TECHNOLOGY & QUALITY

TQ8008

1.5MHz, 600mA, High Efficiency PWM Step-Down DC/DC Converter

Description

The TQ8008 is a high-efficiency PWM step-down DC-DC converter. The device is available in an adjustable version and fixed output voltages of 1.2V and 1.8V. Supply current during operation is only 20μA and drops to ≤1μA in shutdown. The 2.5V to 5.5V input voltage range makes the TQ8008 ideally suited for single Li-Ion battery-powered applications.

The output voltage can be regulated as low as 0.6V. The TQ8008 can also run at 100% duty cycle for low dropout operation, extending battery life in portable system. Idle mode operation at light loads provides very low output ripple voltage for noise sensitive applications. Switching frequency is internally set at 1.5MHz, allowing the use of small surface mount inductors and capacitors.

The switching ripple is easily smoothed-out by small package filtering elements due to a fixed operation frequency of 1.5MHz. This along with small TSOT-23-5 package provides small PCB area application. Other features include soft start, lower internal reference voltage with 2% accuracy, over temperature protection, and over current protection.

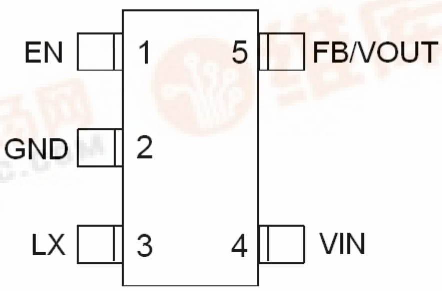
Features

- +2.2V to +5.5V Input Range
- Adjustable Output From 0.6V to VIN
- 1.2V, 1.8V and Adjustable Output Voltage
- 600mA Output Current
- 95% Efficiency
- No Schottky Diode Required
- 300μA Quiescent Current
- 1.5MHz Fixed-Frequency PWM Operation
- Short Circuit and Thermal Fault Protection
- Space Saving 5-pin Thin SOT23 package

Application

- Cellular Telephones
- Personal Information Appliances
- Wireless and DSL Modems
- Digital Still Cameras
- MP3 Players
- Portable Instruments

Pin Configuration



SOT23 - 5

Order Information

TQ8008 - XX

OUTPUT VOLTAGE:
18: 1.8V
ADJ: Adjustable

PRODUCT NAME

Pin Function

Pin Number	Pin Name.	Function Description
1	EN	Chip Enable (Active High)
2	GND	Ground
3	LX	Pin for switching
4	VIN	Power Input
5	FB/VOUT	Feedback Input Pin

Typical Application Circuit

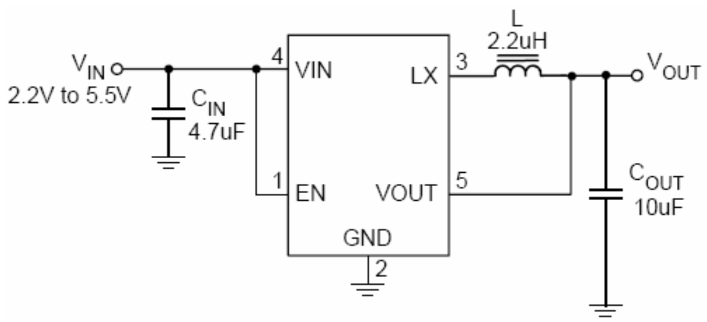
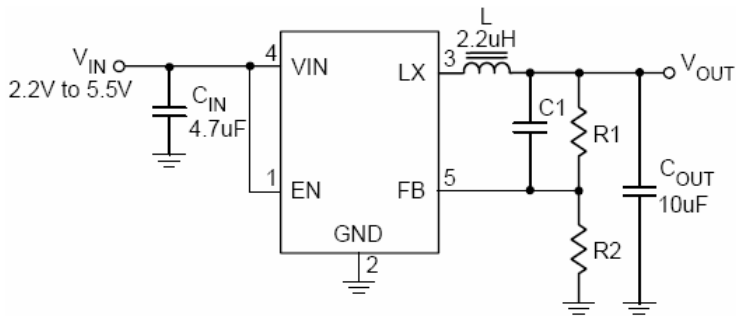


