AN-1772 LM3691 Evaluation Board

1 Introduction

The LM3691 evaluation board is a working demonstration of a step down DC-DC converter. For further information on buck converter topology, device electrical characteristics, and component selection please refer to the *High Accuracy, Miniature 1A, Step-Down DC-DC Converter for Portable Applications* (SNVS506) data sheet.

2 General Description

The LM3691 step-down DC-DC converter is optimized for powering ultra-low voltage circuits from a single Li-Ion cell or 3 cell NiMH/NiCd batteries. It provides up to 1A load current, over an input voltage range from 2.3V to 5.5V. There are several different fixed voltage output options available.

LM3691 has a mode-control pin that allows the user to select Forced PWM mode or Auto mode that changes modes between ECO mode and PWM mode automatically depending on the load. In ECO, LM3691 offers superior efficiency and very low I_q under light load conditions.

The LM3691 is available in a 6-bump DSBGA package. Only three external surface-mount components, a 1µH inductor, a 4.7 µF input capacitor and a 4.7µF output capacitor, are required.

3 Operating Conditions

Input Voltage Range	2.3V to 5.5V
Recommended Load Current	0 mA to 1000 mA
Junction Temperature (T_J) Range	−30°C to +125°C
Ambient Temperature (T_A) Range	−30°C to +85°C

4 Typical Application

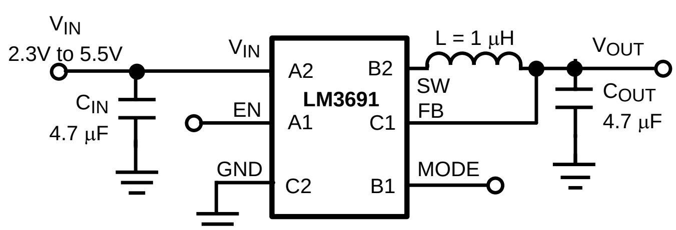

Figure 1. Typical Application Circuit

5 Connection Diagram and Package Mark Information

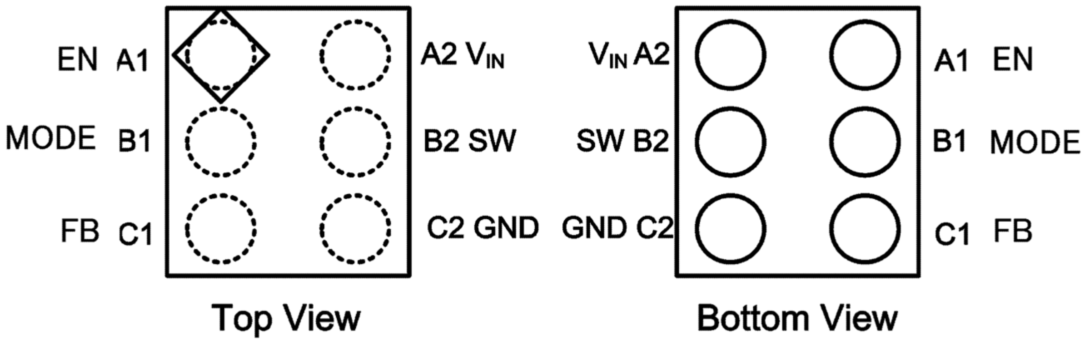

Figure 2. 6-Bump Thin DSBGA Package, Large Bump

Table 1. Pin Descriptions

Pin DSBGA	Name	Description
A1	EN	Enable pin. The device is in shutdown mode when voltage to this pin is <0.4V and enabled when >1.2V. Do not leave this pin floating.
B1	MODE	MODE Pin: Mode = 1, Forced PWM Mode = 0, ECO Do not leave this pin floating. Setting the Mode pin low (<0.4V) places the LM3691 in ECO mode. During Auto mode the device automatically switches between ECO/PWM depending on the load. Setting mode pin high (>1.2V) places the part in Forced PWM. The part is in forced PWM regardless of the load.
C1	FB	Feedback analog input. Connect directly to the output filter capacitor. (Figure 1)
A2	VIN	Power supply input. Connect to the input filter capacitor. (Figure 1)
B2	SW	Switching node connection to the internal PFET switch and NFET synchronous rectifier.
C2	GND	Ground pin.

