SGM62116
High-Efficiency Buck-Boost Converter

GENERAL DESCRIPTION

The SGM62116 is a fully-integrated synchronous Buck-Boost converter which is capable of operating from 1.8V to 5.5V input and suitable for battery powered applications such as 1-cell Li-ion battery, 2-cell or 3-cell Alkaline/NiMH batteries. The device integrates 900mA typical average input current limit.

The SGM62116 adopts the peak current mode control with a fixed 2.4MHz switching frequency to regulate the output voltage. In addition, the SGM62116 offers configurable seamless transition PFM (pulse frequency modulation) mode or FPWM (forced PWM) mode via configuration of MODE/SYNC pin configuration. PFM enables higher light load efficiency, while FPWM mode ensures constant switching frequency throughout entire load range. External clock synchronization is also available with SGM62116.

The SGM62116 offers various protection features to improve device robustness. Integrated soft-start to reduce inrush current during startup, cycle-by-cycle over-current protection, over-voltage protection and thermal shutdown protection are implemented. In addition, the device features true load-disconnect when the EN pin is pulled low.

The device is available in a Green WLCSP-1.11×1.84-8B package.

FEATURES

- **1.8V to 5.5V Input Voltage Range (Minimal 2V for Startup)**
- **1.2V to 5.5V Output Voltage Range (Adjustable)**
- **Up to 94% Efficiency**
- **35μA (TYP) Quiescent Current**
- **Fixed 2.4MHz Switching Frequency**
- **Seamless Transition Pulse Frequency Modulation**
- **Automatic Mode Transition**
- **Synchronization to External Clock Available**
- **OTP, Input OCP and Output OVP**
- **True Shutdown Function with Load-Disconnect**
- **Available in a Green WLCSP-1.11×1.84-8B Package**

APPLICATIONS

TWS, VR Glasses
Portable Medical Equipment
LED Bias
Sensors

TYPICAL APPLICATION

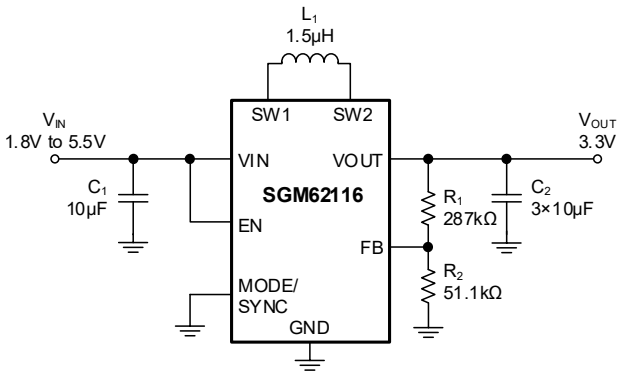


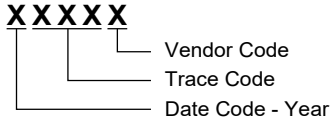
Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM62116	WLCSP-1.11×1.84-8B	-40℃ to +85℃	SGM62116YG/TR	XXXXX 62116	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.



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

Input Voltages
VIN, SW1, SW2, VOUT, MODE/SYNC, EN, FB .. -0.3V to 6V
Package Thermal Resistance
WLCSP-1.11×1.84-8B, θ_{JA} ..... 110℃/W
Junction Temperature ..... +150℃
Storage Temperature Range ..... -65℃ to +150℃
Lead Temperature (Soldering, 10s) ..... +260℃
ESD Susceptibility
HBM 3000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage at VIN ..... 1.8V to 5.5V
Operating Ambient Temperature, T_A ..... -40℃ to +85℃
Operating Junction Temperature, T_J ..... -40℃ to +125℃

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

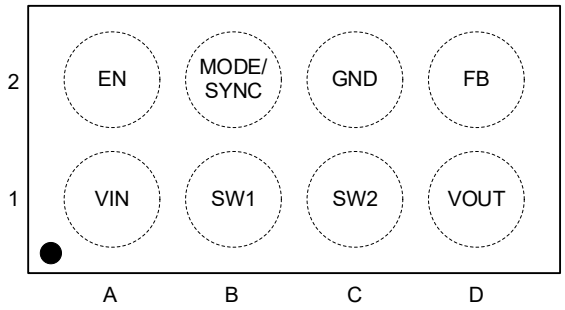
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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 CONFIGURATION