Figure 1 . Fixed Voltage Regulator



VOUT = 0.6 x (1 + R1 / R2)

with R1 R2≦1M and internal reference voltage

Figure 2 . Adjustable Voltage Regulator

Absolute Maximum Ratings†

Vcc(Input Supply Voltage) 6.5V
Power Dissipation, P_D @ T_A = 25°C
TSOT-23-5 .... 0.4W
Operating Junction Temperature Range ……….………………..……. -40°C to 125°C
Operating ambient Temperature Range ……….……………….…….. -40°C to 85°C
Lead Temperature (Soldering, 10 sec.) ……………..…………..……………….. 260°C
Storage Temperature Range ……………………………...………. -65°C to 125°C

† **Notice:** Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

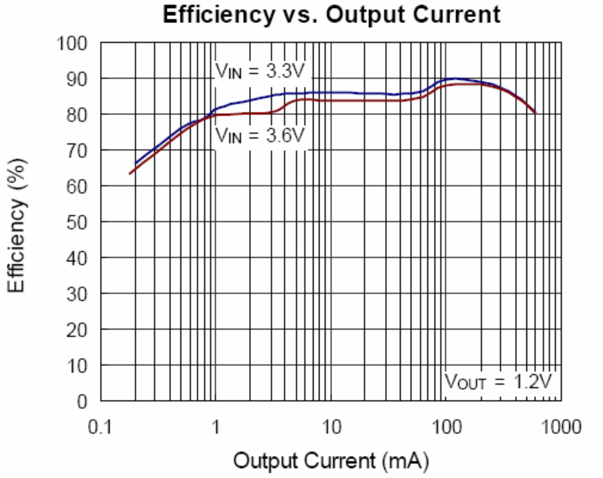
V_{IN} = 3.6V; V_{OUT} = 2.5V; V_{REF} = 0.6V; L = 4.7μH; C_{IN} = 2.2μF; C_{OUT} = 10μF; TA = 25°C; unless otherwise specified.

Parameter	Symbol	Test Conditions		Min	Typ	Max	Units
Input Voltage Range	V_{IN}			2.2	--	5.5	V
Quiescent Current	I_Q	I_{OUT} = 0mA, V_{FB} = V_{REF} + 5%		--	300	--	μA
Shutdown Current	$I_{Q(SD)}$	EN = GND		--	0.1	1	μA
Reference Voltage	V_{REF}	For adjustable output voltage		0.588	0.6	0.612	V
Adjustable Output Range	V_{OUT}			V_{REF}	--	V_{IN}	V
Output Voltage Accuracy	ΔV_{OUT}	V_{IN} = 2.2 to 5.5V, V_{OUT} = 1.0V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = 2.2 to 5.5V, V_{OUT} = 1.2V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = 2.2 to 5.5V, V_{OUT} = 1.5V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = 2.2 to 5.5V, V_{OUT} = 1.8V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = 2.8 to 5.5V, V_{OUT} = 2.5V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = 3.5 to 5.5V, V_{OUT} = 3.3V 0mA < I_{OUT} < 600mA		-3	--	+3	%
	ΔV_{OUT}	V_{IN} = V_{OUT} + 0.2V to 5.5V 0mA < I_{OUT} < 600mA		-3	--	+3	%
FB Input Current	I_{FB}	V_{FB} = V_{IN}		-50	--	50	nA
PMOSFET R_{ON}	$P_{RDS(ON)}$	I_{OUT} = 200mA	V_{IN} = 3.6V	--	0.35	--	Ω
			V_{IN} = 2.5V	--	0.45	--	
NMOSFET R_{ON}	$N_{RDS(ON)}$	I_{OUT} = 200mA	V_{IN} = 3.6V	--	0.30	--	Ω
			V_{IN} = 2.5V	--	0.40	--	
P-Channel Current Limit	$I_{P(LM)}$	V_{IN} = 2.2 to 5.5 V		0.8	--	1.5	A
EN High-Level Input Voltage	V_{ENH}	V_{IN} = 2.2V to 5.5V		1.5	--	--	V
EN Low-Level Input Voltage	V_{ENL}	V_{IN} = 2.2V to 5.5V		--	--	0.4	V
Undervoltage Lock Out threshold				--	1.8	--	V
Hysteresis				--	0.1	--	V
Oscillator Frequency	f_{OSC}	V_{IN} = 3.6V, I_{OUT} = 100mA		1.2	1.5	1.8	MHz
Thermal Shutdown Temperature	T_{SD}			--	160	--	°C
Min. On Time				--	50	--	ns
Max. Duty Cycle				100	--	--	%
LX Leakage Current		V_{IN} = 3.6V, V_{LX} = 0V or V_{LX} = 3.6V		-1	--	1	μA

