

## FEATURES

- Wide Input Voltage from 4.5V to 16V
- Adjustable Output Voltage from 0.6V to 12V
- Continuous Output Current
  - Qual 4A Continuous Current
  - Dual 7A Continuous Current within 3.3V output voltage
- Internal Soft-Start Time 2.8ms
- Stable with low ESR Ceramic Capacitors
- Pre-Biased Output Start-Up
- Constant On Time (COT) control mode
- Enable Control
- Power Good (PG) Indicator
- Cycle-by-Cycle Output Current Limit Protection
- Short Circuit and Over-Load Hiccup Protection
- Thermal Shutdown Protection
- BGA-77(9mm×15mm×5mm) Package
- Pb-Free RoHS Compliant

## DESCRIPTION

The M4644 is a qual 4A step-down switching mode Power SoC (System on Chip) with integrated power MosFETs, inductor and input decoupling capacitor in BGA-77 package. The input voltage is from 4.5V to 16V with excellent load regulation and line regulation.

M4644 has internal automatic compensation, and the output voltage is adjustable from 0.6V to 12V by a bottom feedback resistor.

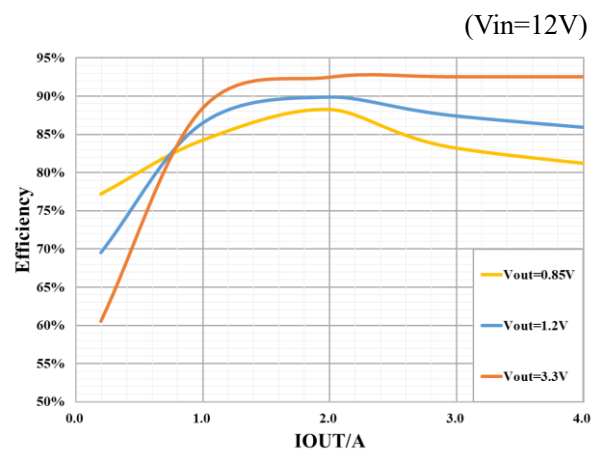
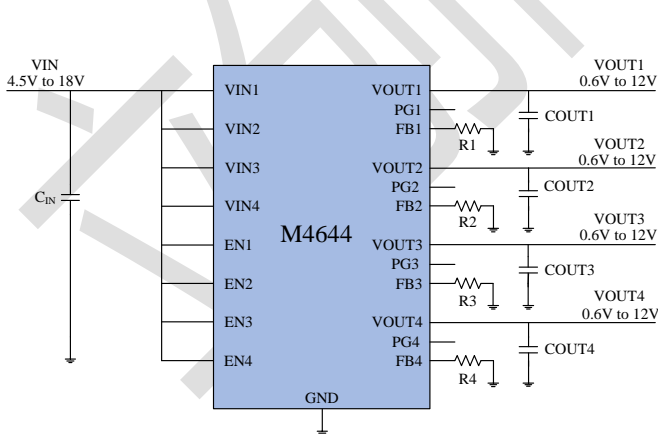
The M4644 provides high efficiency with Constant On Time (COT) control mode for fast transient response and good loop stability.

M4644 can also provide OCP, SCP, UVP, output voltage limit, and thermal shutdown protection.

## APPLICATIONS

- Telecom Systems
- Servers & Data Centers
- Solid-State and Hard Disk Drives
- PoLs Power Supply

