SGM66099C
Synchronous Boost Converter
with Ultra-Low Quiescent Current

GENERAL DESCRIPTION

The SGM66099C is an ultra-low quiescent current synchronous Boost converter. An operating input voltage range from 1.6V to 5.2V is suitable for Li-Mn battery, NiMH and Li-Ion rechargeable batteries. The 1.7µA (TYP) quiescent current maximizes the light load efficiency and also increases the effective battery operation time. In addition, the high-side synchronous rectifier provides output disconnect feature which minimizes unnecessary current drawn from the battery during shutdown mode.

The SGM66099C is able to deliver 300mA output current from 3.3V to 5V conversion, and achieves 93% peak efficiency at 200mA load.

The device offers down mode where the desired output voltage is regulated even when the input voltage is higher than the output. In addition, when the input voltage is 300mV above the output voltage set point, the device enters pass-through mode.

The device integrates various protection features such as over-voltage protection and thermal shutdown. In addition, the synchronous rectifier supports short-circuit protection which further improves the robustness of the device.

The SGM66099C offers adjustable output voltage version. It is available in Green WLCSP-1.3×0.83-6B and TDFN-2×2-6AL packages.

FEATURES

- **Operating Input Voltage Range: 1.6V to 5.2V**
- **Adjustable Output Voltage from 2.5V to 5.4V**
- **Ultra-Low Quiescent Current**
  - **0.05µA (TYP) Ultra-Low I_Q into VIN Pin**
  - **1.7µA (TYP) Ultra-Low I_Q into VOUT Pin**
- **1.2MHz Fixed Frequency Operation**
- **Up to 93% Efficiency from 10mA to 300mA Load**
- **Power-Save Mode for Improved Efficiency at Low Output Power**
- **Regulated Output Voltage in Down Mode**
- **True Disconnection during Shutdown**
- **Short-Circuit Protection**
- **Over-Voltage Protection**
- **Thermal Shutdown**
- **Available in Green WLCSP-1.3×0.83-6B and TDFN-2×2-6AL Packages**

APPLICATIONS

LCD and LED Bias
Portable and Wearable Applications
Low Power Wireless Applications
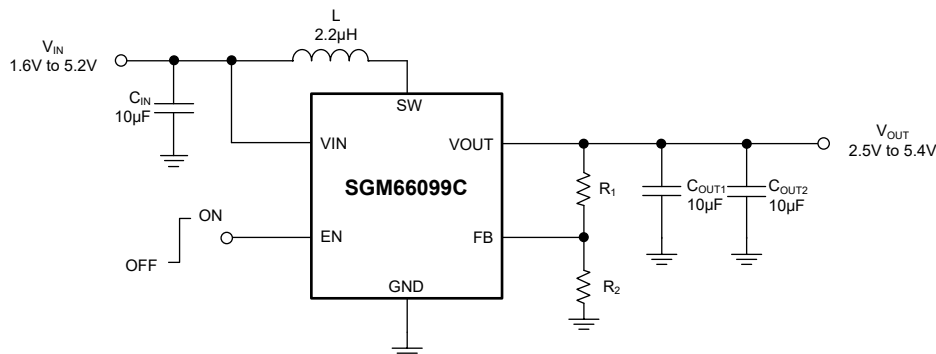Battery Powered Systems

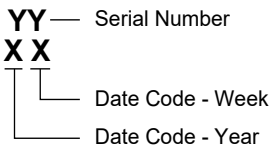## TYPICAL APPLICATION

Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM66099C-ADJ	WLCSP-1.3×0.83-6B	-40℃ to +85℃	SGM66099C-ADJYG/TR	0H XX	Tape and Reel, 3000
	TDFN-2×2-6AL	-40℃ to +85℃	SGM66099C-ADJYTDI6G/TR	05F XXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code. XXXX = Date Code and Trace Code.

WLCSP-1.3×0.83-6B

YY — Serial Number
X X
    └── Date Code - Week
  └──── Date Code - Year

TDFN-2×2-6AL

Y Y Y — Serial Number
X X X X
    └── Trace Code
  └──── Date Code - Year
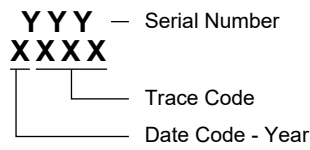
Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

VIN.. -0.3V to 5.5V
SW, VOUT, FB, EN to GND............................... -0.3V to 6.0V
Package Thermal Resistance
WLCSP-1.3×0.83-6B, θ_{JA} .... 143℃/W
TDFN-2×2-6AL, θ_{JA}.. 105℃/W
Junction Temperature...+150℃
Storage Temperature..................................-65℃ to +150℃
Lead Temperature (Soldering, 10s)...........................+260℃
ESD Susceptibility
HBM.. 1000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range .... 1.6V [1] to 5.2V
Output Voltage Range ....2.5V to 5.4V
Operating Ambient Temperature Range........-40℃ to +85℃
Operating Junction Temperature Range......-40℃ to +125℃

NOTE: 1. Refer to the "Start-up and Enable" for detailed description.