(TOP VIEW)



WLCSP-1.11×1.84-8B

PIN DESCRIPTION

PIN	NAME	I/O	DESCRIPTION
A1	VIN	I	Input Power Supply.
A2	EN	I	Active High Logic, Device Enable Input. Do not leave it floating.
B1	SW1	I	Buck Leg Connection for Inductor.
B2	MODE/SYNC	I	Logic 0 for PFM Mode and logic 1 for FPWM Mode. Do not leave it floating. Clock signal for synchronization.
C1	SW2	I	Boost Leg Connection for Inductor.
C2	GND	G	Ground for Power Stage and Control Stage.
D1	VOUT	O	Converter Output.
D2	FB	I	Voltage Feedback Pin. Connect a resistor divider at FB pin to program the output voltage.

NOTE: I = input, O = output, G = ground.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, V_{OUT} = 3.6V, T_J = -40℃ to +85℃ and typical values are at T_J = +25℃, unless otherwise noted.)

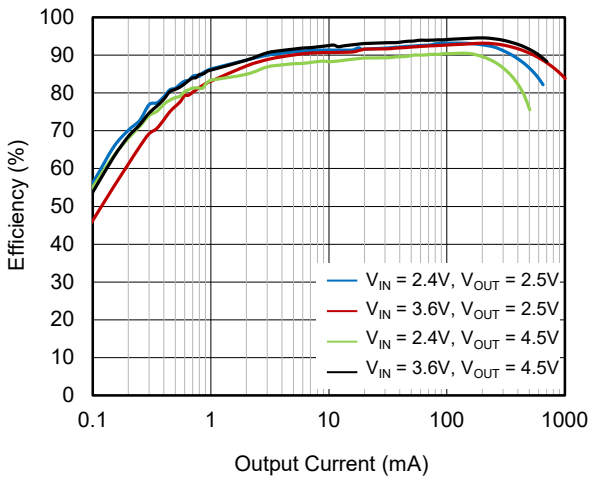
PARAMETER		SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range		V_{IN}		1.8 (1)		5.5	V
Output Voltage Range		V_{OUT}		1.2		5.5	V
Feedback Voltage		V_{FB}	MODE/SYNC = V_{IN}, I_{OUT} < 5mA	494	500	506	mV
			MODE/SYNC = GND, I_{OUT} < 5mA		6		%
Load Regulation			MODE/SYNC = GND		0.008		%/mA
Oscillator Frequency		f	T_J = +25℃	2190	2400	2610	kHz
Frequency Range for Synchronization				2200	2400	2600	kHz
Average Input Current Limit		I_{SW}			900		mA
High-side Switch On-Resistance					140	180	mΩ
Low-side Switch On-Resistance					80	130	mΩ
Line Regulation					0.5		%
Quiescent Current	VIN	I_Q	I_{OUT} = 0mA, V_{EN} = 3.6V		35	55	μA
	VOUT				4	8	μA
Shutdown Current		I_S	V_{EN} = 0V		0.02	0.5	μA
Control Stage							
Under-Voltage Lockout Threshold Raising		V_{UVLO}		1.6	1.8	2.0	V
Under-Voltage Lockout Threshold Falling				1.3	1.5	1.7	V
EN, MODE/SYNC Input Low Voltage		V_{IL}				0.4	V
EN, MODE/SYNC Input High Voltage		V_{IH}		1.3			V
EN, MODE/SYNC Input Current			Clamped on GND or VIN		0.02	0.5	μA
Over-Temperature Protection		T_{SD}			140		℃
Over-Temperature Hysteresis					20		℃

NOTE:

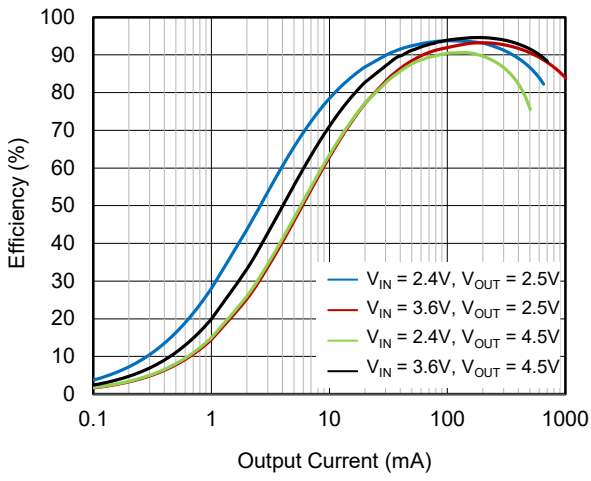
1. The required startup voltage is 2V (TYP). The part is functionally down to 1.8V.