## TYPICAL APPLICATION&EFFICIENCY



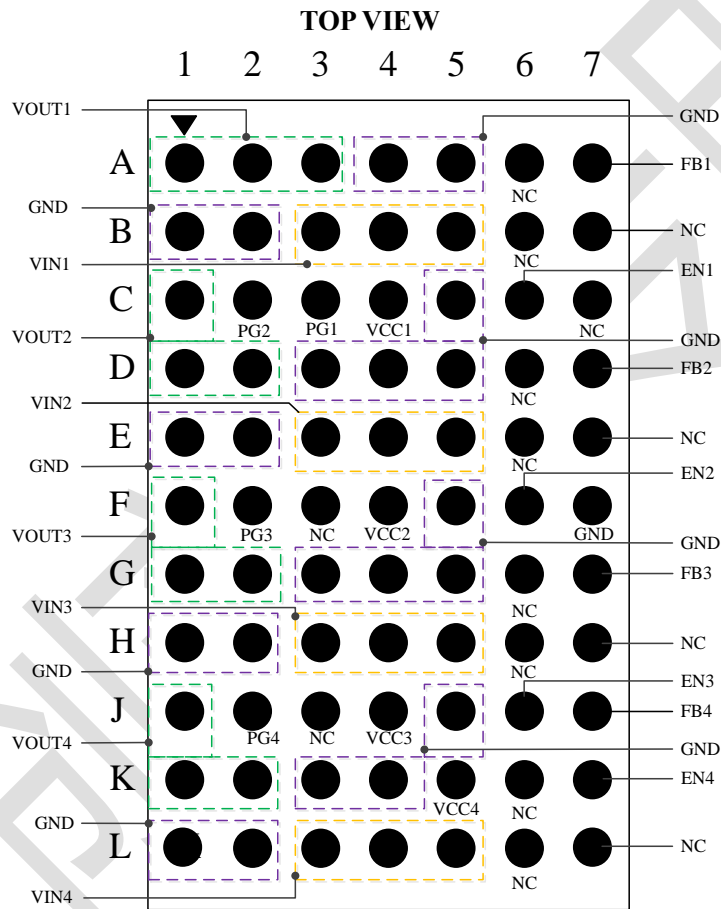


### ORDERING INFORMATION

PART NUMBER	TOP MARKING	PACKAGE	MOQ	MSL
M4644DBGH-T	M4644 YWWLLL	BGA-77 (9mm×15mm×5mm)	170/ Tray	3

NOTES: Y: Year, WW: Week, LLL: Lot Number.

### PACKAGE REFERENCE



**PACKAGE REFERENCE (continued)****Table1: Pins A1–F7**

PIN	NAME	PIN	NAME	PIN	NAME	PIN	NAME	PIN	NAME	PIN	NAME
A1	VOUT1	B1	GND	C1	VOUT2	D1	VOUT2	E1	GND	F1	VOUT3
A2	VOUT1	B2	GND	C2	PG2	D2	VOUT2	E2	GND	F2	PG3
A3	VOUT1	B3	VIN1	C3	PG1	D3	GND	E3	VIN2	F3	NC
A4	GND	B4	VIN1	C4	VCC1	D4	GND	E4	VIN2	F4	VCC2
A5	GND	B5	VIN1	C5	GND	D5	GND	E5	VIN2	F5	GND
A6	NC	B6	NC	C6	EN1	D6	NC	E6	NC	F6	EN2
A7	FB1	B7	NC	C7	NC	D7	FB2	E7	NC	F7	GND

**Table2: Pins G1–L7**

PIN	NAME	PIN	NAME	PIN	NAME	PIN	NAME	PIN	NAME
G1	VOUT3	H1	GND	J1	VOUT4	K1	VOUT4	L1	GND
G2	VOUT3	H2	GND	J2	PG4	K2	VOUT4	L2	GND
G3	GND	H3	VIN3	J3	NC	K3	GND	L3	VIN4
G4	GND	H4	VIN3	J4	VCC3	K4	GND	L4	VIN4
G5	GND	H5	VIN3	J5	GND	K5	VCC4	L5	VIN4
G6	NC	H6	NC	J6	EN3	K6	NC	L6	NC
G7	FB3	H7	NC	J7	FB4	K7	EN4	L7	NC



