Synchronous Step-Up Converter with Ultra Low Quiescent Current

SSP8099

General Description

The SSP8099 is a synchronous step-up converter . It is designed for products powered by alkaline battery, NiMH rechargeable battery, Li-Mn battery or rechargeable Li-Ion battery, for which high efficiency under light load condition is critical to achieve long battery life operation.

The SSP8099 can support up to 300mA output current from 3.3V to 5V conversion, and achieve up to 90% efficiency at 200mA load.

The SSP8099 also offers both down mode and pass-through operation for different applications. In down mode, the output voltage can still be regulated at target value even when input voltage is higher than output voltage. In pass-through mode, the output voltage follows input voltage. The SSP8099 exits down mode and enters into pass-through mode when VIN > VOUT + 0.3V.

The SSP8099 supports true shutdown function when it is disabled, which disconnects the load from the input supply to reduce the current consumption.

The SSP8099 offers both adjustable output voltage version and fixed output voltage versions. It is available in Green WLCSP-1.22×0.83-6B and TDFN-2×2-6AL packages.

Features

● Operating Input Voltage Range: 0.9V to 5.2V
● Ultra Low Quiescent Current
   Low shutdown mode current：<1μA
   Ultra Low IQ into VIN Pin：<2μA
● 1.0MHz Fixed Frequency Operation
● Adjustable Output Voltage from 2.5V to 5.2V
● Fixed Output Voltage Versions Available
● Power-Save Mode for Improved Efficiency at Low Output Power
● Regulated Output Voltage in Down Mode
● True Disconnection During Shutdown
● Up to 90% Efficiency from 10mA to 300mA Load
● -40℃ to +85℃ Operating Ambient Temperature Range
● Available in Green WLCSP-1.22×0.83-6B and TDFN-2×2-6AL Packages

APPLICATIONS

- Single-Cell Li-Ion to 5V Converters
- Handheld Instruments
- Wearable Applications
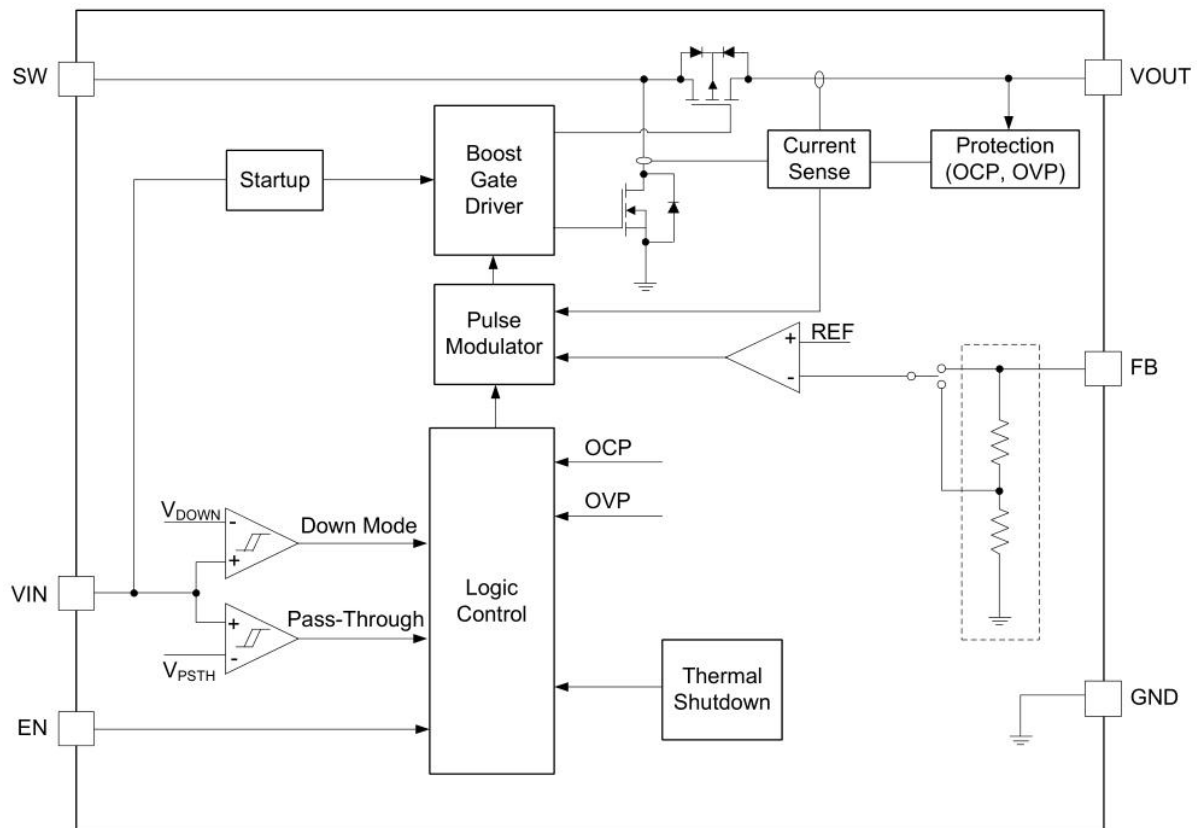- Low Power Wireless Applications
- Battery Powered Systems

