MAXIM

Low-Noise, High PSRR, Low-Dropout, 120mA Linear Regulator

General Description

The MAX8940 low-noise, low-dropout (LDO) linear regulator is designed to deliver up to 120mA continuous output current. This regulator achieves a low 120mV dropout for 120mA load current. The MAX8940 uses an advanced architecture to achieve low output voltage noise of 25µV$_{RMS}$ and PSRR of 45dB at 100kHz.

The MAX8940 is preset to either 2.8V or 3.0V. Designed with a p-channel MOSFET series pass transistor, the MAX8940 maintain very low ground current (40µA).

The regulator is designed and optimized to work with low-value, low-cost ceramic capacitors. The MAX8940 requires only 1µF (typ) of output capacitance for stability with any load. When disabled, current consumption drops to below 1µA.

Package is a 5-pin SC70.

Applications

Cellular and Cordless Phones
PDA and Palmtop Computers
Base Stations
Bluetooth Portable Radios and Accessories
Wireless LANs
Digital Cameras
Personal Stereos
Portable and Battery-Powered Equipment

Features

♦ **Space-Saving SC70**

♦ **25µV$_{RMS}$ Output Noise at 100Hz to 100kHz Bandwidth**

♦ **65dB PSRR at 10kHz**

♦ **120mV Dropout at 120mA Load**

♦ **Stable with 1µF Ceramic Capacitor for Any Load**

♦ **Guaranteed 120mA Output**

♦ **Output Voltages: 2.8V or 3V**

♦ **Low 40µA Ground Current**

♦ **Excellent Load/Line Transient**

♦ **Overcurrent and Thermal Protection**

Ordering Information

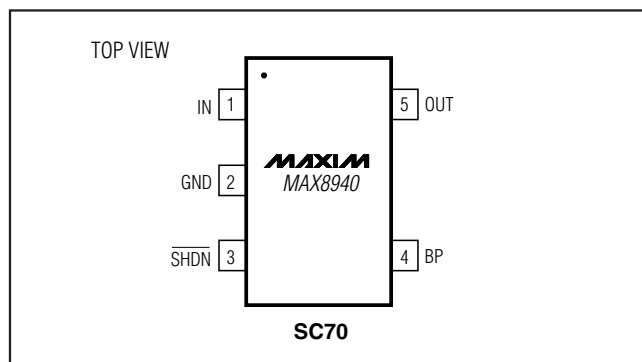| PART*	TEMP RANGE	PIN-PACKAGE
MAX8940EXKxy-T	-40°C to +85°C	5 SC70
MAX8940EXKxy+T	-40°C to +85°C	5 SC70

xy is the output voltage code (see Output Voltage Selector Guide).

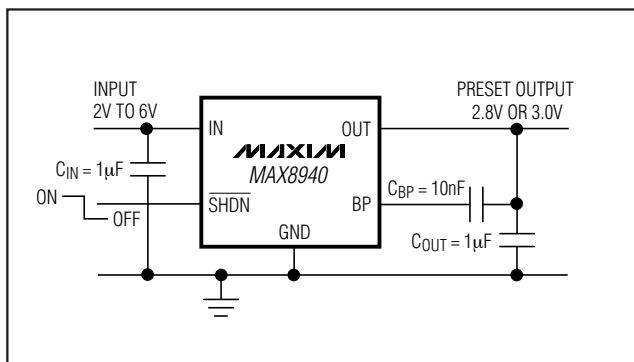*+Denotes a lead(Pb)-free/RoHS-compliant package.*

Output Voltage Selector Guide

PART	V$_{OUT}$ (V)	TOP MARK
MAX8940EXK28-T	2.8	AUE
MAX8940EXK30-T	3	AUD

Pin Configuration

TOP VIEW

SC70

Typical Operating Circuit

MAXIM _____ *Maxim Integrated Products* **1**

Low-Noise, High PSRR, Low-Dropout, 120mA Linear Regulator

ABSOLUTE MAXIMUM RATINGS

IN to GND ....-0.3V to +7V
Output Short-Circuit Duration ....Infinite
OUT, $\overline{SHDN}$ to GND ....-0.3V to (IN + 0.3V)
FB, BP, N.C. to GND.................................-0.3V to (OUT + 0.3V)
Continuous Power Dissipation (T_A = +70°C)
   5-Pin SC70 (derate 3.1mW/°C above +70°C)..............0.247W