## PIN FUNCTIONS

PIN #	NAME	DESCRIPTION
B3–B5, E3–E5, H3–H5, L3–L5	VIN1, VIN2, VIN3, VIN4	<b>Input Voltage.</b> Input capacitor is recommended to be placed between VIN1 and GND.
A4–A5, B1–B2, C5, D3–D5, E1–E2, F5, F7, G3–G5, H1–H2, J5, K3–K4, L1–L2	GND	<b>Ground.</b>
A1–A3	VOUT1	<b>Output Voltage of Channel 1.</b>
C1, D1–D2	VOUT2	<b>Output Voltage of Channel 2.</b>
F1, G1–G2	VOUT3	<b>Output Voltage of Channel 3.</b>
J1, K1–K2	VOUT4	<b>Output Voltage of Channel 4.</b>
A7, D7, G7, J7	FB1, FB2, FB3, FB4	<b>Feedback of Channel.</b> A top feedback resistor whose value is 60.4k $\Omega$ is placed internally between VOUT and FB of each channel, the output voltage is adjustable from 0.6V to 12V by an external bottom feedback resistor.
C4, F4, J4, K5	VCC1, VCC2, VCC3, VCC4	<b>Internal 5V LDO Output.</b> An output capacitor to GND has been placed internally.
C6, F6, J6, K7	EN1, EN2, EN3, EN4	<b>Enable Control.</b> Pulling this pin low shuts the chip down. Pulling it high enables the chip.
C3, C2, F2, J2	PG1, PG2, PG3, PG4	<b>Power Good.</b>
A6, B6, C7, E6, H6, L6, A6, D6, G6, K6	NC1	<b>Not Connected1.</b>
B7, E7, H7, L7	NC2	<b>Not Connected2.</b>



## ABSOLUTE MAXIMUM RATINGS

	SYMBOL	MIN	MAX	UNIT
Voltage at Vin	V <sub>IN</sub>	-0.3	20	V
Voltage at EN	EN	-0.3	20	V
Voltage at Other Pins		-0.3	6	V
Junction Temperature Range	T <sub>J</sub>	-40	125	°C
Storage Temperature Range	T <sub>S</sub>	-55	150	°C
Power Dissipation (T <sub>A</sub> =+25°C)	P <sub>D</sub> <sup>Notes 1)</sup>		9.4	W

## RECOMMENDED OPERATING CONDITIONS

	SYMBOL	MIN	MAX	UNIT
Input Voltage Range	V <sub>IN</sub>	4.5	16	V
Output Voltage Range	V <sub>OUT</sub>	0.6	12	V
Output Current	I <sub>OUT</sub>		4	A
Junction Temperature Range	T <sub>J</sub>	-40	125	°C

## THERMAL RESISTANCE

	SYMBOL	MIN	MAX	UNIT
Junction to Ambient	θ <sub>JA</sub> <sup>Notes 2)</sup>		10.6	°C/W
Junction to Case	θ <sub>JC</sub> <sup>Notes 2)</sup>		2.8	°C/W

### NOTES:

- 1) The maximum allowable continuous power dissipation at any ambient temperature (T<sub>A</sub>) is calculated by  $P_D(\max) = (T_J(\max) - T_A) / \theta_{JA}$ . Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the power module will go into thermal shutdown.
- 2) Measured on EVB, 4-layer PCB 1oZ.