Order information

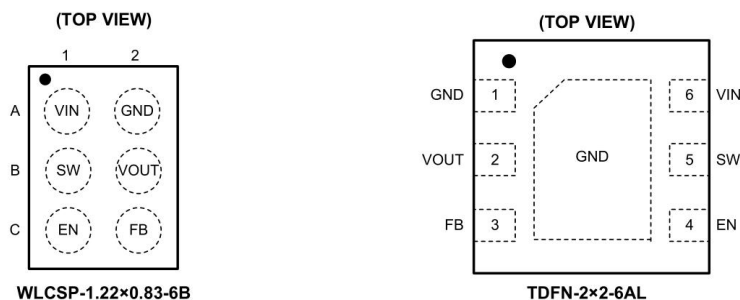| Product model	Package	Manner of packing	Minimum packing quantity
SSP8099-XXYG	WLCSP-1.22×0.83-6B		3000
SSP8099-XXYT	TDFN-2×2-6AL	Reel	3000
SSP8099-ADJYG	WLCSP-1.22×0.83-6B		3000
SSP8099-ADJYT	TDFN-2×2-6AL		3000

Note:"XX" stands for output voltages.Output Voltage：2.5V、3.0V、3.3V、3.6V、4.5V、5V

"ADJ" means the output voltage is adjustable.

FUNCTIONAL BLOCK DIAGRAM

PIN CONFIGURATIONS
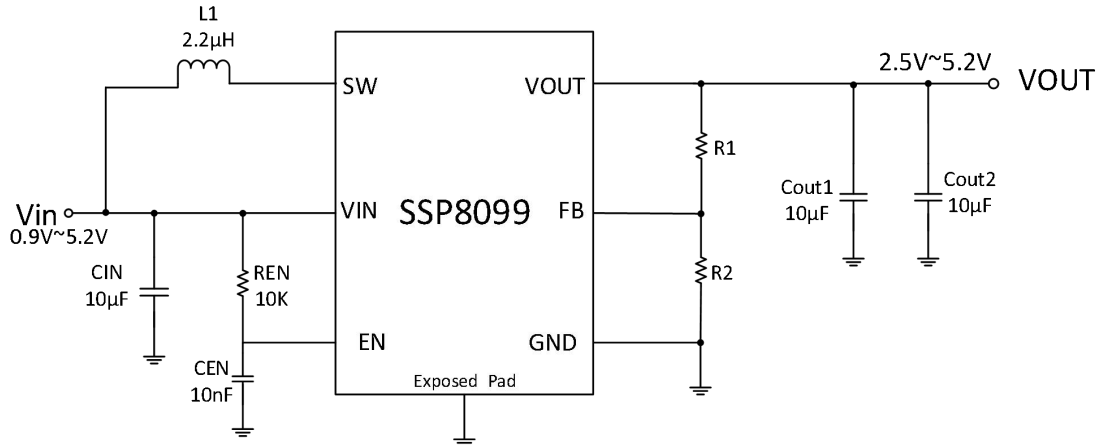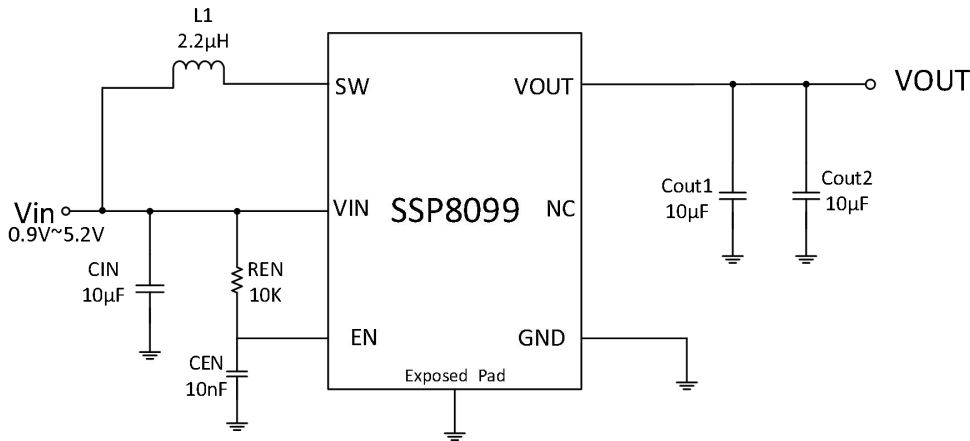