θ_{JA}
   5-Pin SC70 ....324°C/W
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} = V_{OUT} + 0.5V, T_A = -40°C to +85°C, unless otherwise noted. C_{IN} = 1μF, C_{OUT} = 1μF, C_{BP} = 10nF. Typical values are at +25°C; the MAX8940 is tested with 2.45V output, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}			2.8		6	V
Output Voltage Accuracy		I_{OUT} = 1mA, T_A = +25°C		-1		+1	%
		I_{OUT} = 100μA to 80mA, T_A = +25°C		-2		+2	
		I_{OUT} = 100μA to 80mA		-3		+3	
Maximum Output Current	I_{OUT}			120			mA
Current Limit	I_{LIM}	OUT = 90% of nominal value		130	200	300	mA
Dropout Voltage (Note 2)		V_{OUT} = 3V, I_{OUT} = 80mA			80	170	mV
		V_{OUT} = 3V, I_{OUT} = 120mA			120		
		V_{OUT} = 2.8V, I_{OUT} = 80mA			90	200	
		V_{OUT} = 2.8V, I_{OUT} = 120mA			135		
Ground Current	I_Q	I_{OUT} = 0.05mA			40	90	μA
		V_{IN} = V_{OUT} (nom) - 0.1V, I_{OUT} = 0mA			220	500	
Line Regulation	V_{LNR}	V_{IN} = (V_{OUT} + 0.5V) to 6V, I_{OUT} = 0.1mA			0.001		%/V
Load Regulation	V_{LDR}	I_{OUT} = 1mA to 80mA			0.003		%/mA
Shutdown Supply Current	I_{SHDN}	$\overline{SHDN}$ = 0V	T_A = +25°C		0.003	1	μA
			T_A = +85°C		0.05		
Ripple Rejection	PSRR	f = 10kHz, I_{OUT} = 10mA			65		dB
		f = 100kHz, I_{OUT} = 10mA			45		

MAXIM

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = V_{OUT} + 0.5V, T_A = -40°C to +85°C, unless otherwise noted. C_{IN} = 1µF, C_{OUT} = 1µF, C_{BP} = 10nF. Typical values are at +25°C; the MAX8940 is tested with 2.45V output, unless otherwise noted.) (Note 1)

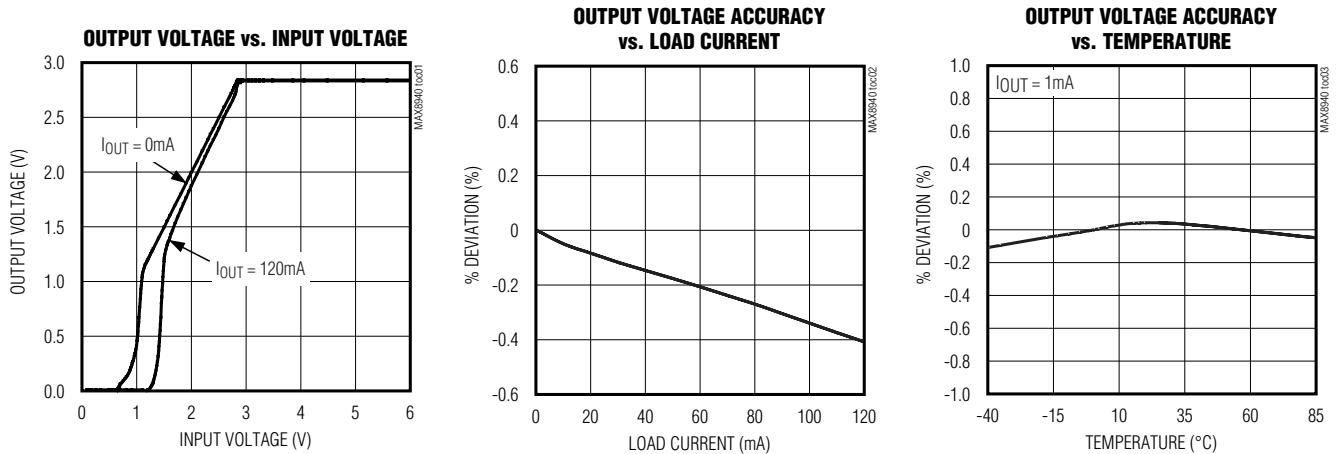| PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Noise Voltage (RMS)		f = 100Hz to 100kHz, I_{LOAD} = 10mA			25		µV
		f = 100Hz to 100kHz, I_{LOAD} = 80mA			13		
Shutdown Exit Delay		R_{LOAD} = 50Ω (Note 3)				300	µs
$\overline{SHDN}$ Logic Low Level		V_{IN} = 2.8V to 6V				0.4	V
$\overline{SHDN}$ Logic High Level		V_{IN} = 2.8V to 6V		1.5			V
$\overline{SHDN}$ Input Bias Current		V_{IN} = 6V, $\overline{SHDN}$ = 0V or 6V	T_A = +25°C				µA
			T_A = +85°C		0.01		
Thermal Shutdown					160		°C
Thermal-Shutdown Hysteresis					10		°C