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.
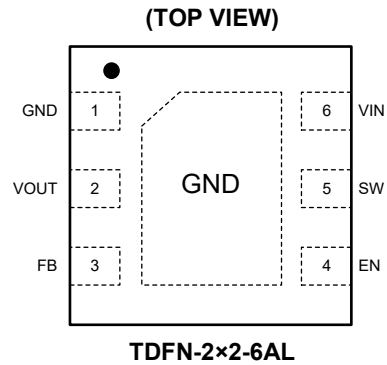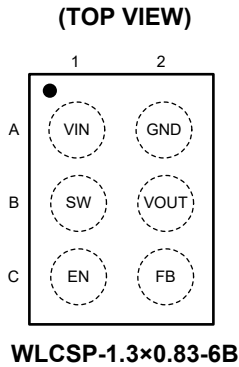
ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

PIN CONFIGURATIONS

(TOP VIEW)

WLCSP-1.3×0.83-6B

(TOP VIEW)

TDFN-2×2-6AL

PIN DESCRIPTION

PIN		NAME	TYPE	FUNCTION
WLCSP-1.3×0.83-6B	TDFN-2×2-6AL			
A1	6	VIN	P	Power Supply Input.
A2	1	GND	G	Ground.
B1	5	SW	O	Switch Node. Drain connection of low-side power MOSFET.
B2	2	VOUT	O	Boost Converter Output.
C1	4	EN	I	Device Enable Node. Pulling this pin logic high enables the device, and logic low disables the device.
C2	3	FB	I	Voltage Feedback of Adjustable Output Voltage. Connect a resistive divider to program the desired output voltage.
—	Exposed Pad	GND	—	Connect to GND.

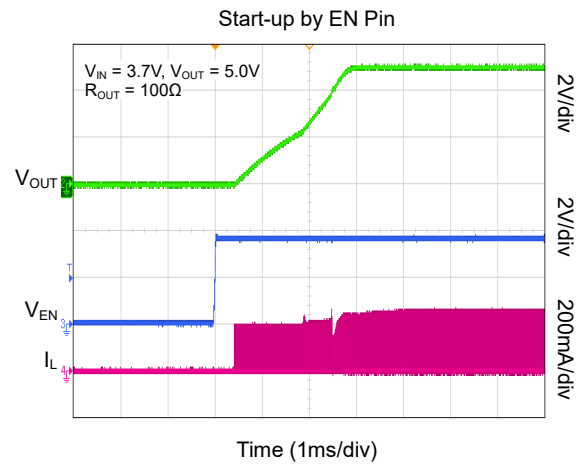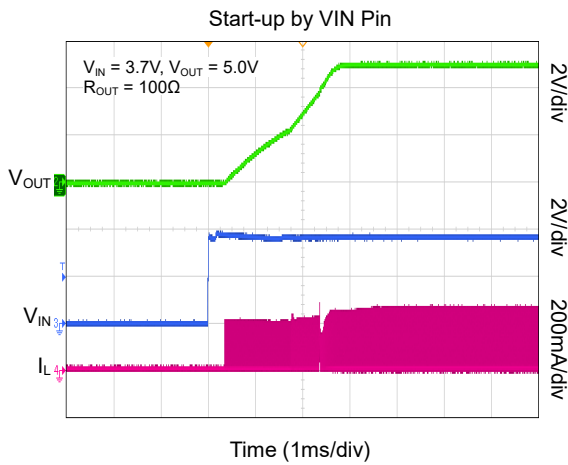NOTE: I: input, O: output, G: ground, P: power for the circuit.

