

# Adjustable Off-Line Inductorless Switching Regulator

## Features

- ▶ Efficient operation without magnetics
- ▶ No high voltage capacitors
- ▶ Adjustable main output voltage (9V to 50V)
- ▶ Additional 3.3V or 5V internal regulator
- ▶ Up to 100mA combined output current
- ▶ Single BOM for 120VAC/230VAC
- ▶ Built-in soft start
- ▶ Less than 200mW standby power

## Applications

- ▶ White goods
- ▶ Household appliances
- ▶ Lighting controls
- ▶ Circuit breakers
- ▶ Keep-alive supplies

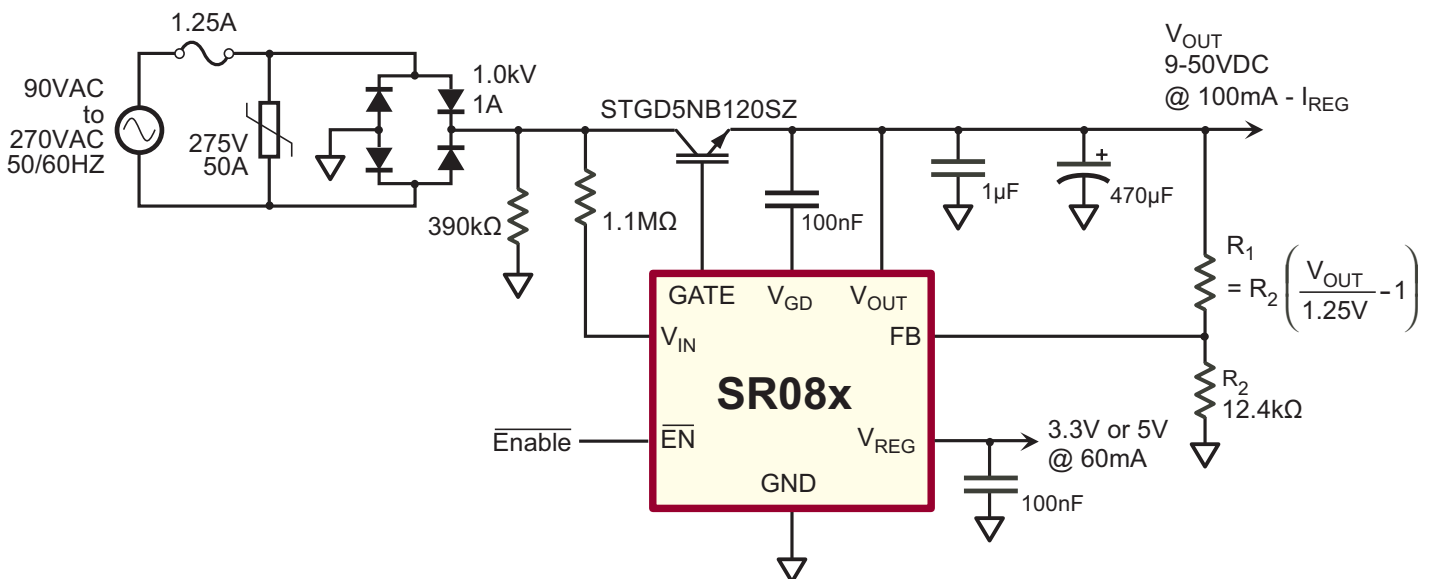
## General Description

The Supertex SR08x is an inductorless switching regulator designed to operate directly from a rectified AC line. The operating principle is to turn on a pass transistor when the rectified AC is below the output voltage, and to turn it off when the output voltage reaches a specific level. A linear regulator supplied by  $V_{OUT}$  provides an additional fixed 3.3V output (SR086) or 5V output (SR087). Efficiencies of around 55% may be realized for loads up to 1W in 120VAC applications, with around 50% efficiencies for loads up to 800mW in 230VAC applications.

A logic-level enable input allows the SR08x to be disabled – useful when the SR08x is employed as a keep-alive power supply.