Note 1: Limits are 100% tested at +25°C. Limits over operating temperature range are guaranteed by design.
Note 2: Dropout is defined as V_{IN} - V_{OUT} when V_{OUT} is 100mV below the value of V_{OUT} for V_{IN} = V_{OUT} + 0.5V.
Note 3: Time needed for V_{OUT} to reach 90% of final value.
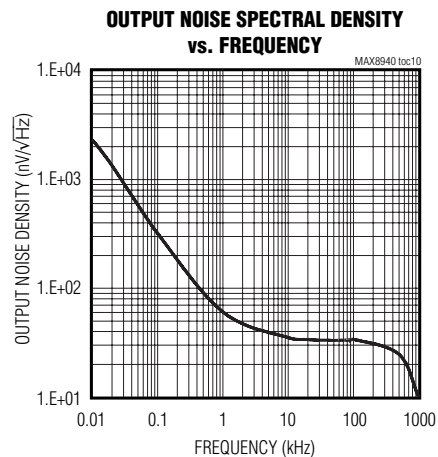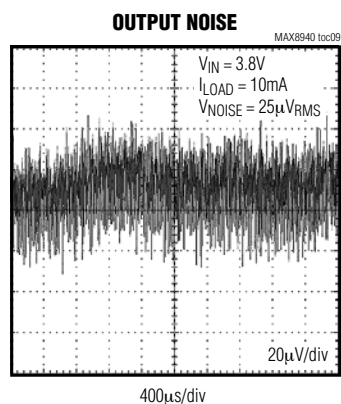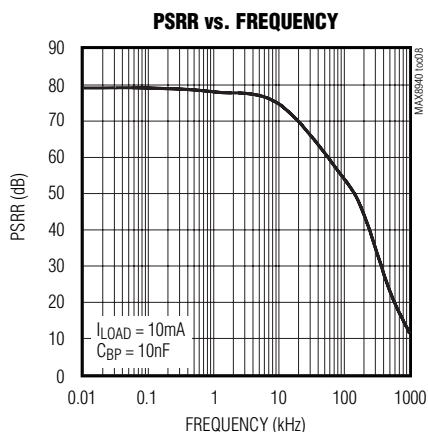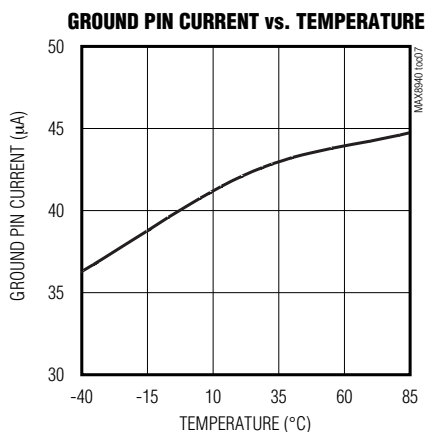
_____*Typical Operating Characteristics*

(V_{IN} = V_{OUT} + 0.5V, C_{IN} = 1µF, C_{OUT} = 1µF, C_{BP} = 10nF, T_A = +25°C, unless otherwise noted.)