WLCSP-1.22×0.83-6B

TDFN-2×2-6AL

PIN DESCRIPTION

PIN		NAME	TYPE	FUNCTION
WLCSP-1.22×0.83-6B	TDFN-2×2-6AL			
A1	6	VIN	P	Power Supply Input.
A2	1	GND	G	Ground.
B1	5	SW	O	Switch Pin of the Converter. It is connected to the inductor.
B2	2	VOUT	O	Boost Converter Output.
C1	4	EN	I	Enable Logic Input. Logic high voltage enables the device; logic low voltage disables the device. Do not leave it floating.
C2	3	FB	I	Voltage Feedback of Adjustable Output Voltage. Connect to the center tap of a resistor divider to program the output voltage. Connect to the GND pin or keep floating for fixed output voltage versions.
—	Exposed Pad	GND	—	Connect to GND.

NOTE: I: input, O: output, G: ground, P: power for the circuit

Application Circuits

Adjustable Output Voltage Version

Fixed Output Voltage Version

ABSOLUTE MAXIMUM RATINGS

VIN, SW, VOUT, FB, EN to GND .... -0.3V to 6.0V
Package Thermal Resistance
WLCSP-1.22×0.83-6B, θJA .... 143°C/W
TQFN-2×2-6AL, θJA .... 105°C/W
Junction Temperature ....+150°C
Storage Temperature ....-65°C to +150°C
Lead Temperature (Soldering, 10s) .... +260°C
ESD Susceptibility
HBM 2000V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range .... 0.9V[1] to 5.2V
Output Voltage Range .... 2.5V to 5.2V
Operating Ambient Temperature Range ... . -40°C to +85°C
Operating Junction Temperature Range .... -40°C to +125°C
NOTE (1): Refer to the "Startup and Low Supply Voltage Operation" for detailed description.

ELECTRICAL CHARACTERISTICS

(VIN = 0.9V to 5.2V, C IN = 10μF, C OUT = 20μF, Full = -40℃ to +85℃, typical values are at VIN = 3.7V, T A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Power Supply							
Input Voltage Range	VIN		+25℃	0.9		5.2	V
Quiescent Current into VIN Pin	I Q	IC enabled, No load, no switching(Vin=Vout)	Full		0.05	0.2	μA
		IC enabled, No load, no switching, boost or down mode	Full		1	2	μA
Shutdown Current into VIN Pin	I SD	EN = GND, VIN = 3.6V	Full		0.1	1	μA
Output							
Output Voltage Range	VOUT		Full	2.5		5.2	V
Output Voltage		SSP8099 -5.0, VIN < VOUT , PWM mode	Full	4.85	5.00	5.09	V
		SSP8099 -5.0, VIN < VOUT , PFM mode	+25℃		5.08		V
		SSP8099 -4.5, VIN < VOUT , PWM mode	Full	4.37	4.50	4.58	V
		SSP8099 -4.5, VIN < VOUT , PFM mode	+25℃		4.57		V
		SSP8099 -3.6, VIN < VOUT , PWM mode	Full	3.50	3.60	3.67	V
		SSP8099 -3.6, VIN < VOUT , PFM mode	+25℃		3.65		V
		SSP8099 -3.3, VIN < VOUT , PWM mode	Full	3.21	3.30	3.35	V
		SSP8099 -3.3, VIN < VOUT , PFM mode	+25℃		3.35		V
		SSP8099 -3.0, VIN < VOUT , PWM mode	Full	2.92	3.00	3.05	V
		SSP8099 -3.0, VIN < VOUT , PFM mode	+25℃		3.04		V
		SSP8099 -2.5, VIN < VOUT , PWM mode	Full	2.44	2.50	2.54	V
		SSP8099 -2.5, VIN < VOUT , PFM mode	+25℃		2.54		V
Feedback Reference Voltage	V REF	VIN < VOUT , PWM mode	Full	0.975	1.000	1.025	V
		VIN < VOUT , PFM mode	+25℃		1.020		V

