ to OUT. A 100kΩ resistor works well for most applications. $\overline{RST}$ can be used as a power-on-reset (POR) signal to a microcontroller (µC), or drive an external LED to indicate power failure. When the MAX1857 is shut down, $\overline{RST}$ is held low independent of the output voltage. If unused, leave $\overline{RST}$ grounded or unconnected.

Current Limit

The MAX1857 monitors and controls the pass transistor's gate voltage, limiting the output current to 1.2A. This current limit doubles when the output voltage is within 4% of the nominal value to improve performance with large load transients. The output can be shorted to ground for an indefinite period of time without damaging the part.

Thermal Overload Protection

Thermal overload protection limits total power dissipation in the MAX1857. When the junction temperature exceeds T_J = +170°C, a thermal sensor turns off the pass transistor, allowing the device 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 MAX1857 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 MAX1857'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 330mW or:

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

where $T_J - T_A$ is the temperature difference between the MAX1857 die junction and the surrounding air; θ_{JC} is the thermal resistance from the junction to the case; and θ_{CA} is the thermal resistance from the case through the PC board, copper traces, and other materials to the surrounding air.

The MAX1857 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.

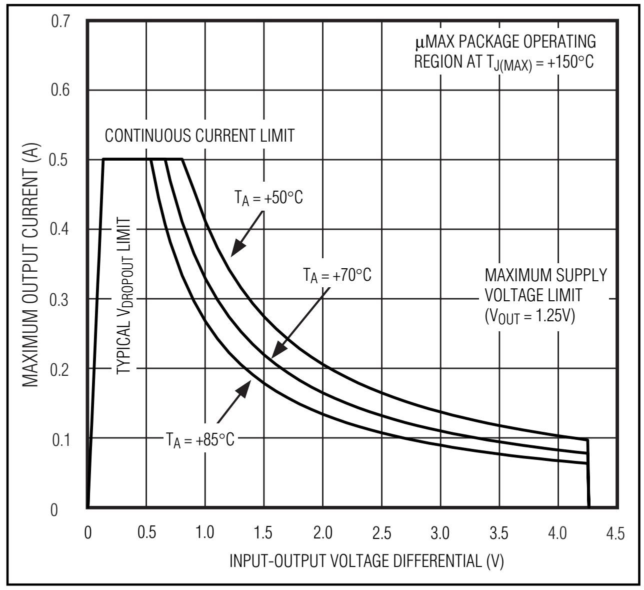


Figure 3. Power Operating Regions: Maximum Output Current vs. Supply Voltage

Applications Information

Capacitor Selection and Regulator Stability

Capacitors are required at the MAX1857'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 equivalent series resistance (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}) 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. Connect C_{IN} and C_{OUT} as close to the MAX1857 as possible to minimize the impact of PC board trace inductance.

Noise, PSRR, and Transient Response

The MAX1857 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 MAX1857 load-transient response graphs (see *Typical Operating Characteristics*) show two components of the output response: a DC shift from the output impedance due to the load current change, and the transient response. A typical transient response for a step change in the load current from 5mA to 500mA is 18mV. 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 MAX1857 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 *Typical Operating Characteristics*):

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

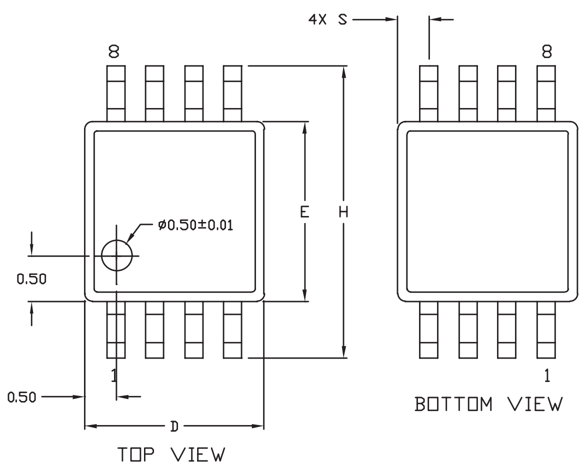
The MAX1857 ground current remains below 150µA in dropout.

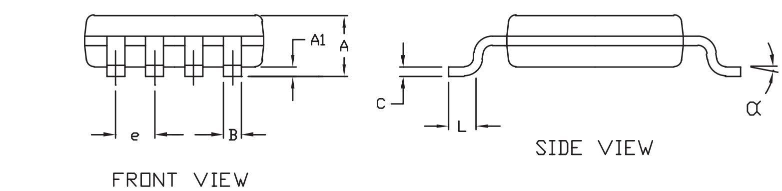
Chip Information

TRANSISTOR COUNT: 845

500mA, Low-Dropout, Ripple-Rejecting LDO in µMAX

Package Information





8LUMAXD.EPS

					JEDEC			
	INCHES		MILLIMETERS		INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
A	0.037	0.043	0.94	1.10	---	0.043	---	1.10
A1	0.002	0.006	0.05	0.15	0.002	0.006	0.05	0.15
B	0.010	0.014	0.25	0.36	0.010	0.016	0.25	0.40
C	0.005	0.007	0.13	0.18	0.005	0.009	0.13	0.23
D	0.116	0.120	2.95	3.05	0.114	0.122	2.9	3.1
e	0.0256 BSC		0.65 BSC		0.0256 BSC		0.64 BSC	
E	0.116	0.120	2.95	3.05	0.114	0.122	2.9	3.1
H	0.188	0.198	4.78	5.03	0.193 BSC		4.9 BSC	
L	0.016	0.026	0.41	0.66	0.016	0.027	0.40	0.70
α	0°	6°	0°	6°	0°	6°	0°	6°
S	0.0207 BSC		0.5250 BSC					

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH.
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15MM (.006").
3. CONTROLLING DIMENSION: MILLIMETERS.
4. MEETS JEDEC MO-187.

MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE, 8L uMAX
APPROVAL
DOCUMENT CONTROL NO. 21-0036
REV I
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