**WARNING! Galvanic isolation is not provided. Dangerous voltages are present when connected to the AC line. It is the responsibility of the designer employing the SR08x to ensure adequate safeguards are in place to protect the end user from electrical shock.**

## Typical Application Circuit



## Ordering Options

Device ( $V_{REG}$ )	Package Options
	8-Lead SOIC
SR086 (3.3V)	SR086SG-G
SR087 (5.0V)	SR087SG-G

-G indicates package is RoHS compliant ('Green')

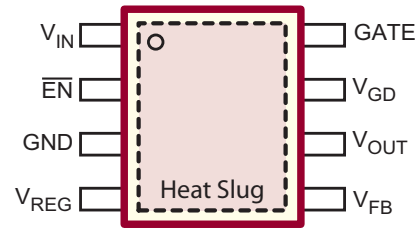


## Absolute Maximum Ratings

Parameter	Value
Output Voltage ( $V_{OUT}$ )	-0.3V to 56V
Feedback Voltage ( $V_{FB}$ )	-0.3V to 6.5V
Enable Voltage ( $V_{EN}$ )	-0.3V to 6.5V
Operating Junction Temperature	-40°C to +125°C

Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied. Continuous operation of the device at the absolute rating level may affect device reliability. All voltages are referenced to device ground.

## Pinout



### SO-8

Backside on the SO-8 package is at ground potential and may be connected to ground or left unconnected.

## Pin Description

Name	Pin #	Description
$V_{IN}$	1	Rectified AC input voltage
$\overline{EN}$	2	Active low enable input
GND	3	Circuit ground <i>Note: circuit ground will be at the AC line potential</i>
$V_{REG}$	4	Regulated output voltage, fixed 3.3V or 5.0V
FB	5	Feedback input
$V_{OUT}$	6	Output voltage (9.0V - 50V adj.)
$V_{GD}$	7	Gate drive supply (referenced to $V_{OUT}$ )
GATE	8	Drives external IGBT pass transistor

## Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Units	Conditions
$V_{OUT}$	Output voltage	9	-	50	V	---
$I_{OUT}$	Load on $V_{OUT}$ including feedback divider and load on $V_{REG}$	100	-	-	$\mu A$	---

## Specifications

(Unless otherwise noted,  $T_A = -40^\circ C$  to  $+85^\circ C$ , Voltages referenced to GND pin)