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Output Over-Voltage Protection Threshold	V OVP	VOUT rising	+25℃	5.50	5.8	5.95	V
OVP Hysteresis			+25℃		100		mV
Leakage Current into FB Pin	I FB_LKG	V FB = 1.1V	Full		10	50	nA
Switching							
Switching Frequency	f SW	VIN = 3.7V	Full		1.0		MHz
Power Switch							
Low-side Switch On-Resistance	R DS(ON)_LS	VOUT = 5.0V (TDFN)	+25℃		280	400	mΩ
		VOUT = 5.0V (WLCSP)	+25℃		220	310	mΩ
		VOUT = 3.3V (TDFN)	+25℃		340	480	mΩ
		VOUT = 3.3V (WLCSP)	+25℃		290	390	mΩ
Rectifier On-Resistance	R DS(ON)_HS	VOUT = 5.0V (TDFN)	+25℃		270	350	mΩ
		VOUT = 5.0V (WLCSP)	+25℃		250	350	mΩ
		VOUT = 3.3V (TDFN)	+25℃		350		mΩ
		VOUT = 3.3V (WLCSP)	+25℃		330		mΩ
Current Limit Threshold	I LIM	VOUT > 2.5V, boost operation	+25℃	0.89	1.3	1.62	A
		VOUT = 2.5V, boost operation	+25℃	0.57	0.8	1.06	A
Control Logic							
EN Input Low Voltage Threshold	V IL	VIN ≤ 1.5V	Full			0.8 × VIN	V
		VIN > 1.5V	Full			0.4	V
EN Input High Voltage Threshold	V IH	VIN ≤ 1.5V	Full	0.8 × VIN			V
		VIN > 1.5V	Full	1.2			V
Leakage Current into EN Pin	I EN_LKG	V EN = 5.0V	+25℃			300	nA

DETAILED DESCRIPTION

The SSP8099 synchronous step-up converter is designed for alkaline battery, coin-cell battery, Li-Ion or Li-Polymer battery powered systems, which requires long battery running time and tiny solution size. The SSP8099 can operate with a wide input voltage from 0.9V to 5.2V.

The SSP8099 operates in peak current mode with typical 1.3A peak switch current limit. The SSP8099 provides the true shutdown function and the load is completely disconnected from the input so as to minimize the leakage current. It also adopts down mode and pass-through operation when input voltage is close to or higher than the regulated output voltage.

The SSP8099 is available in both adjustable and fixed output voltage versions.

Enable and Disable

When the EN pin is pulled to high, the SSP8099 is enabled. When the EN pin is pulled to low, the SSP8099 goes into shutdown mode. In shutdown mode, the device stops switching and the rectifying PMOS fully turns off, providing the completed disconnection between input and output. Less than 1µA input current is consumed in shutdown mode. In particular, it is recommended to avoid pulling EN high to start the boost when the power supply voltage is higher than 5.2V. See Figure 1, a RC network of 10kΩ and 10nF at EN pin is suggested to ensure the EN active signal a bit later than the spike of the power supply.

Startup and Low Supply Voltage Operation

The SSP8099 is able to start up with 0.9VINput voltage with larger than 3kΩ load. However, if the load during startup is too heavy that the SSP8099 fails to charge the output voltage to above 2.2V, then it won't be able to start up successfully.

The SSP8099 may not be shut down by pulling the EN to logic low when the supply voltage is below 0.85V, while the supply voltage can drop to as low as 0.4V for maintain the output voltage with light loadings.