**ELECTRICAL CHARACTERISTICS** $V_{IN}=12V, T_A=25^{\circ}C.$ 

PARAMETERS	SYMBOL	CONDITION	MIN	TYP	MAX	UNIT
Input Voltage	$V_{IN}$		4.5		16	V
Shutdown Current	$I_{SD}$	$V_{EN} = 0V$		1	3	$\mu A$
Quiescent Current	$I_{QI}$	$V_{EN} = 2V, V_{FB} = 0.65V$		305		$\mu A$
Valley Current Limit	$I_{LIMIT\_VY}$			5.5		A
Switching Frequency	$F_{SW}$			600		kHz
Internal pull-up feedback resistor				60.4		k $\Omega$
Soft-Start Time	$T_{SS}$	$V_{FB}$ from 10% to 90%		2.8		ms
Enable Rising Threshold	$V_{EN\_RISING}$	Low to high	1.1	1.25	1.4	V
Enable Falling Threshold	$V_{EN\_FALLING}$	High to low	0.9	1.05	1.2	V
Enable Input Resistor.	$V_{EN\_PD}$			1.5		M $\Omega$
VCC Regulator	$V_{CC}$	$V_{IN}>5.2V, I_{VCC}=0\mu A$		5		V
PG High Threshold	$V_{PGH\_R}$	$V_{FB}$ Rising, $V_{FB}$ in respect to $V_{FB\_REF}$ , $V_{OUT} < Target$		85		%
	$V_{PGH\_F}$	$V_{FB}$ Falling, $V_{FB}$ in respect to $V_{FB\_REF}$ , $V_{OUT} > Target$		105		%
PG Low Threshold	$V_{PGL\_R}$	$V_{FB}$ Rising, $V_{FB}$ in respect to $V_{FB\_REF}$ , $V_{OUT} > Target$		115		%
	$V_{PGL\_F}$	$V_{FB}$ Falling, $V_{FB}$ in respect to $V_{FB\_REF}$ , $V_{OUT} < Target$		75		%
PG Delay	$T_{PG\_DELAY}$			50		$\mu s$
Thermal Shutdown				160		$^{\circ}C$
Thermal Shutdown Hysteresis				20		$^{\circ}C$



## OPERATION

The M4644 is a qual 4A synchronous step-down switching mode Power SoC (System on Chip) with integrated High-Side and Low-Side power MosFETs, inductor and input decoupling capacitor in BGA-77 package. Only FB resistors, input and output capacitors are needed to complete the design over 4.5V to 16V input voltage range. The M4644 supports output voltage of 0.6V to 12V with the fixed switching frequency of 600kHz.

M4644 works on COT control mode that offers excellent transient response over the wide range of input voltage. M4644 operates in Forced Continuous Conduction Mode (FCCM) which keeps low output ripple. The soft start time of M4644 is 2.8ms internally. Fully integrated protection features include OCP, UVP, UVP and OTP and all these faults can be indicated by PG. The protection function details are shown below.

### VIN Under-Voltage Lockout (VIN UVLO)

VIN Under-voltage lockout (VIN UVLO) protects the chip from operating at an insufficient VIN voltage. The M4644 VIN UVLO comparator monitors the VIN voltage. The VIN UVLO rising threshold is about 4.1V, while its falling threshold is consistently 3.6V.

### Pre-Bias Start-Up

M4644 is designed for monotonic start-up into pre-biased loads. If the output is pre-biased to a certain voltage during start-up, the BST voltage is refreshed and charged, and the voltage on the soft start is charged as well. If the BST voltage exceeds its rising threshold voltage and the soft-start voltage exceeds the sensed output voltage at FB, the part works normally.

### Over-Current Protection (OCP)

M4644 has both valley current-limit control and peak current limit control. During low side MosFET on, the

inductor current is monitored. When the sensed inductor current reaches the valley current limit, the low side MosFET limit comparator. The device enters overcurrent protection (OCP) mode, and the high side MosFET waits until the valley current limit disappears before turning on again. During the high side MosFET on period, the inductor current is compared with the peak current-limit. If the peak current limit is triggered, the high side MosFET on pulse will be terminated immediately. The output voltage drops until  $V_{FB}$  is below the UVP threshold. Once FB UVP is triggered, M4644 enters hiccup mode to restart the part periodically.

### Output Over-Voltage Protection (OVP)

M4644 monitors a resistor-divided  $V_{FB}$  to detect over or under-voltage. When  $V_{FB}$  becomes higher than 115% of the target voltage, the over-voltage protection (OVP) comparator output goes to high, and the circuit will turn on low side MosFET to discharge the output. Low side MosFET will be turned off until the negative current limit is triggered then low side MosFET will remain off for 5 $\mu$ s to turn on again. M4644 will repeat above process until the output OVP condition is removed.