OUTPUT VOLTAGE vs. INPUT VOLTAGE

OUTPUT VOLTAGE ACCURACY vs. LOAD CURRENT

OUTPUT VOLTAGE ACCURACY vs. TEMPERATURE

Low-Noise, High PSRR, Low-Dropout, 120mA Linear Regulator

Typical Operating Characteristics (continued)

(V_{IN} = V_{OUT} + 0.5V, C_{IN} = 1µF, C_{OUT} = 1µF, C_{BP} = 10nF, T_A = +25°C, unless otherwise noted.)

DROPOUT VOLTAGE vs. LOAD CURRENT

GROUND PIN CURRENT vs. INPUT VOLTAGE

GROUND PIN CURRENT vs. LOAD CURRENT

GROUND PIN CURRENT vs. TEMPERATURE

PSRR vs. FREQUENCY

OUTPUT NOISE

OUTPUT NOISE SPECTRAL DENSITY vs. FREQUENCY

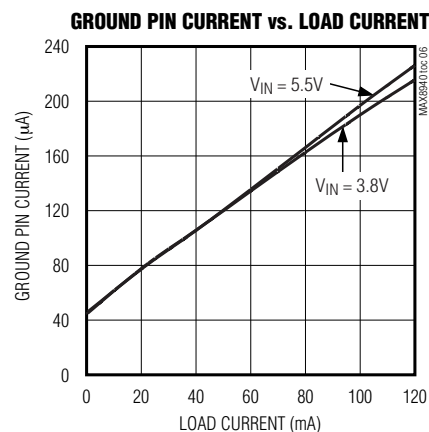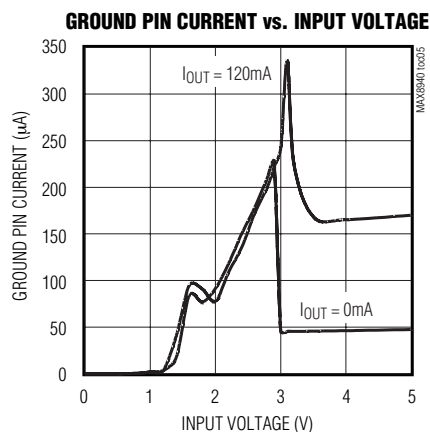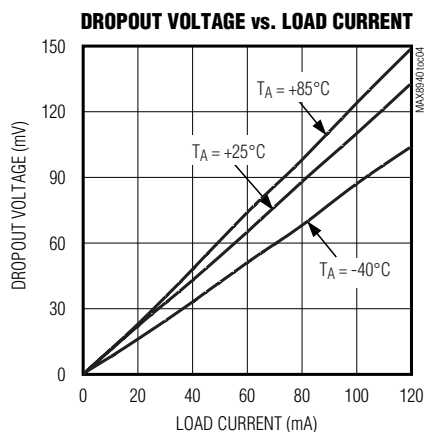**MAXIM**

MAX8940

Typical Operating Characteristics (continued)

($V_{IN} = V_{OUT} + 0.5V$, $C_{IN} = 1\mu F$, $C_{OUT} = 1\mu F$, $C_{BP} = 10nF$, $T_A = +25°C$, unless otherwise noted.)