Current Limit Operation

The SSP8099 employs cycle-by-cycle over-current protection (OCP) function. If the inductor peak current reaches the current limit threshold ILIM , the main switch turns off so as to stop further increase of the input current. In this case the output voltage will decrease until the power balance between input and output is achieved. If the output drops below the input voltage,

The SSP8099 enters into down mode. The peak current is still limited by I LIM cycle-by-cycle in down mode. If the output drops below 2.2V, the SSP8099 enters into startup process again. In pass-through operation, current limit function is not enabled.

Output Short-to-Ground Protection

The SSP8099 starts to limit the switch current to about 200mA when the output voltage is below 2.2V. If short-to-ground condition occurs, switch current is limited at about 200mA. Once the short circuit is released, the SSP8099 goes back to soft start again and regulates the output voltage.

Over-Voltage Protection

SSP8099 has an output over -voltage protection (OVP) to protect the device in case that the external feedback resistor divider is wrongly connected. When the output voltage of the SSP8099 exceeds the OVP threshold of 5.8V, the device stops switching. Once the output voltage falls 0.1V below the OVP threshold,

the device starts operating again.

Power-Save Mode Operation under Light Load Condition

The step-up converter of SSP8099 enters into power-save mode operation under light load condition.

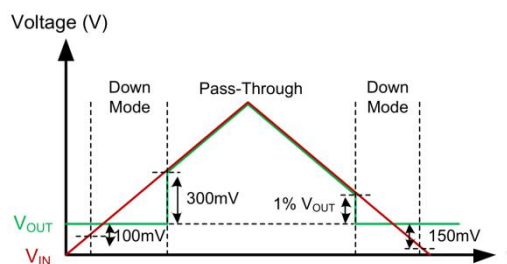## Down Mode Regulation and Pass-Through Operation

The SSP8099 features down mode and pass-through operation when input voltage is close to or higher than output voltage.

DETAILED DESCRIPTION

In the down mode, output voltage is regulated at target value even when VIN > VOUT . The control circuit changes the behavior of the rectifying PMOS by pulling its gate to input voltage instead of to ground. In this way, the voltage drop across the PMOS is increasing as high as to regulate the output voltage. The power loss also increases in this mode, which needs to be taken into account for thermal consideration.

In the pass-through operation, the step-up converter stops switching. The rectifying PMOS constantly turns on and low-side switch constantly turns off. The output voltage is the input voltage minus the voltage drop across the DC resistance (DCR) of the inductor and the on-resistance of the rectifying PMOS.

With VIN ramping up, the SSP8099 goes into down mode first when VIN > VOUT - 100mV. It stays in down mode until VIN > VOUT + 0.3V and then goes automatically into pass-through operation. In the pass-through operation, output voltage follows input voltage. The SSP8099 exits pass-through mode and goes back to down mode when VIN ramps down to 101% of the target output voltage. It stays in down mode until input voltage falls 150mV below the output voltage,returning to boost operation.

Down Mode and Pass-Through Operation

Design Requirements

A typical application example is the memory LCD, which normally requires 5VOUTput as its bias voltage and only consumes less than 1mA current. The following design procedure can be used to select external component values for the SSP8099 .

Table 1. Design Requirements

PARAMETERS	VALUES
Input Voltage	2.7V ~ 4.2V
Output Voltage	5V
Output Current	1mA
Output Voltage Ripple	±50mV

Programming the Output Voltage

There are two ways to set the output voltage of the SSP8099. For adjustable output voltage version, select the external resistor divider R 1 and R 2 , as shown in Equation 1, and the output voltage is programmed to the desired value. When the output voltage is regulated, the typical voltage at the FB pin is V REF of 1.0V.

$$V_{OUT}=V_{REF}\times（R_1+R_2）/R_2 \qquad （1）$$

For fixed output voltage versions, the FB pin should be connected to GND or kept floating. The SSP8099 offers diverse fixed voltage versions.

In this example, 5VOUTput is required to bias the memory LCD. For the best accuracy, the current following through R2 should be 100 times larger than FB pin leakage current. Changing R2 towards a lower value increases the robustness against noise injection. Changing R2 towards higher values reduces the FB divider current for achieving the highest efficiency at low load currents. 1MΩ and 249kΩ resistors are selected for R 1 and R 2 in this example. High accuracy resistors are recommended for better output voltage accuracy.