### Under-Voltage Protection (UVP)

When  $V_{FB}$  drops below 75% of  $V_{REF}$ , the UVP comparator output goes to high, and M4644 enters the hiccup protection.

### Thermal Shutdown

The junction temperature of M4644 is monitored internally. If the junction temperature exceeds the threshold value (typically 160°C), the converter shuts off. This is a non-latched protection. The device will power up again when the junction temperature drops below typically 140°C.



## USER GUIDE

### Output Voltage

The output voltage is set by the external feedback bottom resistor as the typical application circuit on Page 1. The bottom feedback resistor  $R_2$  can be calculated as:

$$R_2 = \frac{60.4}{\frac{V_{OUT}}{V_{FB}} - 1}$$

Table 1 lists the recommended feedback resistor values for common output voltages.

**Table 3: FB Resistor Values for Common Output Voltages.**

V <sub>OUT</sub> (V)	R <sub>2</sub> (kΩ)
0.9	120
1.0	90.6
1.2	60.4
1.5	40
1.8	30
2.5	19
3.3	13.3
5	8.2

### Input Capacitor Selection

The input current of the step-down converter is discontinuous with sharp edges, therefore, placing input filter capacitors is necessary. For better performance, low ESR ceramic capacitor with X5R or X7R dielectrics are highly recommended because of their lowest temperature variations. The RMS current of the input capacitor is calculated:

$$I_{CIN\_RMS} = I_{OUT} \sqrt{D(1-D)}$$

in which D is the Duty Cycle and when the current is continuous,  $D = V_{OUT}/V_{IN}$ ;  $I_{OUT}$  is the output load current. As the equation above, when D is 0.5, the highest RMS current is approximately:

$$I_{CIN\_RMS} = \frac{1}{2} \times I_{OUT}$$

So, it is recommended to choose the capacitors with the RMS current rating higher than  $1/2 I_{OUT}$ .

The power dissipation on the input capacitors can be estimated with the RMS current and the ESR.

Electrolytic or tantalum capacitors can also be used. The input voltage ripple caused by the capacitor can be calculated as:

$$\Delta V_{CIN} = \frac{I_{OUT}}{F_{SW} \cdot C_{IN}} \cdot \frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

in which,  $F_{SW}$  is switching frequency.

### Output Capacitor Selection

Output capacitors are required to keep output voltage stable. To minimize the output voltage ripple, low ESR ceramic capacitors should be used. The output voltage ripple can be estimated as:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8F_{SW}^2 C_{OUT} L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In which, L is the inductor fixed at 1μH internally.

If electrolytic or tantalum capacitors are used, the ESR will dominate the output voltage ripple as:

$$\Delta V_{OUT} = R_{ESR} \cdot \frac{V_{OUT}}{F_{SW} L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

### PCB Layout Guide

To optimize the electrical and thermal performance, some PCB layout guidelines should be considered as below:

1. Make the power loop minimized.
2. Use wide trace for the high current paths and keep it as short as possible. It helps to minimize the PCB conduction loss and thermal stress.
3. The GND should be connected to a strong ground plane for better heat dissipation and noise protection.
4. Place the input decoupling capacitor close to VIN and GND.
5. Do not set the GND under the chip.