6 BOM for Common Configurations

Mfr.	Part #	Description	Designation	Quantity
Texas Instruments	LM3691	DC/DC converter	U1	1
TDK	C1608X5R0J475K	4.7 µF, 6.3V, 0603 ceramic capacitor	C1	1
TDK	C1608X5R0J475K	4.7 µF, 6.3V, 0603 ceramic capacitor	C2	1
Murata	LQM2HPN1R0MG0	1 µH Multilayer chip inductor	L1	1

7 Evaluation Board Layout

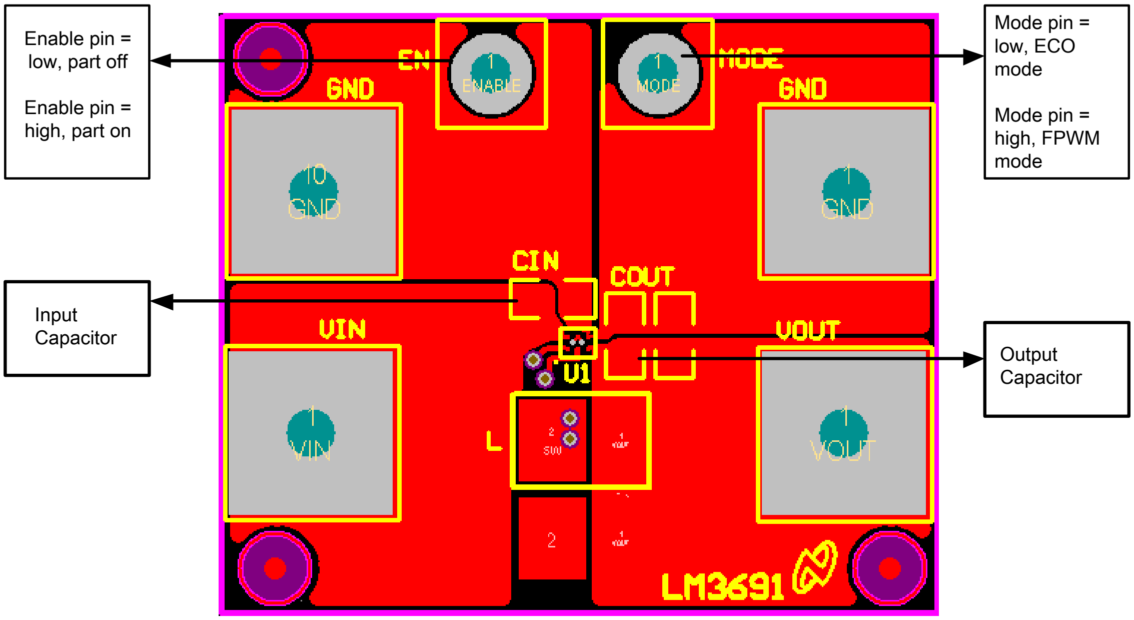

Figure 3. TOP VIEW

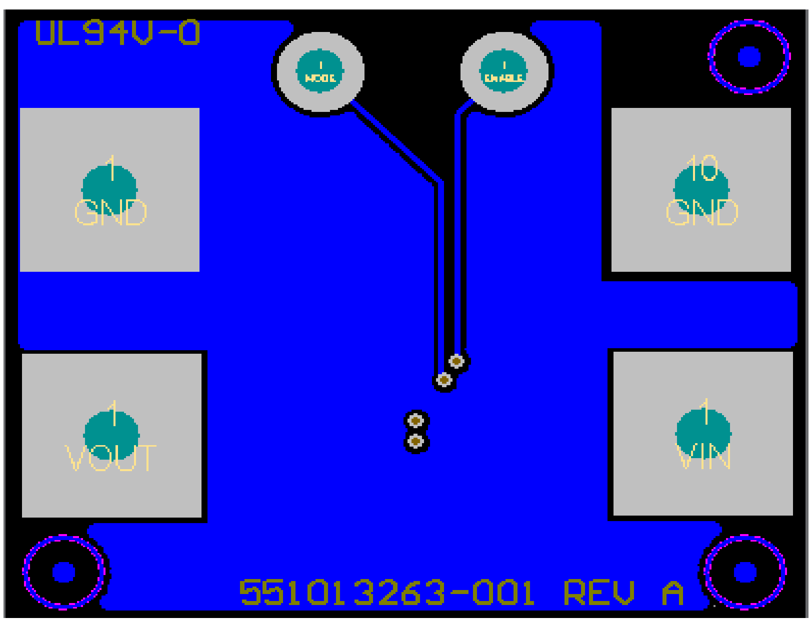

Figure 4. BOTTOM VIEW

8 DSBGA Package Assembly and Use

Use of the DSBGA package requires specialized board layout, precision mounting and careful re-flow techniques, as detailed in *AN-1112 DSBGA Wafer Level Chip Scale Package* (SNVA009). Refer to the section *Surface Mount Assembly Considerations*. For best results in assembly, alignment ordinals on the PC board should be used to facilitate placement of the device. The pad style used with DSBGA package must be the NSMD (Non-Solder Mask Defined) type. This means that the solder-mask opening is larger than the pad size. This prevents a lip that otherwise forms if the solder-mask and pad overlap, from holding the device off the surface of the board and interfering with mounting.