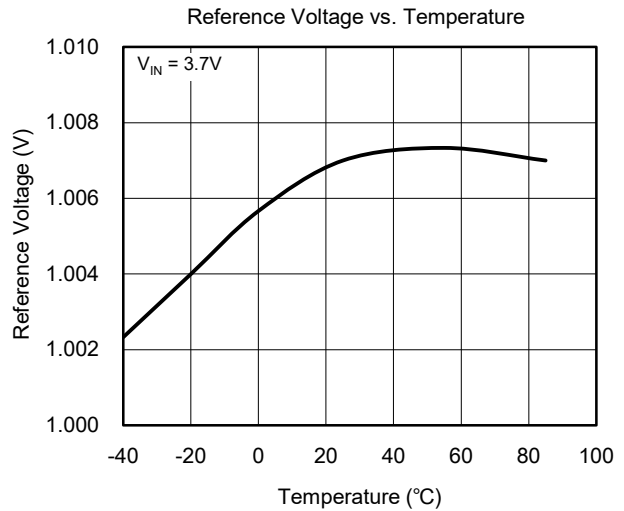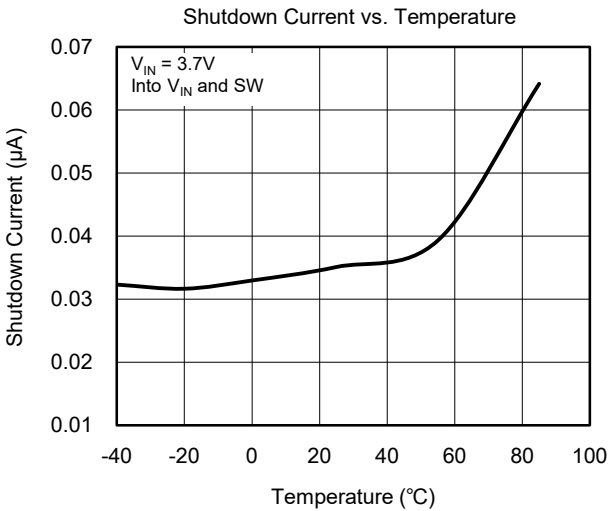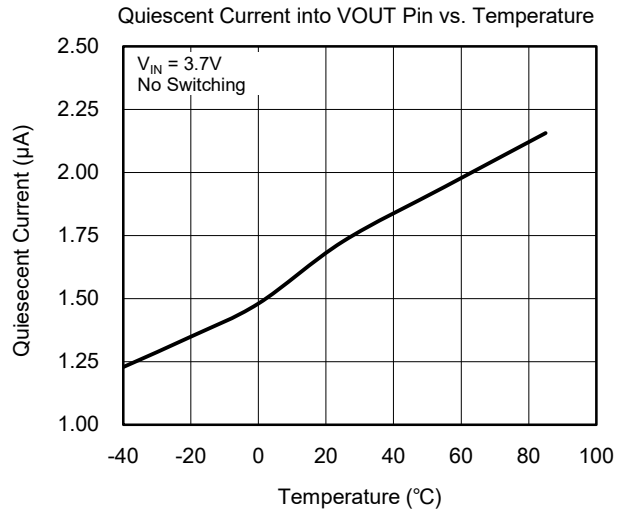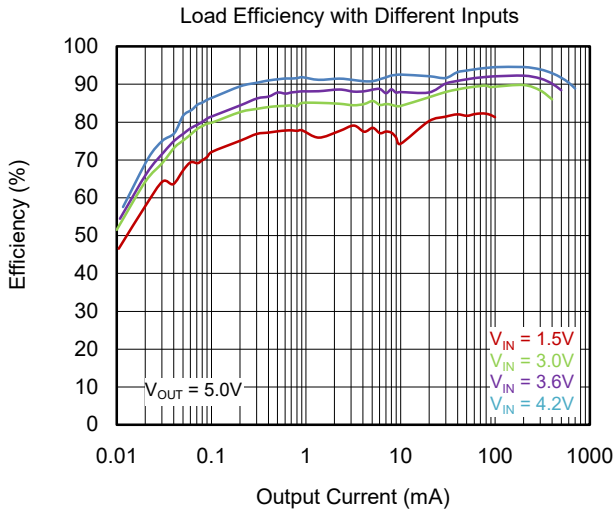# ELECTRICAL CHARACTERISTICS

(V_{IN} = 1.6V to 5.2V, C_{IN} = 10μF, C_{OUT} = 20μF. T_J = -40℃ to +85℃, typical values are at V_{IN} = 3.7V, T_J = +25℃, unless otherwise noted.)