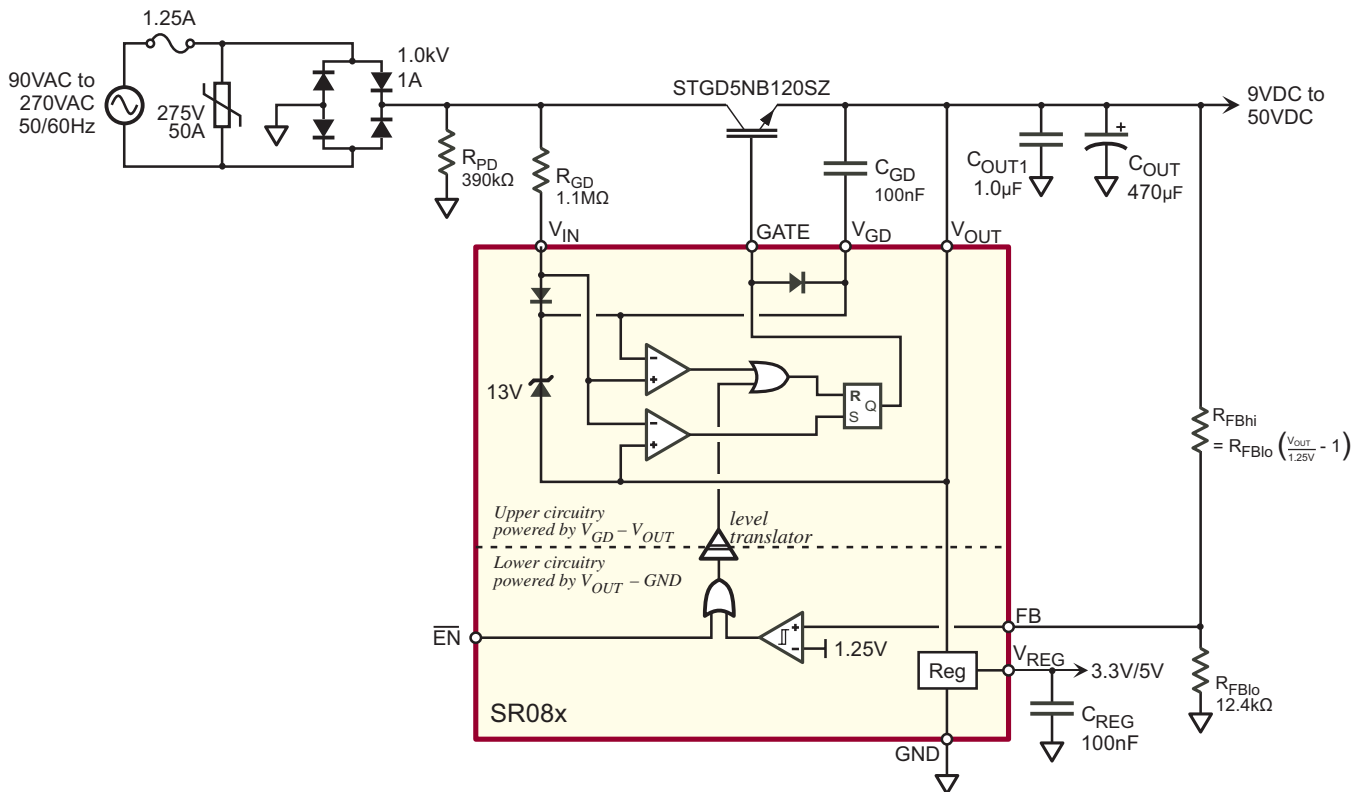
Symbol	Parameter	Min	Typ	Max	Units	Conditions
$I_{GD}$	Current consumption at $V_{GD}$	-	-	60	$\mu A$	---
$I_{OUT(int)}$	Current consumption of the lower circuitry	-	-	400	$\mu A$	$V_{OUT} = 9-50V$
$V_{GD}$	Gate drive supply voltage <sup>1</sup>	11	13	15	V	---
$V_{GATE(hi)}$	GATE output high voltage <sup>1</sup>	11	-	15	V	---
$V_{GATE(lo)}$	GATE output low voltage <sup>1</sup>	-	-	0.5	V	---
$V_{FB(off)}$	Feedback voltage (GATE off)	1.18	1.25	1.31	V	---
$V_{FB(hys)}$	Feedback voltage hysteresis	-	50	-	mV	---

Specifications (cont.)