TYPICAL PERFORMANCE CHARACTERISTICS

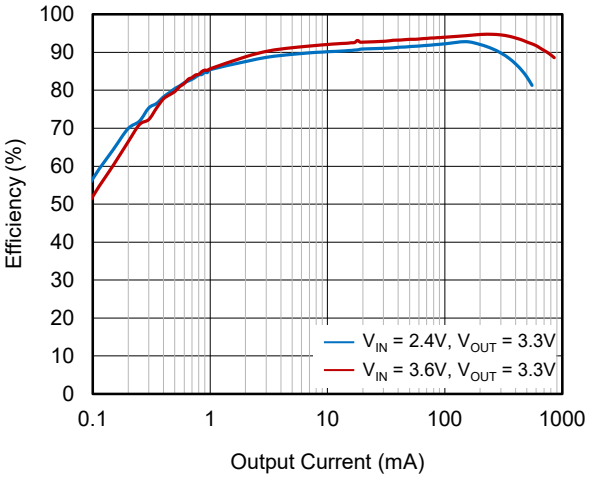
Efficiency vs. Output Current (PFM)



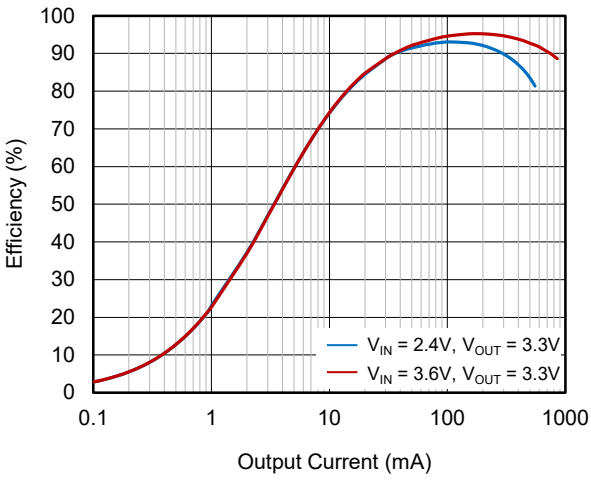
Efficiency vs. Output Current (FPWM)



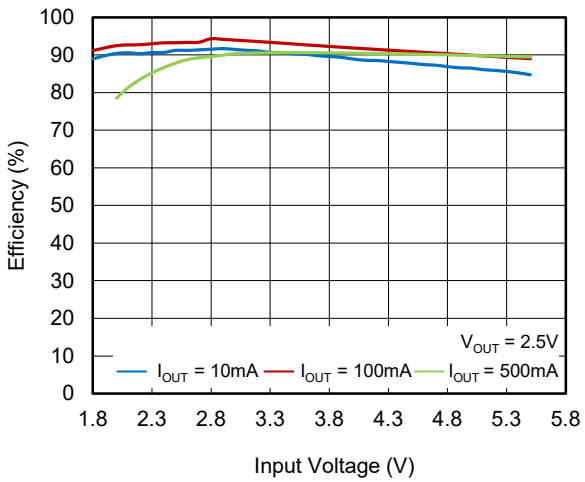
Efficiency vs. Output Current (PFM)



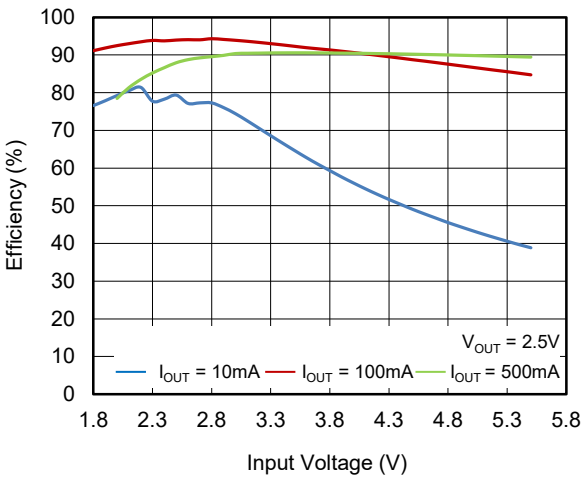
Efficiency vs. Output Current (FPWM)