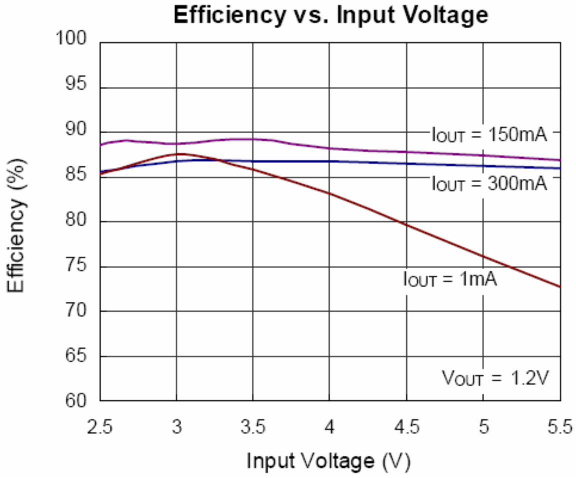
Typical Performance Curves

Note: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

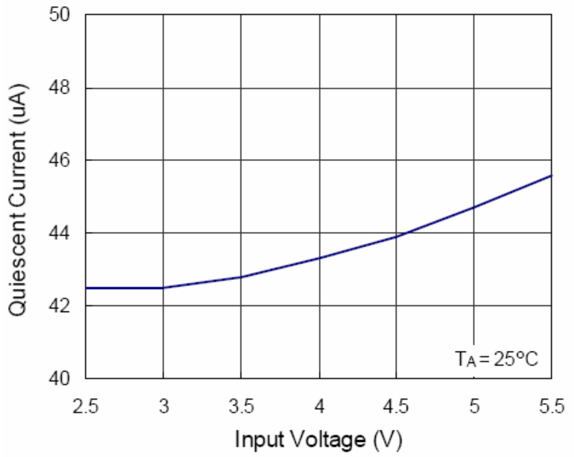
Efficiency vs. Output Current



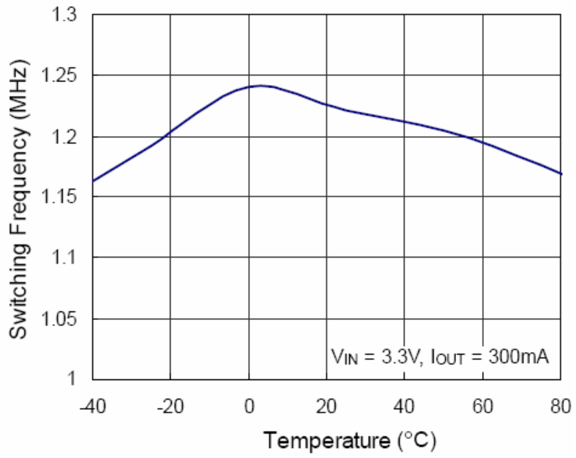
Efficiency vs. Input Voltage



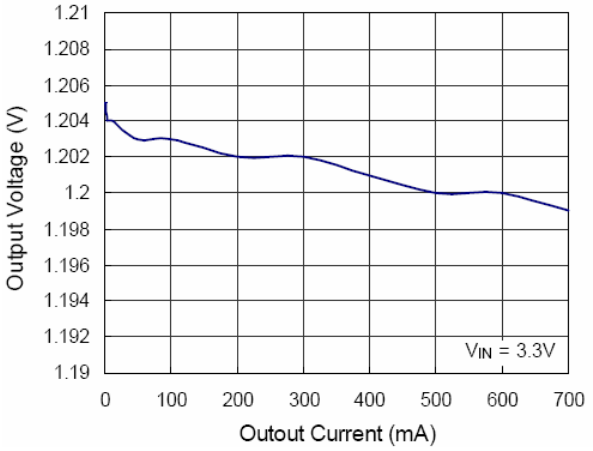
Quiescent Current vs. Input Voltage



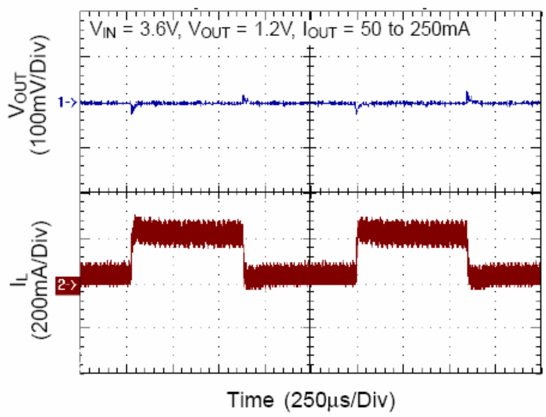
Switching Frequency vs. Temperature



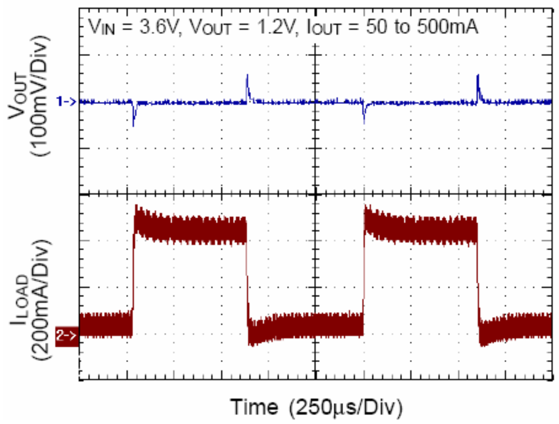
Output Voltage vs. Outout Current