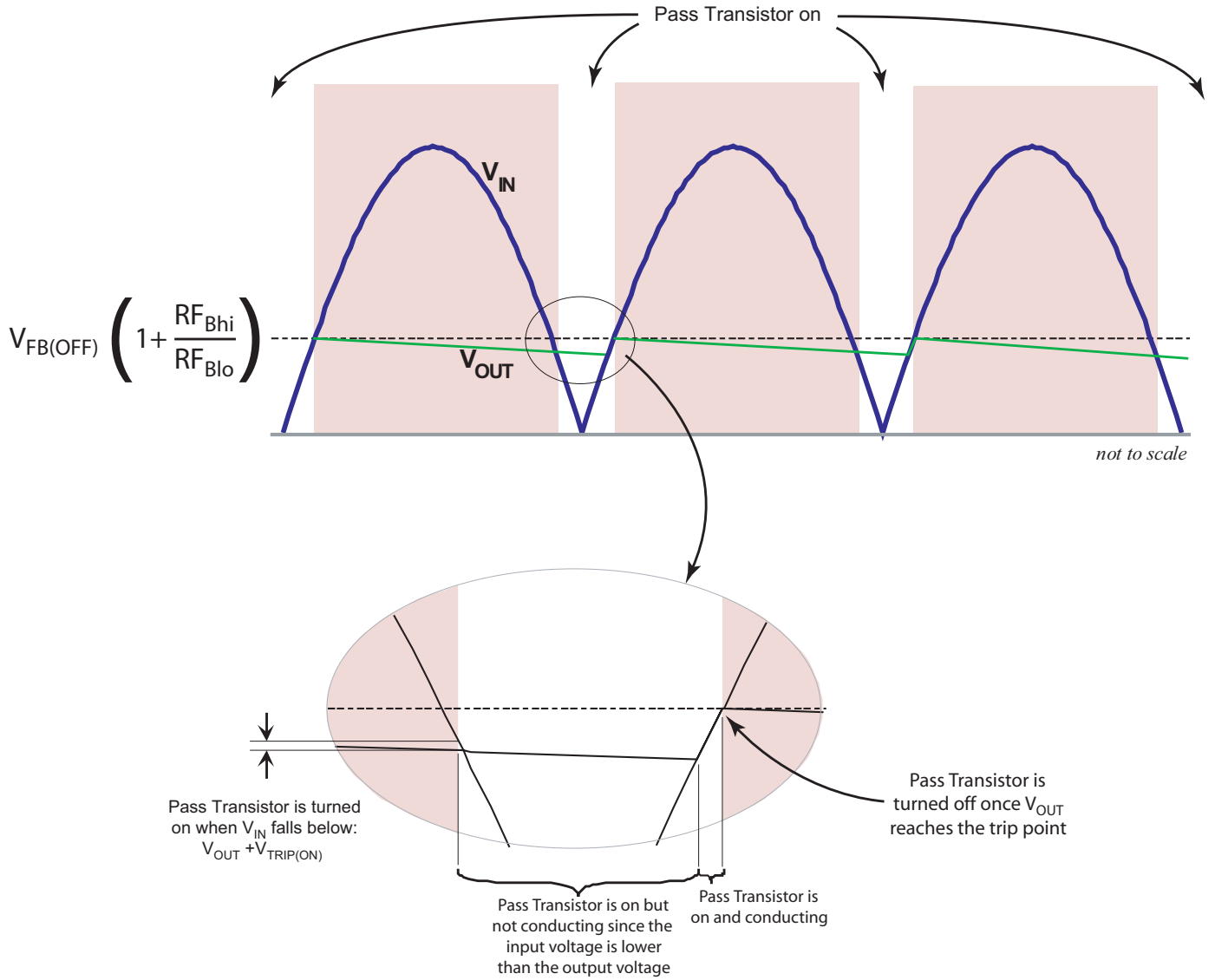
Symbol	Parameter	Min	Typ	Max	Units	Conditions
$I_{FB}$	FB input current	-	-	500	nA	---
$V_{TRIP(on)}$	$V_{IN}$ trip voltage, GATE on <sup>1</sup>	0	-	3	V	---
$V_{TRIP(off)}$	$V_{IN}$ trip voltage, GATE off <sup>1</sup>	9	-	15	V	---
$V_{EN(on)}$	Enable voltage, on	0.2	-	-	V	---
$V_{EN(off)}$	Enable voltage, off	-	-	0.75	$V_{REG}$	---
$t_{DIG(on)}$	$V_{IN}$ – GATE turn-on delay	0	-	1.0	$\mu$ s	$C_{GATE} = 1nF$
$t_{DIG(off)}$	$V_{IN}$ – GATE turn-off delay	-	-	600	ns	$C_{GATE} = 1nF$
$t_{DFG(off)}$	FB – GATE turn-off delay	-	-	450	ns	$C_{GATE} = 1nF$ $V_{FB} = 1.5V$
$V_{REG}$	Regulated output voltage SR086 SR087	3.125 4.750	3.300 5.000	3.465 5.250	V	$I_{LOAD} = 1mA$ , $V_{OUT} = 9V$
$\Delta V_{I,REG}$	$V_{REG}$ load regulation	-50	-	+50	mV	$0mA < I_{LOAD} < 60mA$ , $V_{OUT} = 9V$ , $T_{Amb} = 25^{\circ}C$
$V_D$	GATE – $V_{GD}$ diode drop	-	-	800	mV	$I = 20mA$

<sup>1</sup> Referenced to  $V_{OUT}$ .