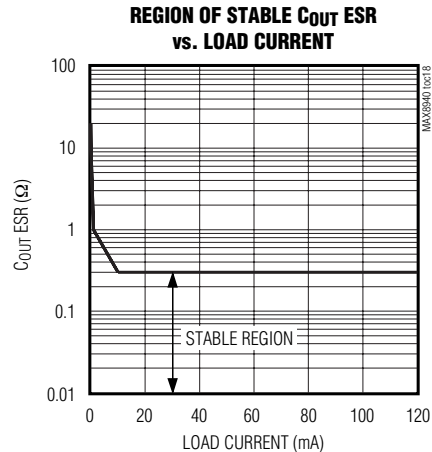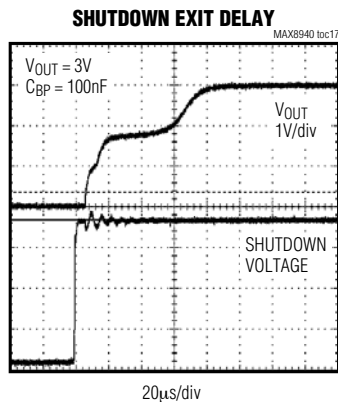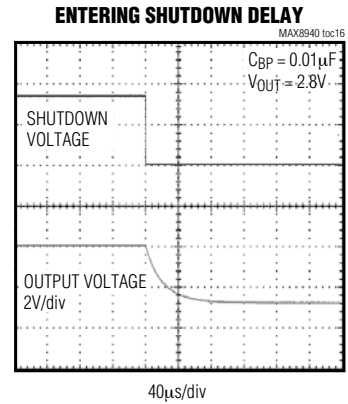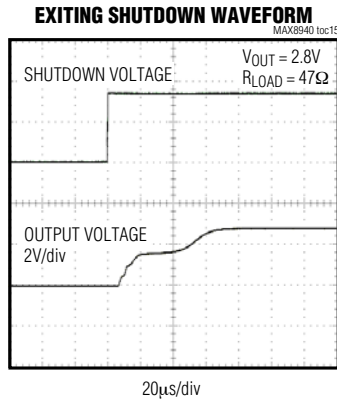**OUTPUT NOISE vs. BP CAPACITANCE**

MAX8940 toc11

LOAD TRANSIENT RESPONSE

MAX8940 toc12

$V_{IN} = 3.5V$
$I_{LOAD} = 0$ TO $50mA$

V_{OUT}
$10mV/div$

1ms/div

LOAD TRANSIENT RESPONSE NEAR DROPOUT

MAX8940 toc13

$V_{IN} = 3.1V$
$I_{LOAD} = 0$ TO $50mA$
$V_{OUT} = 3V$

V_{OUT}
$10mV/div$

1ms/div

LINE TRANSIENT RESPONSE

MAX8940 toc14

$V_{IN} = 3.5V$ TO $4V$

V_{OUT}
$2mV/div$

200µs/div

EXITING SHUTDOWN WAVEFORM

MAX8940 toc15

$V_{OUT} = 2.8V$
$R_{LOAD} = 47\Omega$

SHUTDOWN VOLTAGE

OUTPUT VOLTAGE
2V/div

20µs/div

ENTERING SHUTDOWN DELAY

MAX8940 toc16

$C_{BP} = 0.01\mu F$
$V_{OUT} = 2.8V$

SHUTDOWN VOLTAGE

OUTPUT VOLTAGE
2V/div

40µs/div

SHUTDOWN EXIT DELAY

MAX8940 toc17

$V_{OUT} = 3V$
$C_{BP} = 100nF$

V_{OUT}
$1V/div$

SHUTDOWN VOLTAGE

20µs/div

REGION OF STABLE C_{OUT} ESR vs. LOAD CURRENT

MAX8940 toc18

STABLE REGION

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MAX8940

PIN	NAME	FUNCTION
1	IN	Unregulated Input Supply
2	GND	Ground
3	$\overline{SHDN}$	Shutdown. Pull low to disable the regulator.
4	BP	Noise Bypass for Low-Noise Operation. Connect a 10nF capacitor from BP to OUT. It is short to OUT in shutdown mode.
5	OUT	Regulated Output Voltage. Bypass with a capacitor to GND. See the *Capacitor Selection and Regulator Stability* section for more details.

Detailed Description

The MAX8940 is a low-noise, low-dropout, low-quiescent current linear regulator designed for space-restricted applications. The part is available with preset output voltages 2.8V or 3.0V. This device can supply loads up to 120mA. As shown in the *Functional Diagram*, the MAX8940 consist of an innovative bandgap core and noise bypass circuit, error amplifier, p-channel pass transistor, and internal feedback voltage-divider.

The 1.225V bandgap reference is connected to the error amplifier's inverting input. The error amplifier 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 low. This 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 high, allowing less current to pass to the output. The output voltage is fed back through an internal resistor voltage-divider connected to the OUT pin.

An external bypass capacitor connected to BP reduces noise at the output. Additional blocks include a current limiter, thermal sensor, and shutdown logic.