TYPICAL APPLICATION

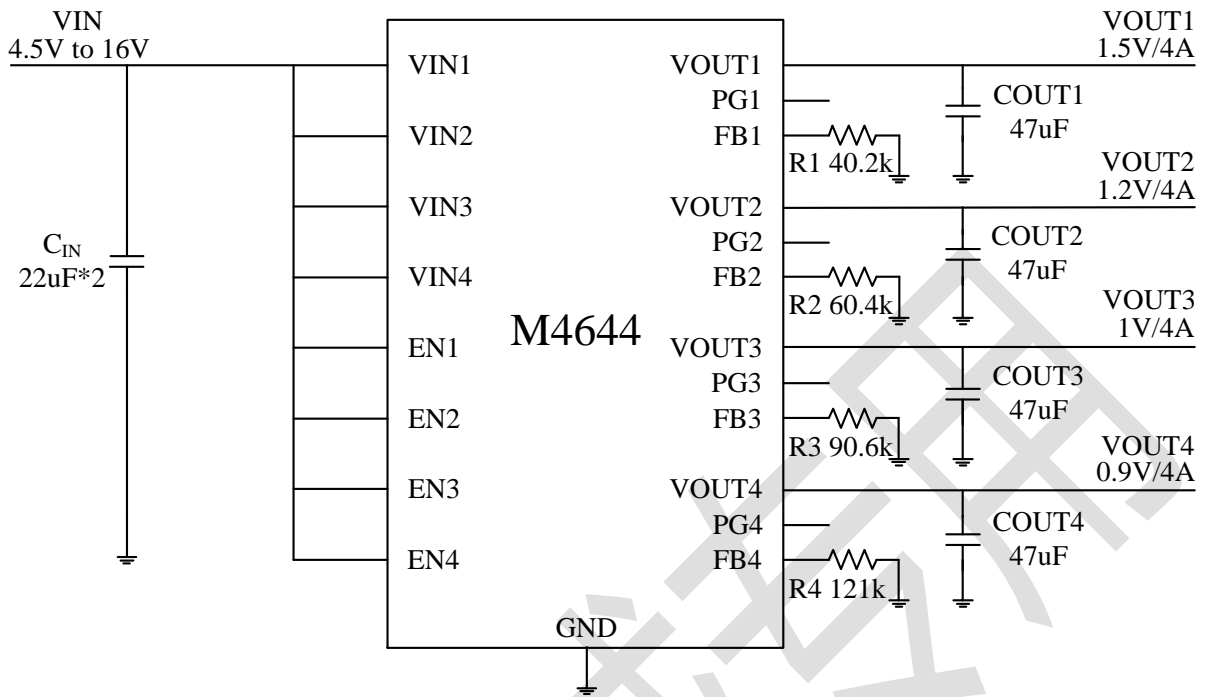
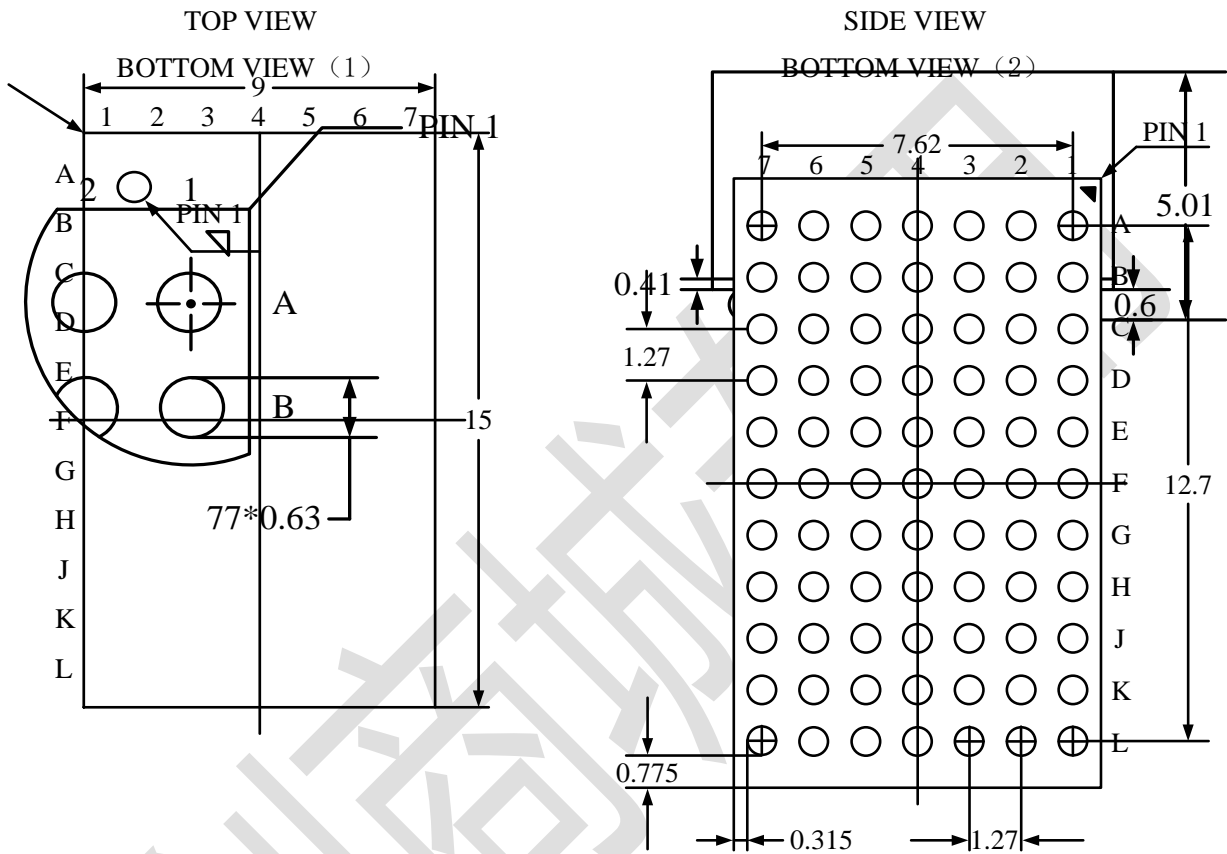