Block Diagram

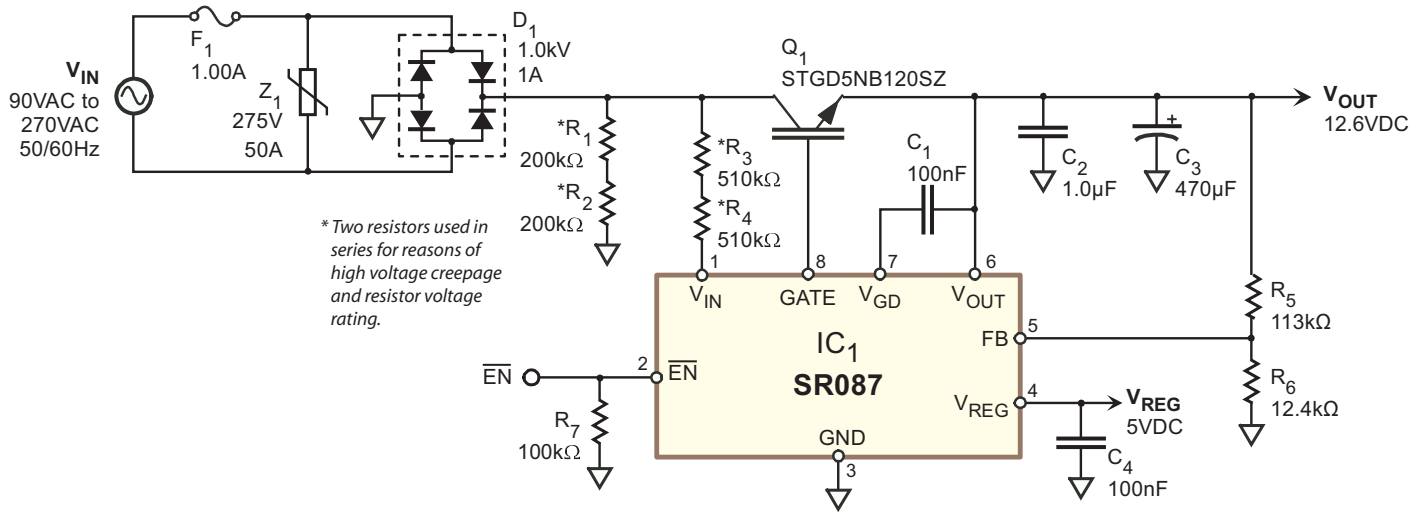


SR08x Timing



Data Sheet Application Section:

Typical Application Circuit



Output Voltage\*

V<sub>OUT</sub> may be adjusted in the range of 9V to 50V\*, by changing feedback resistor R<sub>5</sub> according to the following equation.

$$R_5 = R_6 \left( \frac{V_{OUT}}{1.25V} - 1 \right)$$

Leave R<sub>6</sub> at 12.4kΩ or less - it assures a minimum 100μA load required for the proper operation of the SR087. Change R<sub>3</sub> and R<sub>4</sub> according to the R<sub>3</sub>+R<sub>4</sub> equation below. Select C<sub>2</sub> and C<sub>3</sub> with appropriate voltage ratings. For C<sub>3</sub>, use a low ESR capacitor with an adequate ripple current rating (800mA<sub>RMS</sub>). Use ceramic for C<sub>2</sub>.

Since V<sub>REG</sub> is a linear regulator supplied from V<sub>OUT</sub>, the maximum current available from V<sub>REG</sub> is reduced as V<sub>OUT</sub> is increased due to power considerations.

$$I_{REG(max)} = \frac{1.5W}{V_{OUT} - 5V} \quad \text{or } 60mA, \text{ whichever is less.}$$

Input Voltage

To reduce standby power for 230VAC-only applications, or for supply voltages less than 90Vrms, R<sub>3</sub> and R<sub>4</sub> should be changed according to the R<sub>3</sub>+R<sub>4</sub> equation below. R<sub>1</sub>+R<sub>2</sub> should remain at 400kΩ or less. Two resistors in series are employed to ensure adequate creepage distances for 230VAC operation. For 120VAC-only applications, single resistors may be employed.