Internal P-Channel Pass Transistor
The MAX8940 features a 1Ω (typ) p-channel MOSFET pass transistor. This provides seve-ral advantages over similar designs using a PNP pass transistor, including longer battery life. The p-channel MOSFET requires no base drive, which considerably reduces quiescent current. PNP-based regulators waste considerable current in dropout when the pass transistor saturates. They also use high base-drive current under heavy loads. The MAX8940 does not suffer from these problems and

consume only 40µA of quiescent current in light load and 220µA in dropout (see the *Typical Operating Characteristics*).

Shutdown
The MAX8940 features a low-power shutdown mode that reduces quiescent current less than 1µA. Driving $\overline{SHDN}$ low disables the voltage reference, error amplifier, gate-drive circuitry, and pass transistor (see the *Functional Diagram*), and the device output enters a high-impedance state. Connect $\overline{SHDN}$ to IN for normal operation.

Current Limit
The MAX8940 includes a current limiter, which monitors and controls the pass transistor's gate voltage, limiting the output current to 200mA. For design purposes, consider the current limit to be 130mA (min) to 300mA (max). The output can be shorted to ground for an indefinite amount of time without damaging the part.

Thermal-Overload Protection
Thermal-overload protection limits total power dissipation in the MAX8940. When the junction temperature exceeds $T_J = +160°C$, the thermal sensor signals the shutdown logic, turning off the pass transistor and allowing the IC to cool down. The thermal sensor turns the pass transistor on again after the IC's junction temperature drops by 10°C, resulting in a pulsed output during continuous thermal-overload conditions.

Thermal-overload protection is designed to protect the MAX8940 in the event of a fault condition. For continual operation, do not exceed the absolute maximum junction temperature rating of $T_J = +150°C$.

Operating Region and Power Dissipation
The MAX8940 maximum power dissipation depends on the thermal resistance of the case and circuit board,

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the temperature difference between the die junction and ambient, and the rate of airflow. The power dissipation across the device is:

$$P = I_{OUT} (V_{IN} - V_{OUT})$$

The maximum power dissipation is:

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

where $T_J - T_A$ is the temperature difference between the MAX8940 die junction and the surrounding air, θ_{JC} is the thermal resistance of the package, and θ_{CA} is the thermal resistance through the PC board, copper traces, and other materials to the surrounding air.

The GND pin of the MAX8940 performs the dual function of providing an electrical connection to ground and channeling heat away. Connect the GND pin to ground using a large pad or ground plane.

Noise Reduction

For the MAX8940, an external 0.01µF bypass capacitor between BP and OUT with innovative noise bypass scheme reduces output noises dramatically, exhibiting 25µV$_{RMS}$ of output voltage noise with C$_{BP}$ = 0.01µF and C$_{OUT}$ = 1µF. Startup time is minimized by a power-on circuit that precharges the bypass capacitor.

Applications Information

Capacitor Selection and Regulator Stability

Use a 1µF capacitor on the MAX8940 input and a 1µF capacitor on the output. Larger input capacitor values and lower ESRs provide better noise rejection and line-transient response. Reduce output noise and improve load-transient response, stability, and power-supply rejection by using large output capacitors. Note that some ceramic dielectrics exhibit large capacitance and ESR variation with temperature. With dielectrics such as Z5U and Y5V, it may be necessary to use a 2.2µF or larger output capacitor to ensure stability at temperatures below -10°C. With X7R or X5R dielectrics, 1µF is sufficient at all operating temperatures. A graph of the region of stable C$_{OUT}$ ESR vs. load current is shown in the *Typical Operating Characteristics*.

Use a 0.01µF bypass capacitor at BP for low-output voltage noise. The leakage current going into the BP pin should be less than 10nA. Increasing the capacitance slightly decreases the output noise. Values above 0.1µF and below 0.001µF are not recommended.

Noise, PSRR, and Transient Response

The MAX8940 is designed to deliver low noise and high PSRR, as well as low dropout and low quiescent currents in battery-powered systems. The MAX8940 power-supply rejection is 65dB at 1kHz.

When operating from sources other than batteries, 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 *Typical Operating Characteristics* show the MAX8940 line- and load-transient responses.