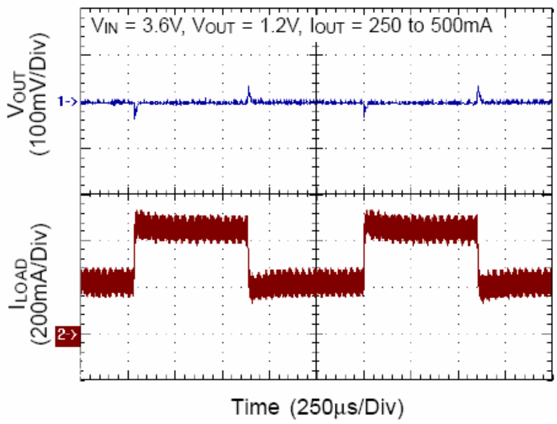
Load Transient Response



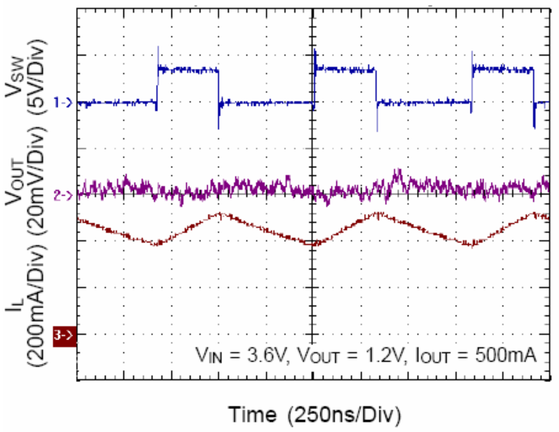
Load Transient Response



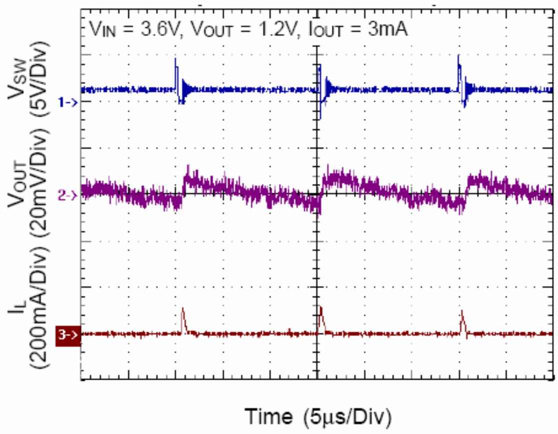
Load Transient Response



PWM Mode Operation



Power-Save Mode Operation



Pin Function Description

EN (Pin 1): Enable Control Input. Forcing this pin above 1.5V enables the part. Forcing this pin below 0.3V shuts down the device. In shutdown, all functions are disabled drawing <1µA supply current. Do not leave EN floating.