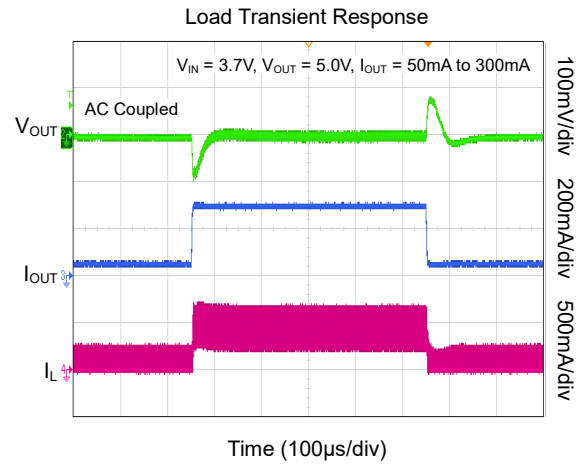| PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Power Supply							
Input Voltage Range	V_{IN}	T_J = +25℃		1.6		5.2	V
Quiescent Current into VIN Pin	I_Q	No load, not switching			0.05	0.4	μA
Quiescent Current into VOUT Pin		No load, not switching, Boost or down mode			1.7	7	μA
Shutdown Current into VIN Pin	I_{SD}	EN = GND, V_{IN} = 3.7V			0.1	1	μA
Output							
Output Voltage Range	V_{OUT}			2.5		5.4	V
Feedback Reference Voltage	V_{REF}	V_{IN} < V_{OUT}, PWM mode		0.977	1.000	1.04	V
		V_{IN} < V_{OUT}, PFM mode			1.015		V
Output Over-Voltage Protection Threshold	V_{OVP}	V_{OUT} rising, T_J = +25℃		5.55	5.80	6.00	V
OVP Hysteresis					50		mV
Leakage Current into FB Pin	I_{FB_LKG}	V_{FB} = 1.1V			10	50	nA
Switching							
Switching Frequency	f_{SW}	V_{IN} = 3.7V	WLCSP	0.85	1.2	1.4	MHz
			TDFN	0.8	1.2	1.4	
Power Switch							
Low-side Switch On-Resistance	R_{DSON_LS}	V_{OUT} = 4.7V, T_J = +25℃	WLCSP		220	330	mΩ
			TDFN		250	370	
		V_{OUT} = 3.3V, T_J = +25℃	WLCSP		280	400	
			TDFN		310	430	
Rectifier On-Resistance	R_{DSON}	V_{OUT} = 4.7V, T_J = +25℃	WLCSP		260	380	mΩ
			TDFN		290	390	
		V_{OUT} = 3.3V, T_J = +25℃	WLCSP		330	470	
			TDFN		370	480	
Current Limit Threshold	I_{LIM}	V_{OUT} > 2.5V, Boost operation, T_J = +25℃		0.80	1.16	1.46	A
		V_{OUT} = 2.5V, Boost operation, T_J = +25℃		0.65	0.85	1.03	A
Control Logic							
EN Input Low Voltage Threshold	V_{IL}					0.3	V
EN Input High Voltage Threshold	V_{IH}			1.2			V
Leakage Current into EN Pin	I_{EN_LKG}	V_{EN} = 5.0V, T_J = +25℃				300	nA
Thermal Shutdown Threshold					150		℃
Thermal Shutdown Hysteresis					25		℃

TYPICAL PERFORMANCE CHARACTERISTICS

C_{IN} = 10µF and C_{OUT} = 20µF, unless otherwise noted.

Load Efficiency with Different Inputs

Quiescent Current into VOUT Pin vs. Temperature

Shutdown Current vs. Temperature

Reference Voltage vs. Temperature

Start-up by VIN Pin

Start-up by EN Pin

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

C_{IN} = 10µF and C_{OUT} = 20µF, unless otherwise noted.

Switching Waveform at Heavy Load

V_{IN} = 3.7V, V_{OUT} = 5.0V, I_{OUT} = 300mA

AC Coupled

V_{OUT} — 20mV/div

V_{SW} — 2V/div

I_L — 500mA/div

Time (500ns/div)

Switching Waveform at Light Load

V_{IN} = 3.7V, V_{OUT} = 5.0V, I_{OUT} = 1mA

AC Coupled

V_{OUT} — 50mV/div

V_{SW} — 2V/div

I_L — 200mA/div

Time (100µs/div)

Load Regulation

V_{IN} = 3.7V, V_{OUT} = 5.0V, I_{OUT} = 0A to 300mA

AC Coupled

V_{OUT} — 100mV/div

I_{OUT} — 200mA/div

I_L — 500mA/div

Time (5ms/div)

Load Transient Response

V_{IN} = 3.7V, V_{OUT} = 5.0V, I_{OUT} = 50mA to 300mA

AC Coupled

V_{OUT} — 100mV/div

I_{OUT} — 200mA/div

I_L — 500mA/div

Time (100µs/div)