Efficiency vs. Input Voltage (PFM)

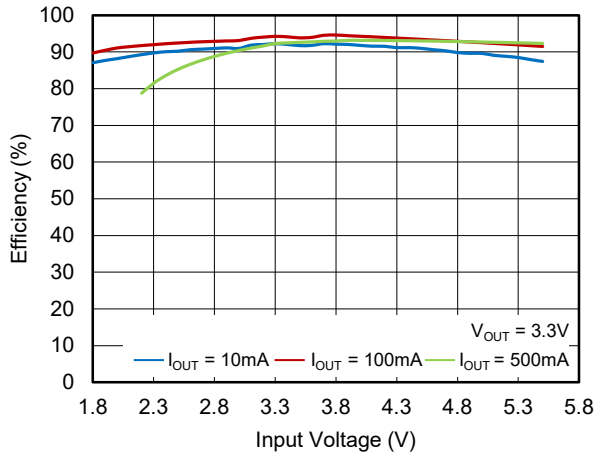


Efficiency vs. Input Voltage (FPWM)

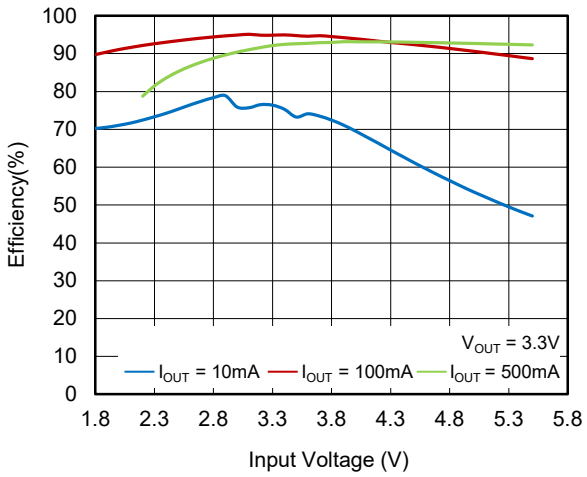


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

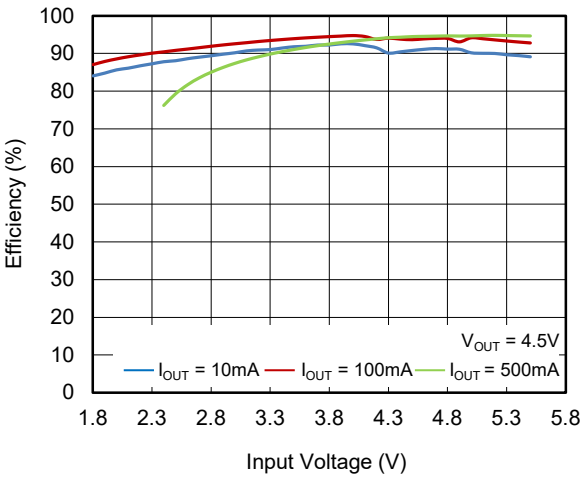
Efficiency vs. Input Voltage (PFM)



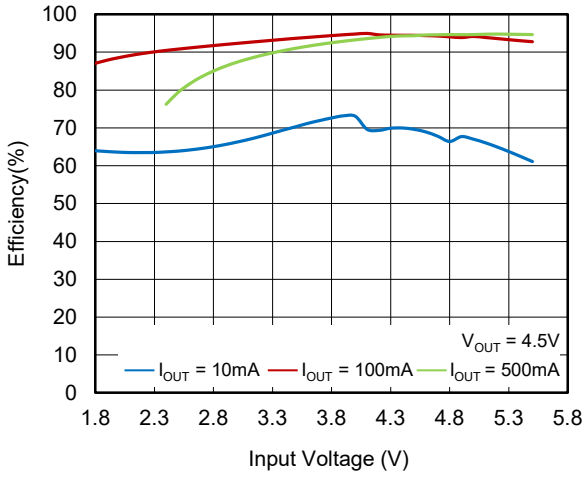
Efficiency vs. Input Voltage (FPWM)