Maximum Output Current

The maximum output capability of the SSP8099 is determined by the input to output ratio and the current limit of the step-up converter. It can be estimated by Equation 2.

$$I_{OUT(MAX)}=V_{IN}*(I_{LIM}-I_{LH}/2)*\eta/V_{OUT} \qquad （2）$$

where η is the conversion efficiency, using 85% for estimation; I LH is the current ripple value and I_{LIM} is the switch current limit.

Minimum input voltage, maximum boost output voltage and minimum current limit I_{LIM} should be used as the worst case condition for the estimation.

APPLICATION INFORMATION

Inductor Selection

Because the selection of the inductor affects steady state operation, transient behavior, and loop stability, the inductor is the most important component in power regulator design. There are three important inductor specifications, inductor value, saturation current, and DC resistance (DCR).

The device has been optimized to operate with inductance values between 1μH and 2.2μH. For best stability consideration, a 2.2μH inductor is recommended for VOUT > 3.0V condition while choosing a 1μH inductor for applications under VOUT ≤ 3.0V condition.

VOUT (V)	Inductance (μH)	Saturation Current (A)	DC Resistance (MΩ)	Size (L × W × H)	Part Number	Manufacturer
> 3.0	2.2	1.95	80	2.5 × 2.0 × 1.2	74404024022	Würth Elektronik
	2.2	1.7	92	2.5 × 2.0 × 1.1	LQH2HPN2R2MJR	muRata
	2.2	1.45	163	2.0 × 1.6 × 1.0	VLS201610CX-2R2M	TDK
≤ 3.0	1.0	2.6	37	2.5 × 2.0 × 1.2	74404024010	Würth Elektronik
	1.0	2.3	48	2.5 × 2.0 × 1.0	MLP2520W1R0MT0S1	TDK
	1.0	1.5	80	2.0 × 1.2 × 1.0	LQM21PN1R0MGH	muRata

Capacitor Selection

For best output and input voltage filtering, low ESR X5R or X7R ceramic capacitors are recommended.

The input capacitor minimizes input voltage ripple, suppresses input voltage spikes and provides a stable system rail for the device. An input capacitor value of 10μF is normally recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the device is recommended.

For the output capacitor of VOUT pin, small ceramic capacitors are recommended, placed as close as possible to the VOUT and GND pins of the device. If, for any reason, the application requires the use of large capacitors which cannot be placed close to the device, the use of a small ceramic capacitor with a capacitance value of 1μF in parallel to the large one is recommended. This small capacitor should be placed as close as possible to the VOUT and GND pins of the device.

From the power stage point of view, the output capacitor sets the corner frequency of the converter while the inductor creates a right-half-plane-zero. Consequently, with a larger inductor, a larger output capacitor must be used. The device has been optimized to operate with inductance values between 1μH and 2.2μH, so the minimal output capacitor value is 20μF (nominal value). Increasing the output capacitor makes the output ripple smaller in PWM mode.

When selecting capacitors, ceramic capacitor's derating effect under bias should be considered. Choose the right nominal capacitance by checking capacitor's DC bias characteristics. In this example, GRM188R60J106ME84D, which is a 10μF ceramic capacitor with high effective capacitance value at DC biased condition, is selected for VOUT rail.

In the case of load hot-plugging, the input capacitance of load device needs to be less than 1/10 of the output capacitance of SSP8099.