Line Regulation

V_{IN} = 2.4V to 5.3V, V_{OUT} = 5.0V, I_{OUT} = 200mA

AC Coupled

V_{OUT} — 500mV/div

V_{IN} — 2V/div

I_L — 500mA/div

Time (50ms/div)
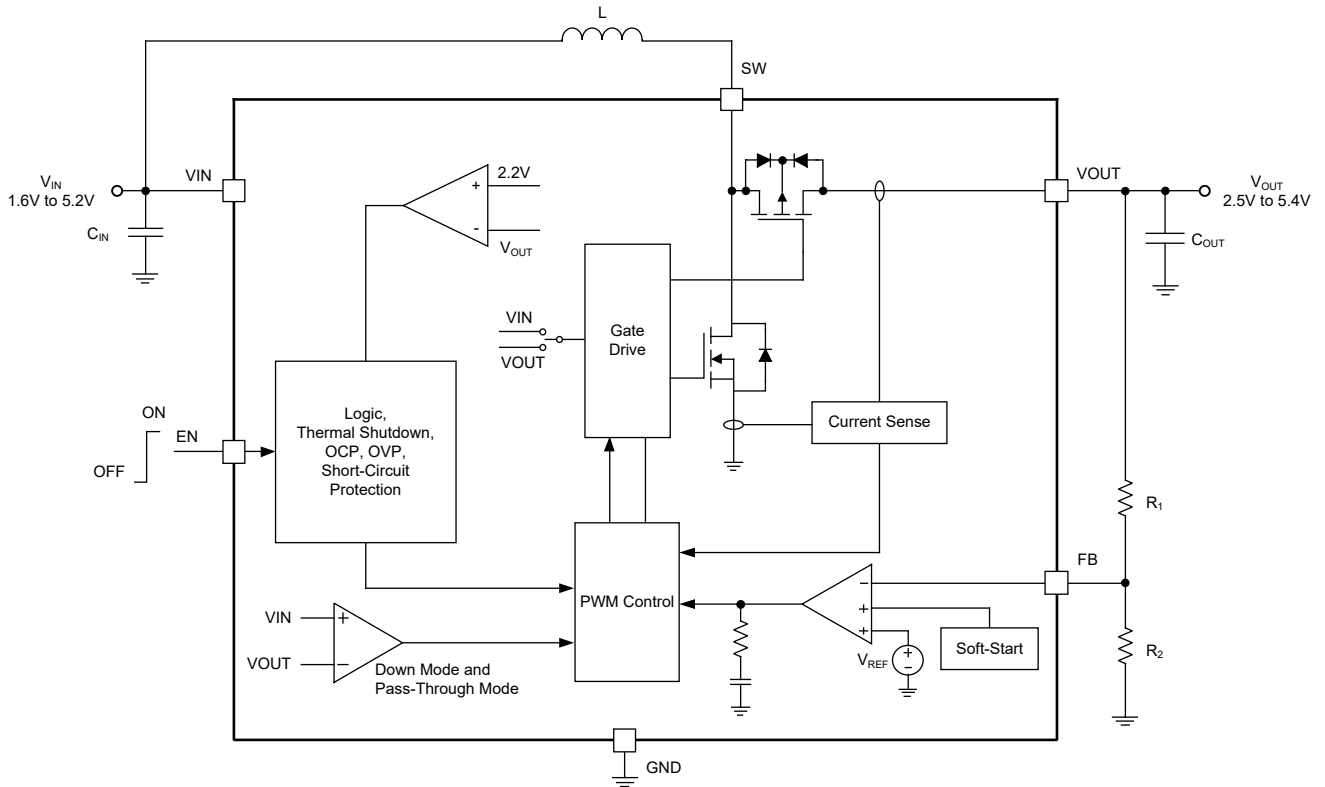
FUNCTIONAL BLOCK DIAGRAM

Figure 2. Block Diagram

DETAILED DESCRIPTION

The SGM66099C synchronous Boost converter is designed for Li-Ion battery powered systems, where the compact solution size and battery operation time are key criterions. The device employs peak current mode control with 1.16A (TYP) peak switch current limit. The SGM66099C is capable of disconnecting the output from input when the device is disabled to avoid unnecessary current consumption. The integrated down mode and pass-through mode ensure a smooth operation when input voltage is close to or higher than the set output voltage. The device is available in an adjustable output voltage version.

Start-up and Enable

Logic high on EN pin enables the SGM66099C, while a logic low disables the device. During logic low state, the device stops operation, and the output voltage is completely disconnected from the input voltage. During logic low state, the shutdown current is less than 1µA.

The SGM66099C is able to start up from 1.6V input voltage with larger than 3kΩ load. Before the output voltage reaches 2.2V during the start-up phase, the switch current is limited to about 350mA (TYP). Therefore, if the load during start-up is too heavy, the device will fail to charge the output voltage to above 2.2V after soft-start time expires, and it will not be able to start up successfully.

Over-Current and Short-Circuit Protection

The SGM66099C implements cycle-by-cycle current limit during an over-current event. When the current limit threshold (I_{LIM}) is reached, the low-side power MOSFET is turned off to prevent the inductor current from further increase. During over-current event, the output voltage will drop until a constant power state is reached between input and output. If the current limit causes the output to drop below the input voltage, the SGM66099C goes into down mode, where the peak current is still limited by the current limit threshold cycle-by-cycle. If the output continues to drop below 2.2V, the device automatically enters short-circuit condition with 350mA (TYP) reduced current limit.

During the output short-to-ground case, as output voltage declines below 2.2V, the SGM66099C reduces the current limit to about 350mA (TYP) to reduce power dissipation within the device. As the short-circuit condition is removed, the device resumes operation and goes through a soft-start sequence to regulate the set output voltage.

Over-Voltage Protection (OVP)

SGM66099C integrates over-voltage protection to protect the device in case of feedback resistor short-to-ground or incorrect feedback resistor value being populated. The SGM66099C stops switching when the OVP threshold of 5.8V (TYP) is reached. The device implements 50mV OVP hysteresis. When the output voltage is 50mV lower than the OVP threshold, the device resumes switching.

Power-Save Mode under Light Load Condition

SGM66099C enters power-save mode under light load condition.

Down Mode and Pass-Through Mode

SGM66099C offers down mode feature where the device can still regulate the set output voltage even when the input voltage is higher than output voltage. If the input voltage continues increasing in down mode, the device automatically enters pass-through mode. Care should be taken in pass-through mode, where the input voltage should not exceed the recommended maximum input voltage.