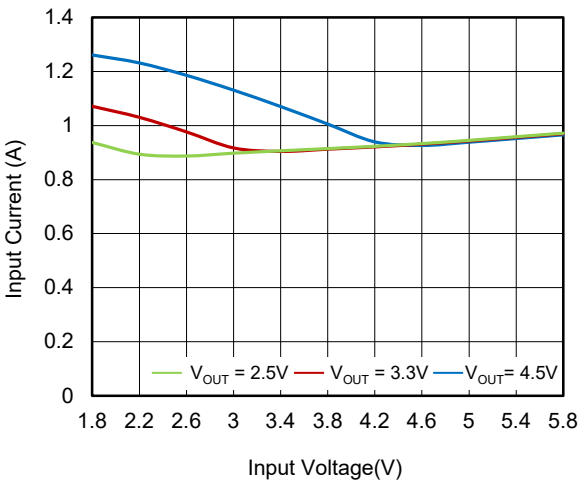
Efficiency vs. Input Voltage (PFM)



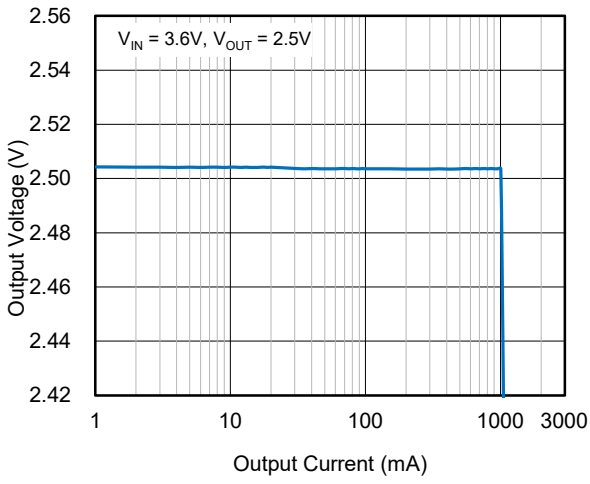
Efficiency vs. Input Voltage (FPWM)