Typical Performance Characteristics

Test Conditions:SSP8099-5.0YT,Vout=5V, L=2.2μH, CIN=2*10μF, COUT=2*10μF, Ta=25℃，unless otherwise indicated.
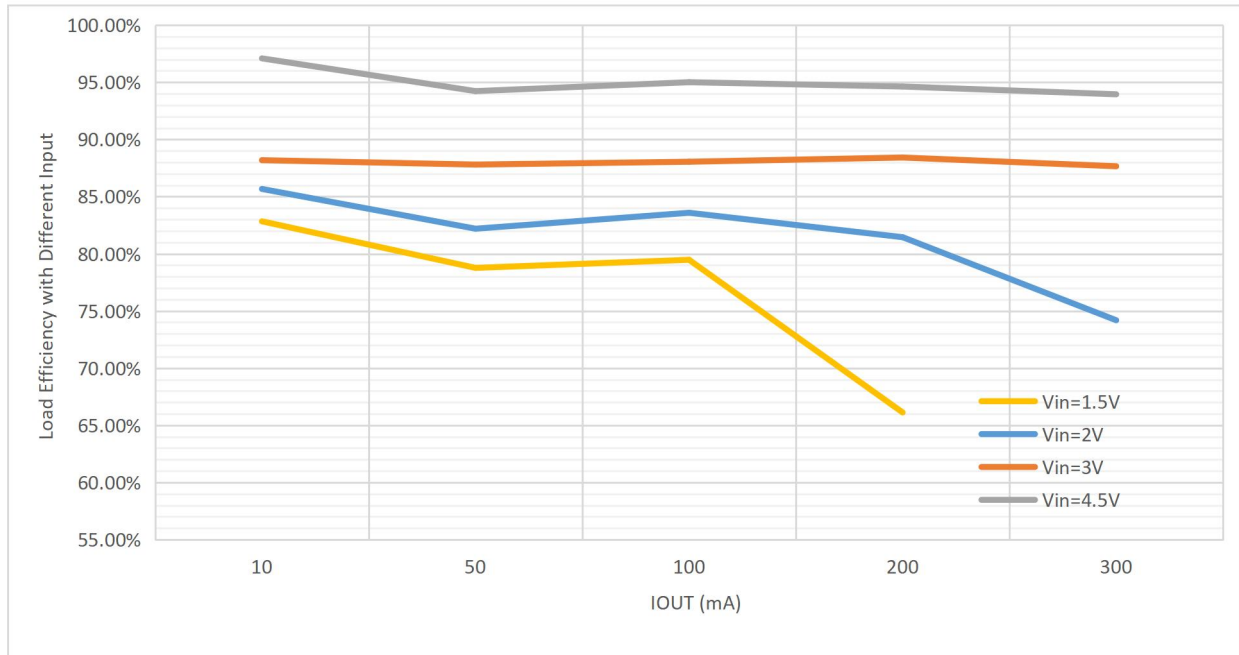

Layout

As for all switching power supplies, the layout is an important step in the design, especially at high peak currents and high switching frequencies. If the layout is not carefully done, the regulator could show stability problems as well as EMI problems. Therefore, use wide and short traces for the main current path and for the power ground paths. The input and output capacitor, as well as the inductor should be placed as close as possible to the device.

PACKAGE OUTLINE DIMENSIONS

WLCSP-1.22×0.83-6B
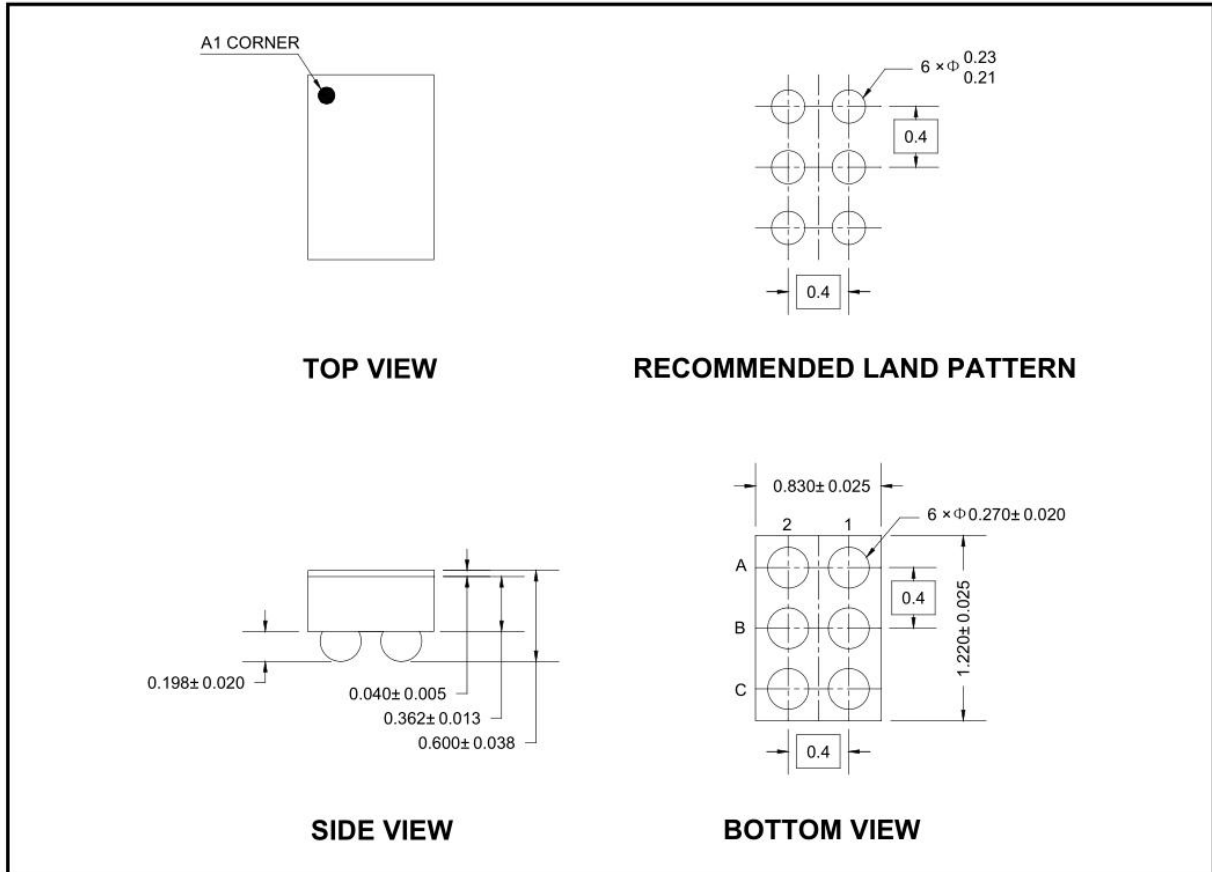
NOTE: All linear dimensions are in millimeters.