In down mode, the control logic pulls the gate of PMOS to the input voltage rather than ground. This method allows effective control of inductor current when V_{IN} > V_{OUT}. Thermal consideration should be taken in down mode, where the voltage drop across the PMOS increases as the delta of V_{IN} and V_{OUT} increases.

In pass-through mode, the complimentary switching action stops. The gate of PMOS is pulled to ground for always-on and the low-side switch remains off. The output voltage equals to the input voltage minus the voltage drop across the DC resistance of the inductor and the on-resistance of the rectifying PMOS.

DETAILED DESCRIPTION (continued)

The SGM66099C enters down mode when the input voltage is equal to or higher than V_{OUT} - 100mV. It remains in down mode until $V_{IN} > V_{OUT}$ + 0.3V and then automatically enters pass-through mode. In the pass-through mode, the high-side PMOS is always turned on to pass the input voltage to the output. As V_{IN} drops below 1% above the target output voltage, the device exits pass-through mode and returns to down mode. The device exits down mode and returns to normal Boost switching operation as V_{IN} drops 250mV below the target output voltage.

Figure 3. Down Mode and Pass-Through Mode

Thermal Shutdown

A thermal shutdown function is implemented to prevent damage caused by excessive heat and power dissipation. Once a junction temperature of +150℃ (TYP) is exceeded, the device is shut down. The device is released from shutdown automatically when the junction temperature decreases by 25℃.
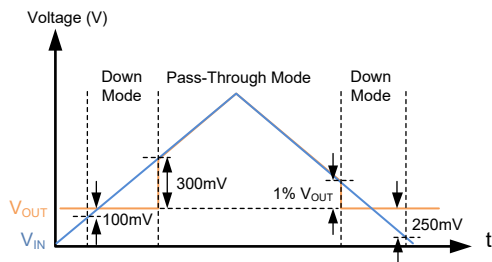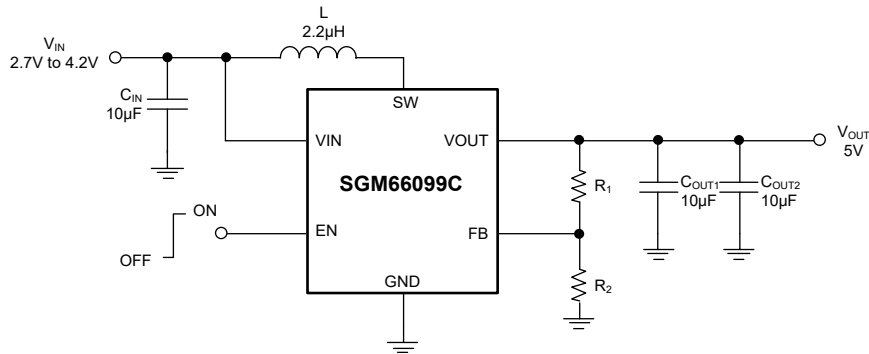
APPLICATION INFORMATION

Figure 4. 5V Output Boost Converter

Design Requirements

5V output at 200mA load current is used to provide system bias power or LED bias voltage from a single cell Li-Ion battery as an example. Please refer the following parts to design external component values for the SGM66099C.

Table 1. Design Requirements

Parameters	Values
Input Voltage	2.7V ~ 4.2V
Output Voltage	5V
Output Current	200mA
Output Voltage Ripple	±50mV

Programming the Output Voltage

External resistor dividers (R_1 and R_2) program the output voltage (Equation 1). V_{REF} is 1.0V (TYP).

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

The leakage current into the FB pin affects the accuracy of output voltage. To achieve the minimum leakage current effect, the current through R_2 should be 100 times greater than the FB pin leakage current. Small R_2 increases the noise immunity, while large R_2 reduces the leakage current flowing through feedback resistors, which improves the no load efficiency of the device. A 1MΩ resistor is chosen for R_1 and a 249kΩ resistor is chosen for R_2 in this case. ±1% accuracy resistors are recommended for R_1 and R_2 to improve output voltage accuracy.

Maximum Output Current

The maximum output load capability of SGM66099C depends on the minimum desired operation input voltage and the current limit of the device. Equation 2 can be used to calculate the maximum load current,

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

where η is the conversion efficiency, using 85% for estimation. I_{LH} is the inductor peak-to-peak ripple current and I_{LIM} is the switch current limit.

For worst-case condition analysis, minimum input voltage, maximum Boost output voltage and minimum current limit (I_{LIM}) should be used.

Inductor Selection

Inductor selection is one of the most important criterions for switch mode power supply, because the inductor selection may affect the power supply's transient response, loop stability, efficiency and steady-state operation. Inductor parameters of DC resistance, inductance and saturation current are critical for a smooth and efficient power supply operation.