Dropout Voltage

A regulator's minimum dropout voltage determines the lowest usable supply voltage. In battery-powered systems, this determines the useful end-of-life battery voltage. Because the MAX8940 uses a p-channel MOSFET pass transistor, the dropout voltage is a function of drain-to-source on-resistance (RDS(ON)) multiplied by the load current (see the *Typical Operating Characteristics*).
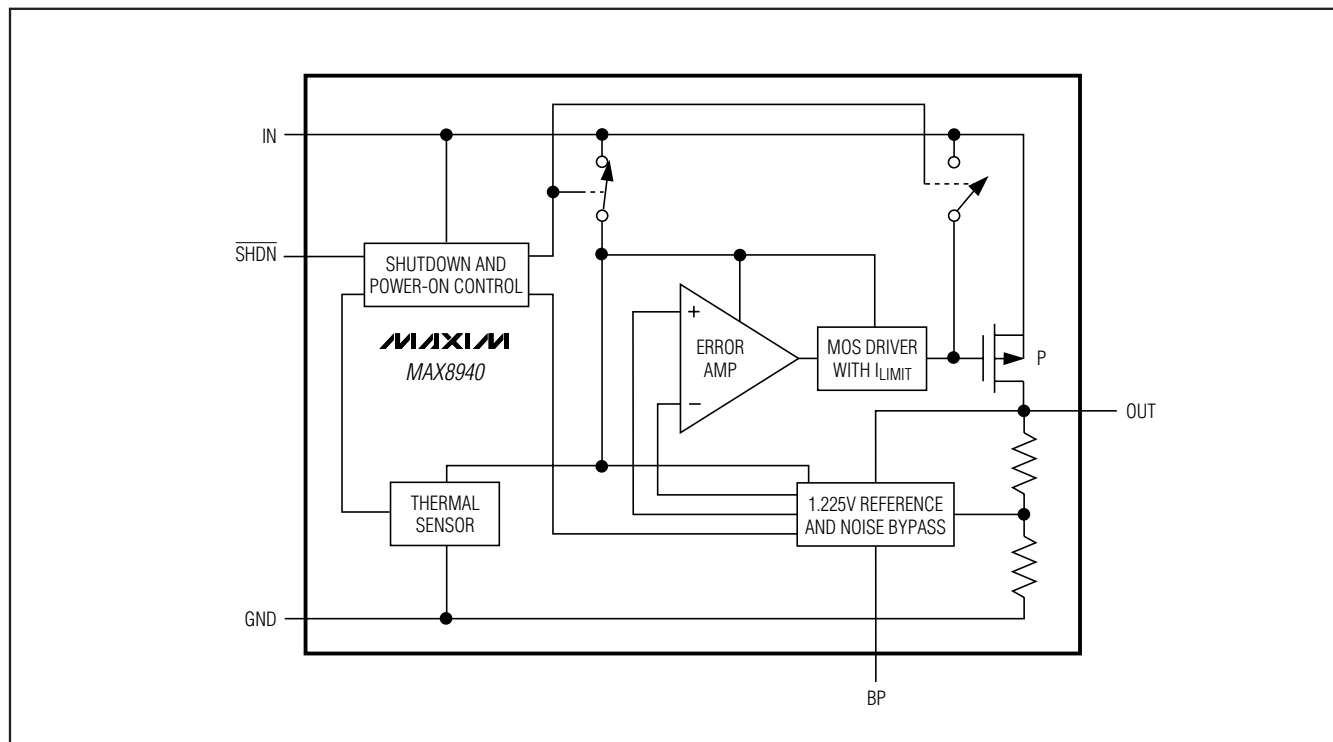
Chip Information