GND (Pin 2): Ground Pin.

LX (Pin 3): Switch Node Connection to Inductor. This pin connects to the drains of the internal main and synchronous power MOSFET switches.

VIN (Pin 4): Main Supply Pin. Must be closely decoupled to GND, Pin 2, with a 2.2µF or greater ceramic capacitor.

VFB (Pin 5) (Adjustable Output): Feedback Pin Receives the feedback voltage from an external resistive divider across the output.

VOUT (Pin 5) (Fixed Output): Output Voltage Feedback Pin An internal resistive divider divides the output voltage down for comparison to the internal reference voltage

Applications Information

The basic TQ8008 application circuit is shown in Figure 1& 2. External component selection is driven by the load requirement and begins with the selection of L followed by C_{IN} and C_{OUT}.

Inductor Selection

For most applications, the value of the inductor will fall in the range of 1μH to 4.7μH. Its value is chosen based on the desired ripple current. Large value inductors lower ripple current and small value inductors result in higher ripple currents. Higher V_{IN} or V_{OUT} also increases the ripple current as shown in equation 1. A reasonable starting point for setting ripple current is ΔI_L = 240mA (40% of 600mA).

$$\Delta I_L = \frac{1}{(f)(L)} V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (1)$$

The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation. Thus, a 720mA rated inductor should be enough for most applications (600mA + 120mA). For better efficiency, choose a low DC-resistance inductor.

The inductor value also has an effect on Burst Mode operation. The transition to low current operation begins when the inductor current peaks fall to approximately 200mA. Lower inductor values (higher ΔI_L) will cause this to occur at lower load currents, which can cause a dip in efficiency in the upper range of low current operation. In Burst Mode operation, lower inductance values will cause the burst frequency to increase.

Inductor Core Selection

Different core materials and shapes will change the size/current and price/current relationship of an inductor. Toroid or shielded pot cores in ferrite much energy, but generally cost more than powdered iron core inductors with similar electrical characteristics. The choice of which style inductor to use often depends more on the price vs size requirements and any radiated field/EMI requirements than on what the TQ8008 requires to operate. Table 1 shows some typical surface mount inductors that work well in TQ8008 applications.

Table 1. Representative Surface Mount Inductors

PART NUMBER	VALUE (μH)	DCR (Ω MAX)	MAX DC CURRENT (A)	SIZE W × L × H (mm³)
Sumida CDRH3D16	1.5 2.2 3.3 4.7	0.043 0.075 0.110 0.162	1.55 1.20 1.10 0.90	3.8 × 3.8 × 1.8
Sumida CMD4D06	2.2 3.3 4.7	0.116 0.174 0.216	0.950 0.770 0.750	3.5 × 4.3 × 0.8

C_{IN} and C_{OUT} Selection

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle V_{OUT}/V_{IN}. To prevent large voltage transients, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

C_{IN} required

$$I_{RMS} \cong I_{OMAX} \frac{\left[V_{OUT}(V_{IN} - V_{OUT})\right]^{1/2}}{V_{IN}}$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief. Note that the capacitor manufacturer's ripple current ratings are often based on 2000 hours of life. This makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required.

The selection of C_{OUT} is driven by the required effective series resistance (ESR).