The internal compensation of the device is optimized with 1.0µH and 2.2µH. When V_{OUT} is higher than 3V, 2.2µH inductance should be selected. When V_{OUT} is less than 3V, 1.0µH inductance should be selected.

APPLICATION INFORMATION (continued)

Table 2. List of Inductors

V_{OUT} (V)	Inductance (µH)	Saturation Current (A)	DC Resistance (mΩ)	Size L × W × H (mm³)	Part Number	Manufacturer
> 3.0	2.2	1.95	80	2.5 × 2.0 × 1.2	SPH252012H2R2MT	Sunlord
	2.2	1.8	114	2.5 × 2.0 × 1.0	SPH252010H2R2MT	Sunlord
	2.2	2.2	130	2.5 × 1.6 × 1.0	TFM201610ALMA2R2MTAA	TDK
≤ 3.0	1.0	2.9	69	2.5 × 2.0 × 1.2	SWPA252012S1R0NT	Sunlord
	1.0	2.45	67	2.5 × 2.0 × 1.0	SPH252010H1R0MT	Sunlord
	1.0	2.9	60	2.5 × 1.6 × 1.0	VLS201610HBX-1R0M-1	TDK

Capacitor Selection

The input capacitor of Boost converter not only minimizes the input voltage ripple, but also reduces any voltage spike presenting on the VIN pin. A 10µF, low ESR and X5R or higher temperature coefficient ceramic capacitor is recommended to place as close to the VIN and GND pins as possible to improve transient response and EMI behavior.

Boost converter's output capacitor plays a significant role in ensuring good system performance. The location of output capacitor will have an effect on the switching spikes on the SW pin, which ultimately affects EMI performance and potentially damages the device due to large switching spikes. The current loop formed by the output capacitor flowing from the VOUT pin and back to the GND pin should be as small as possible. Therefore, a ceramic cap is recommended to put as close to the VOUT and GND pins of the device as possible.

Boost topology presents right-half-plane-zero which is dictated by inductance. In addition, the output capacitor sets the corner frequency of the converter for current mode controlled method. Therefore, when selects a larger inductor, there should be a larger output capacitor. The device's internal compensation is optimized to operate with inductance values between 1.0µH and 2.2µH, resulting in the minimum output capacitor value of 20µF (nominal value). Increasing the output capacitor can reduce output ripple in PWM mode.

Due to the nature of ceramic capacitors' DC bias effect, effective capacitance at the bias voltage should be verified. GRM188R61E106MA73D is used as the output capacitor in this case. 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 SGM66099C.

Layout Considerations

In addition to component selection, layout is a critical step to ensure the performance of any switch mode power supplies. Poor layout could result in system instability, EMI failure, and device damage. Thus, place the inductor, input and output capacitors as close to the device as possible, and use wide and short traces for current carrying traces to minimize PCB inductance.

For Boost converter, the current loop of the output capacitor from VOUT pin back to the GND pin of the device should be as small as possible.
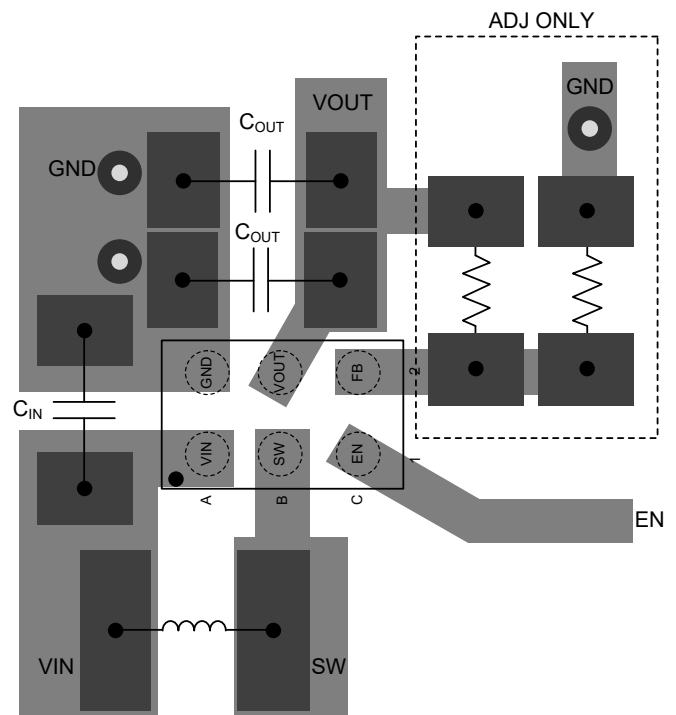

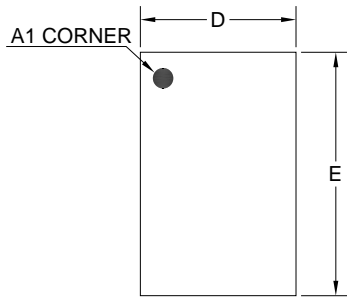**Figure 5. SGM66099C PCB Layout**

REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

MARCH 2023 – REV.A to REV.A.1	**Page**
Added the TDFN Package 1, 2, 3, 4	

Changes from Original (OCTOBER 2022) to REV.A	**Page**
Changed from product preview to production data ....All	