TDFN-2×2-6AL
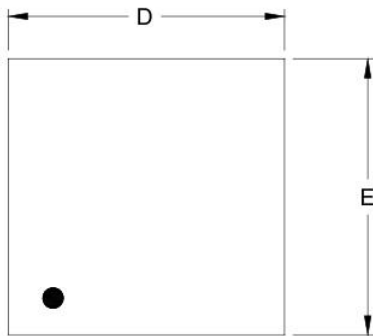
TOP VIEW
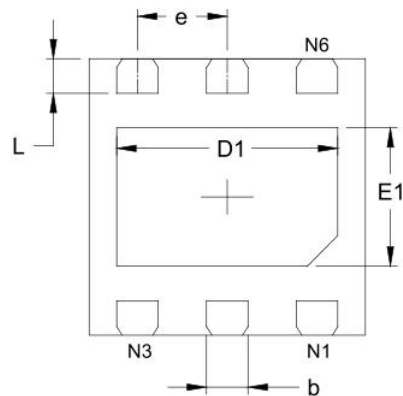
BOTTOM VIEW
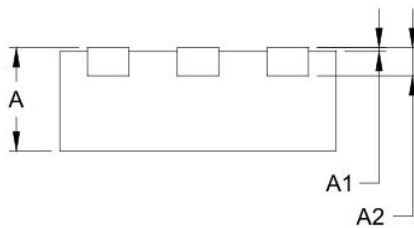
SIDE VIEW
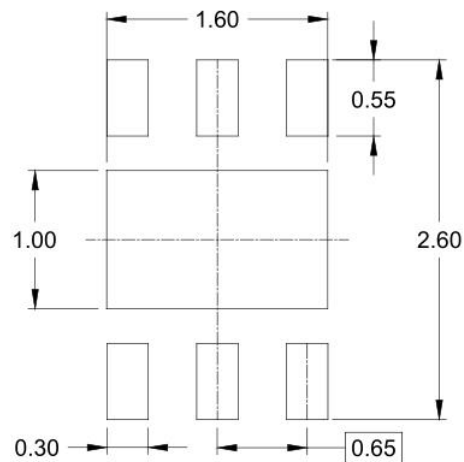
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	1.900	2.100	0.075	0.083
D1	1.500	1.700	0.059	0.067
E	1.900	2.100	0.075	0.083
E1	0.900	1.100	0.035	0.043
b	0.250	0.350	0.010	0.014
e	0.650 BSC		0.026 BSC	
L	0.174	0.326	0.007	0.013

Special Version

The company reserves the right of final interpretation of this specification.

Version Change Description

Versions：V1.0	Writer：XinCHun Li	Time：2022.11.28

Modify the record：

1. Original Version

Statement

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