Output Ripple\*

Storage capacitor C<sub>3</sub> was sized to provide about 2V<sub>P-P</sub> ripple at 100mA load (I<sub>OUT</sub> + I<sub>REG</sub>). For lighter loads, C<sub>3</sub> may be reduced. Conversely, C<sub>3</sub> may be increased for lower ripple. Use a low ESR capacitor with an adequate ripple current rating (800mA<sub>RMS</sub> for 100mA loads). Efficiency and output current capability may drop with increased capacitance because of a smaller conduction angle associated with lower ripple. Due to feedback hysteresis, ripple cannot be reduced below 4%.

$$V_{RIPPLE(P-P)} \approx \frac{I_{OUT} + I_{REG}}{2f_{IN}C_3}$$

\*V<sub>REG</sub> requires at least 4V of headroom. Therefore, V<sub>OUT</sub> including ripple, must not fall below 9V for the SR087, or below 7.3V for the SR086.

R<sub>3</sub> + R<sub>4</sub> Equation:

$$(R_3 + R_4) < \frac{\sqrt{2V_{IN}^2 - V_X^2} - V_X \cos^{-1}\left(\frac{V_X}{\sqrt{2}V_{IN}}\right)}{\pi \cdot 25\mu A} \quad \text{where } V_X = V_{OUT} + 15V$$

Use the minimum anticipated RMS value for V<sub>IN</sub>. Take resistor tolerance into account, selecting the next lower standard value. Choosing a lower value has no effect other than higher standby power.

## Line Transformer

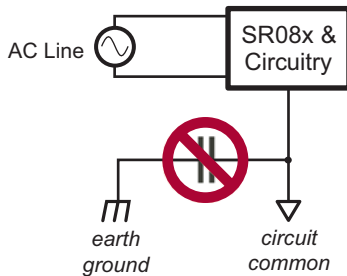
During initial testing it is tempting to use an isolation transformer or a variable transformer on the AC line. However, the high inductance of the transformer (frequently in the mH's) interferes with the normal operation of the SR08x and should not be used. This is not a concern with the normal inductance of the AC line or for AC line filters.



The SR08x draws current from the AC line in short, high current pulses. The transformer's high inductance tends to limit the current pulse. Furthermore, inductive kickback on the falling edge of the current pulse can create high voltage spikes which must be absorbed by the transient protector.

## EMI Capacitor

The use of a small-value capacitor from circuit common to earth ground prevents the SR08x from operating and should not be employed.



## EMI

The SR08x circuit as depicted on Page 1, (Typical Application Circuit), meets FCC Class B and CISPR 14-1 (household appliances) requirements for conducted emissions, for combined loads of less than 20mA ( $I_{OUT} + I_{REG}$ ).

## Fuse

Although the average current drawn from the AC line is low, the RMS current is fairly high due to the current being drawn in short, high-current pulses. Since a fuse is basically a resistor with a power dissipation given by  $I_{RMS}^2 R$ , the fuse must be sized for the RMS current, not the average current. For a 1W load and 120VAC the RMS current is  $700mA_{RMS}$ , and for a 0.5W load at 230VAC it is  $360mA_{RMS}$ .

## Transient Protection

The transient protector must be located before the bridge rectifier. The reason for this is to minimize capacitance to allow the rectified AC to fall below  $V_{OUT}$ .

Since there is no capacitor to absorb AC line transients, complete transient protection must be provided by the TVS or MOV device. Since the recommended IGBT is rated at 1.2kV and the SR08x never sees the full input voltage, the bridge rectifier becomes the limiting element when selection an MOV. If using a 1.0kV bridge, an MOV having a clamping voltage of < 1.0kV is recommended.