PACKAGE OUTLINE DIMENSIONS

WLCSP-1.3×0.83-6B

TOP VIEW
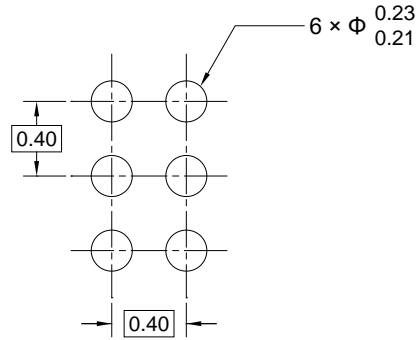
RECOMMENDED LAND PATTERN (Unit: mm)
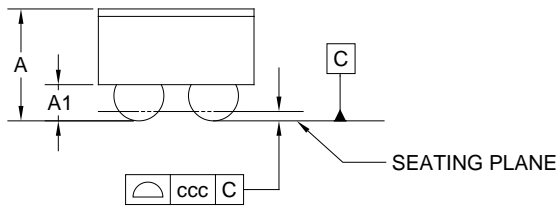
SIDE VIEW
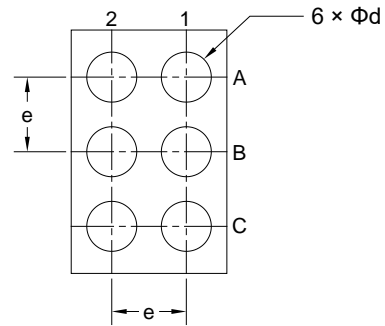
BOTTOM VIEW

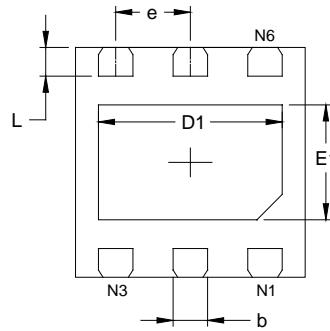| Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.562	0.600	0.638
A1	0.174	0.194	0.214
D	0.805	0.835	0.865
E	1.275	1.305	1.335
d	0.248	0.268	0.288
e	0.400 BSC		
ccc	-	0.050	-

NOTE: This drawing is subject to change without notice.

PACKAGE OUTLINE DIMENSIONS

TDFN-2×2-6AL
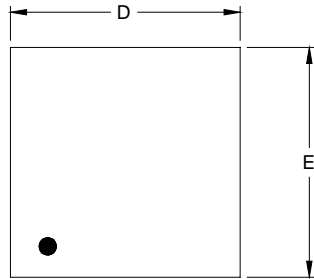
**TOP VIEW**

BOTTOM VIEW
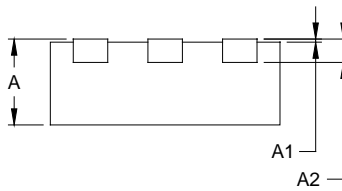
SIDE VIEW
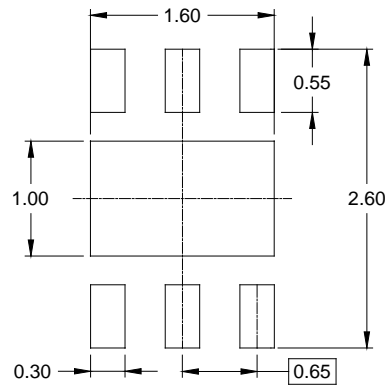
RECOMMENDED LAND PATTERN (Unit: mm)

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

NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS
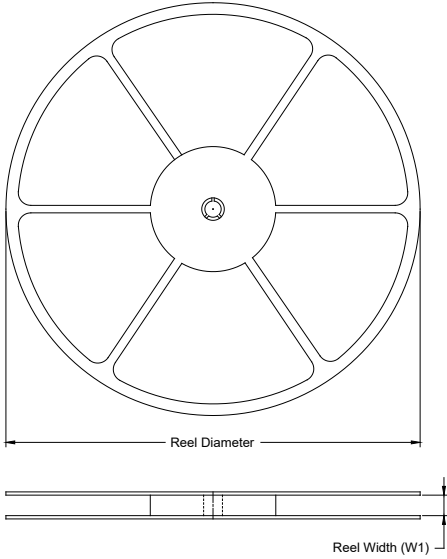
TAPE DIMENSIONS

NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
WLCSP-1.3×0.83-6B	7″	9.5	0.95	1.42	0.74	4.0	4.0	2.0	8.0	Q1
TDFN-2×2-6AL	7″	9.5	2.30	2.30	1.10	4.0	4.0	2.0	8.0	Q2

CARTON BOX DIMENSIONS

NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

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