TRANSISTOR COUNT: 284
PROCESS: BiCMOS

MAX8940

Functional Diagram

Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
5 SC70	X5-1	**21-0076**
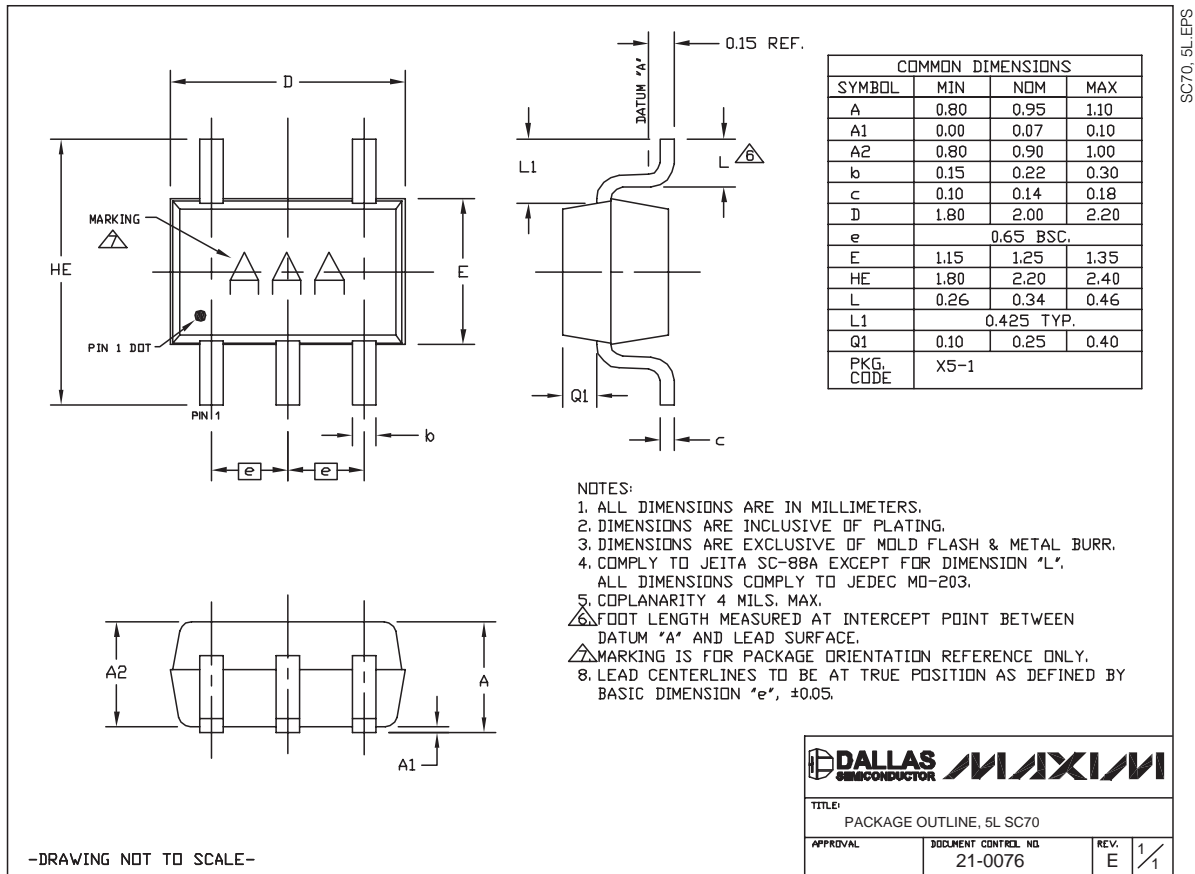
COMMON DIMENSIONS

SYMBOL	MIN	NOM	MAX
A	0.80	0.95	1.10
A1	0.00	0.07	0.10
A2	0.80	0.90	1.00
b	0.15	0.22	0.30
c	0.10	0.14	0.18
D	1.80	2.00	2.20
e	0.65 BSC.		
E	1.15	1.25	1.35
HE	1.80	2.20	2.40
L	0.26	0.34	0.46
L1	0.425 TYP.		
Q1	0.10	0.25	0.40
PKG. CODE	X5-1		

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. COMPLY TO JEITA SC-88A EXCEPT FOR DIMENSION 'L'. ALL DIMENSIONS COMPLY TO JEDEC MO-203.
5. COPLANARITY 4 MILS, MAX.
6. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM 'A' AND LEAD SURFACE.
7. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
8. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION 'e', ±0.05.

TITLE: PACKAGE OUTLINE, 5L SC70

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0076	E	1/1

-DRAWING NOT TO SCALE-

SC70, 5L.EPS

MAX8940

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