## Load

Total load on the SR08x is the total load current drawn from  $V_{OUT}$  ( $I_{OUT}$ ) and, since the linear regulator is supplied from  $V_{OUT}$ , it also includes the current drawn from  $V_{REG}$  ( $I_{REG}$ ). Total load is calculated as follows:

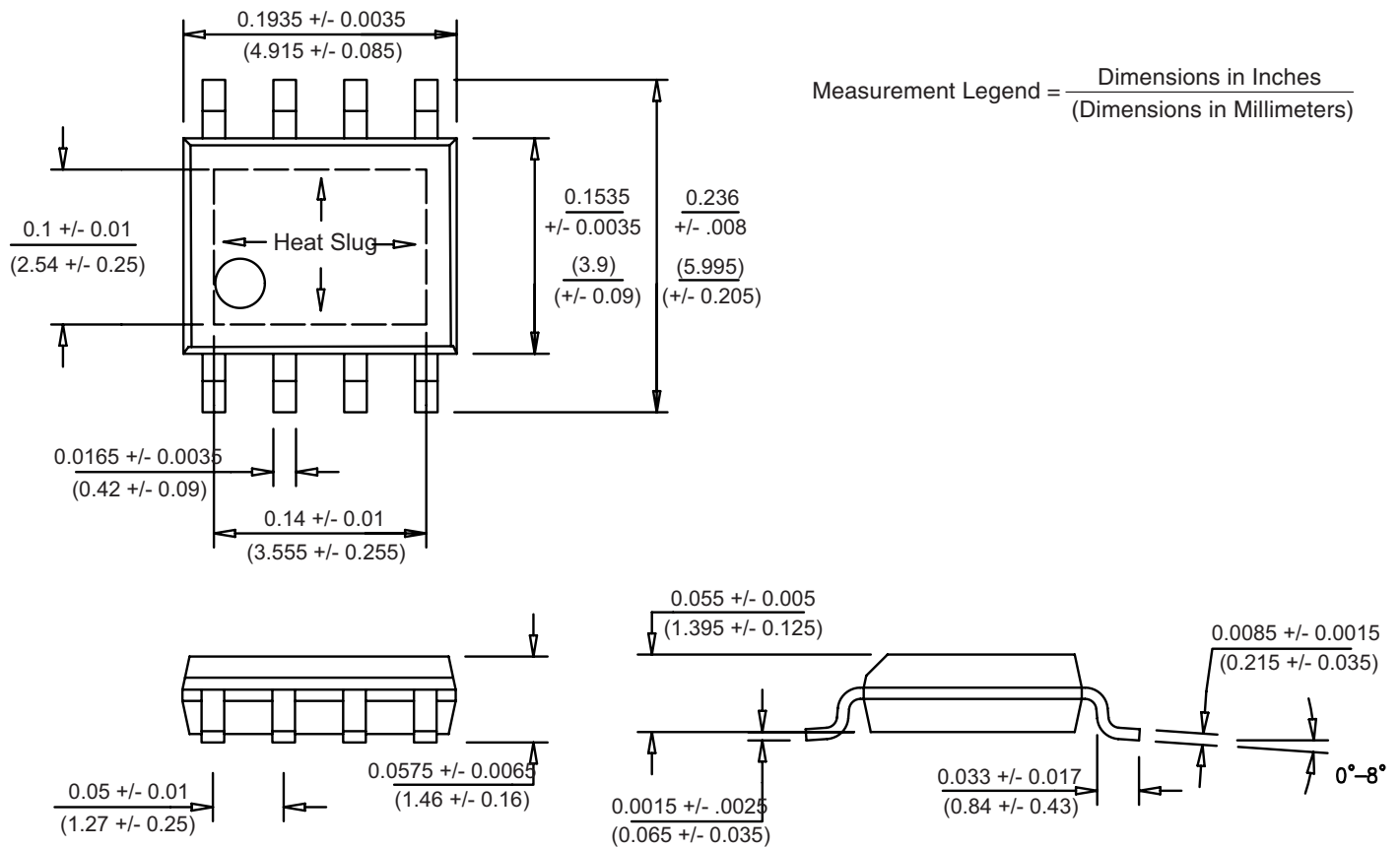
$$I_{LOAD} = I_{OUT} + I_{REG}$$

$$P_{LOAD} = V_{OUT} (I_{OUT} + I_{REG})$$

## UPS

The SR08x will not operate from uninterruptable power supplies having a square wave output. This type of output is usually referred to as 'modified sine wave'

8-LEAD SMALL OUTLINE PACKAGE WITH HEAT SLUG (SG)



(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to <http://www.supertex.com/packaging.html>.)

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