Typically, once the ESR requirement for COUT has been met, the RMS current rating generally far exceeds the $I_{RIPPLE(P-P)}$ requirement. The output ripple ΔV_{OUT} is determined by:

$$\Delta V_{OUT} \cong \Delta I_L \left(ESR + \frac{1}{8fC_{OUT}} \right)$$

where f = operating frequency, C_{OUT} = output capacitance and ΔI_L = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔI_L increases with input voltage. Aluminum electrolytic and dry tantalum capacitors are both available in surface mount configurations. In the case of tantalum, it is critical that the capacitors are surge tested for use in switching power supplies. An excellent choice is the AVX TPS series of surface mount tantalum. These are specially constructed and tested for low ESR so they give the lowest ESR for a given volume. Consult the manufacturer for other specific recommendations.

Using Ceramic Input and Output Capacitors

Higher values, lower cost ceramic capacitors are now becoming available in smaller case sizes. Their high ripple current, high voltage rating and low ESR make them ideal for switching regulator applications. Because the TQ8008's control loop does not depend on the output capacitor's ESR for stable operation, ceramic capacitors can be used **freely** to achieve very low output ripple and small circuit size.

However, care must be taken when ceramic capacitors are used at the input and the output. When a ceramic capacitor is used at the input and the power is supplied by a wall adapter through long wires, a load step at the output can induce ringing at the input, V_{IN}. At best, this ringing can couple to the output and be mistaken as loop instability. At worst, a sudden inrush of current through the long wires can potentially cause a voltage spike at V_{IN}, large enough to damage the part. When choosing the input and output ceramic capacitors, choose the X5R or X7R dielectric formulations. These dielectrics have the best temperature and voltage characteristics of all the ceramics for a given value and size.

Output Voltage Programming

In the adjustable version, the output voltage is set by a resistive divider according to the following formula:

$$V_{OUT} = 0.6V\left(1 + \frac{R1}{R2}\right) \quad (2)$$

The external resistive divider is connected to the output, allowing remote voltage sensing as shown in Figure 3

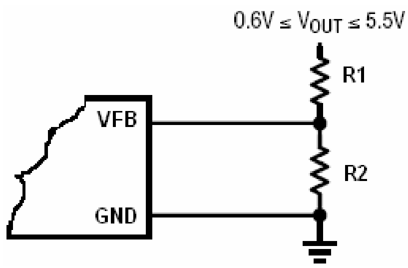


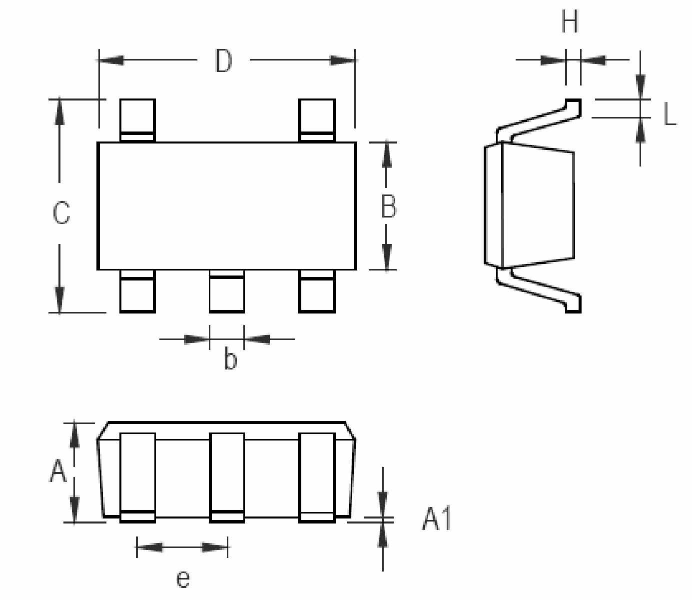
Figure 3

PCB Layout Checklist

When laying out the PCB, the following checklist should be used to ensure proper operation of the TQ8008. Check the following in your layout:

1. The power traces, consisting of the GND trace, the SW trace and the VIN trace should be kept short, direct and wide.
2. Does the V_{FB} pin connect directly to the feedback resistors.
3. Does the (+) plate of C_{IN} connect to V_{IN} as closely as possible. This capacitor provides the AC current to the internal power MOSFETs.
4. Keep the switching node, SW, away from the sensitive V_{FB} node.
5. Keep the (–) plates of C_{IN} and C_{OUT} as close as possible.

Outline Dimension



SOT23 – 5 Package

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.035	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.356	0.559	0.014	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024