The 6-bump package used for LM3691 has 300–micron solder balls and requires 10.82 mils pads for mounting on the circuit board. The trace to each pad should enter the pad with a 90° entry angle to prevent debris from being caught in deep corners. Initially, the trace to each pad should be 7 mil wide, for a section approximately 7 mil long or longer, as a thermal relief. Then each trace should neck up or down to its optimal width. The important criteria is symmetry. This ensures the solder bumps on the LM3691 re-flow evenly and that the device solders level to the board. In particular, special attention must be paid to the pads for bumps A2 and C2, because GND and V_{IN} are typically connected to large copper planes.

The DSBGA package is optimized for the smallest possible size in applications with red or infrared opaque cases. Because the DSBGA package lacks the plastic encapsulation characteristic of larger devices, it is vulnerable to light. Backside metallization and/or epoxy coating, along with frontside shading by the printed circuit board, reduce this sensitivity. However, the package has exposed die edges. In particular, DSBGA devices are sensitive to light, in the red and infrared range, shining on the package's exposed die edges.

9 Board Layout Considerations

PC board layout is an important part of DC-DC converter design. Poor board layout can disrupt the performance of a DC-DC converter and surrounding circuitry by contributing to EMI, ground bounce, and resistive voltage loss in the traces. These can send erroneous signals to the DC-DC converter IC, resulting in poor regulation or instability. Poor layout can also result in re-flow problems leading to poor solder joints between the DSBGA package and board pads. Poor solder joints can result in erratic or degraded performance.

Good layout for the LM3691 can be implemented by following a few simple design rules, as illustrated in Figure 3.

1. Place the LM3691 on 10.82 mil pads. As a thermal relief, connect each pad with a 7 mil wide, approximately 7 mil long trace, and then incrementally increase each trace to its optimal width. The important criterion is symmetry to ensure the solder bumps re-flow evenly (see Section 8).
2. Place the LM3691, inductor and filter capacitors close together and make the traces short. The traces between these components carry relatively high switching currents and act as antennas. Following this rule reduces radiated noise. Special care must be given to place the input filter capacitor very close to the V_{IN} and GND pin.
3. Arrange the components so that the switching current loops curl in the same direction. During the first half of each cycle, current flows from the input filter capacitor, through the LM3691 and inductor to the output filter capacitor and back through ground, forming a current loop. In the second half of each cycle, current is pulled up from ground, through the LM3691 by the inductor, to the output filter capacitor and then back through ground, forming a second current loop. Routing these loops so the current curls in the same direction prevents magnetic field reversal between the two half-cycles and reduces radiated noise.
4. Connect the ground pins of the LM3691, and filter capacitors together using generous component-side copper fill as a pseudo-ground plane. Then connect this to the ground-plane (if one is used) with several vias. This reduces ground-plane noise by preventing the switching currents from circulating through the ground plane. It also reduces ground bounce at the LM3691 by giving it a low-impedance ground connection.
5. Use wide traces between the power components and for power connections to the DC-DC converter circuit. This reduces voltage errors caused by resistive losses across the traces.
6. Route noise sensitive traces such as the voltage feedback path away from noisy traces between the power components. The voltage feedback trace must remain close to the LM3691 circuit and should be routed directly from FB to V_{OUT} at the output capacitor and should be routed opposite to noise

components. This reduces EMI radiated onto the DC-DC converter's own voltage feedback trace.

7. Place noise sensitive circuitry, such as radio IF blocks, away from the DC-DC converter, CMOS digital blocks and other noisy circuitry. Interference with noise-sensitive circuitry in the system can be reduced through distance.

In mobile phones, for example, a common practice is to place the DC-DC converter on one corner of the board, arrange the CMOS digital circuitry around it (since this also generates noise), and then place sensitive preamplifiers and IF stages on the diagonally opposing corner. Often, the sensitive circuitry is shielded with a metal pan and power to it is post-regulated to reduce conducted noise, using low-dropout linear regulators.

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- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
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