Figure 1. Typical Application Circuits of M4644



PACKAGE INFORMATION

BGA-77 (9mm×15mm×5mm) Package

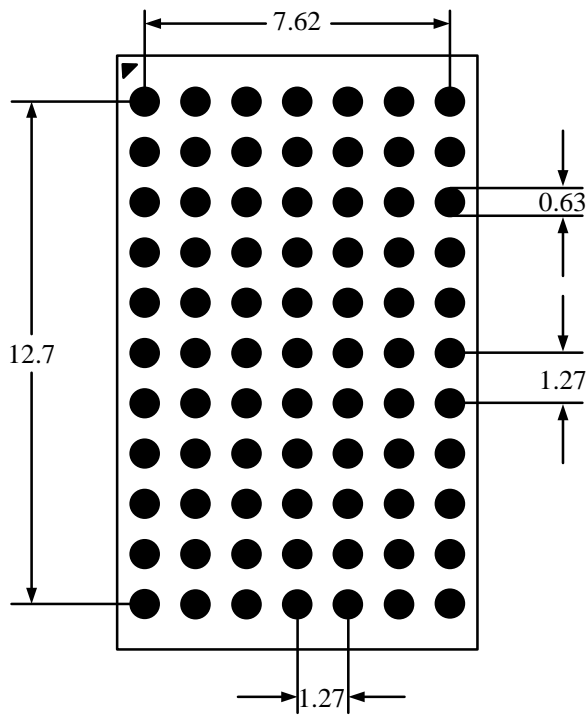




### RECOMMENDED LAND PATTERN

### NOTES:

All dimensions are in MM.



### M4644 VS LXX4644 PIN CONNECTION RECOMMENDATIONS

	M4644		LXX4644		兼容措施
	引脚	连接方式	引脚	连接方式	
B5,E5,H5,L5	VIN	VIN	SVIN1,2,3,4	VIN	可直接兼容
A6,D6,G6,K6	NC	NC	TRACK/SS	C	可直接兼容
B6,E6,H6,L6	NC	NC	MODE1,2,3,4	INTVCC 或 GND	可直接兼容
<b>B7,E7,H7,L7</b>	<b>NC</b>	<b>NC</b>	<b>COMP1,2,3,4</b>	<b>NC 或外接 R/C</b>	<b>不接阻容</b>
C7	NC	NC	CLKIN	NC	可直接兼容
F3	NC	NC	TEMP	NC	可直接兼容
J3	NC	NC	CLKOUT	NC	可直接兼容