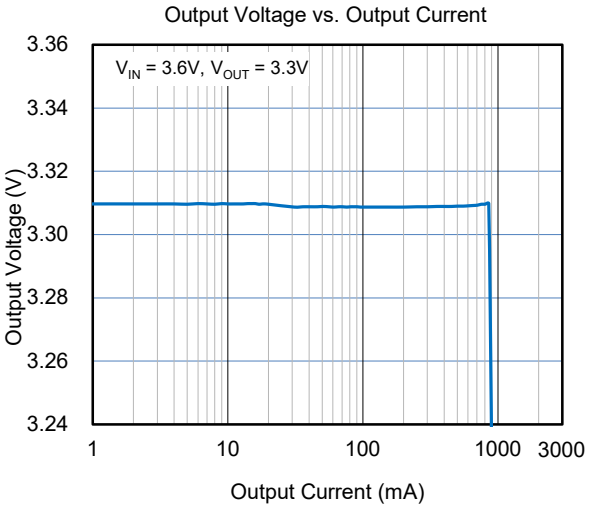
Input Current vs. Input Voltage

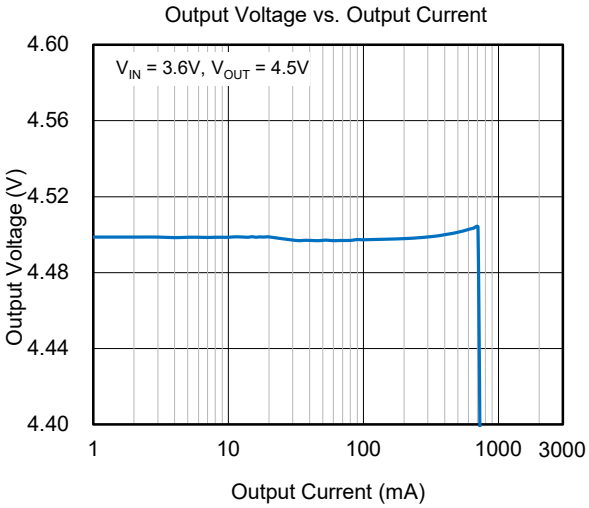


Output Voltage vs. Output Current



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

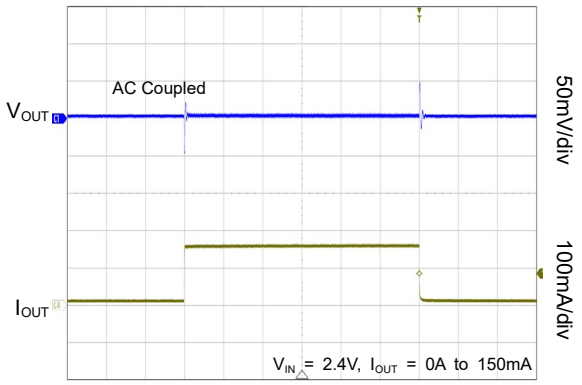




TYPICAL PERFORMANCE CHARACTERISTICS (continued)

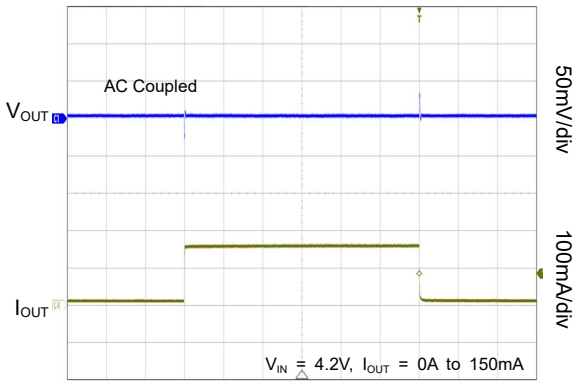
V_{OUT} = 3.3V, unless otherwise noted.

Load Transient Response



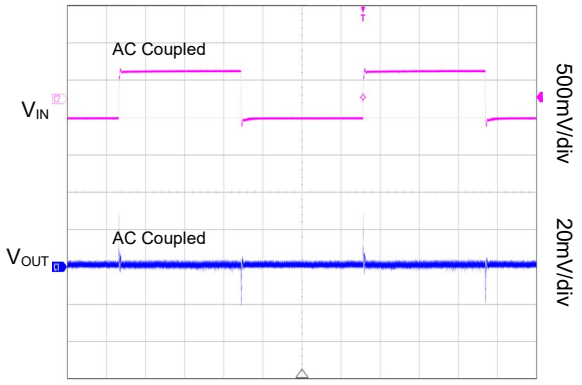
Time (1ms/div)

Load Transient Response



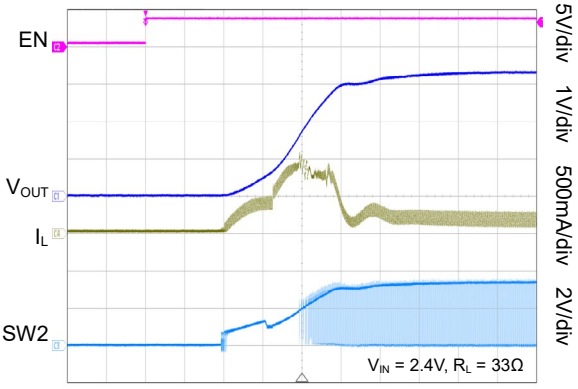
Time (1ms/div)

Line Transient Response



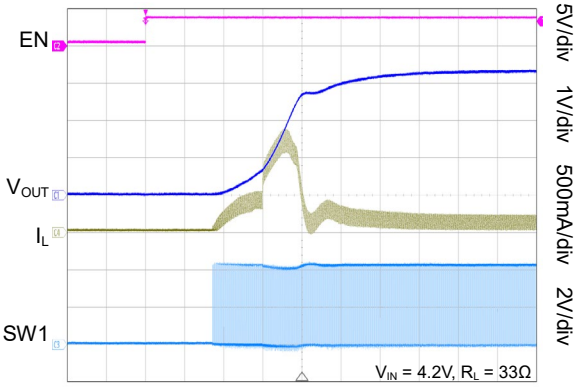
Time (2ms/div)

Startup After Enable



Time (50μs/div)

Startup After Enable



Time (50μs/div)

FUNCTIONAL BLOCK DIAGRAM

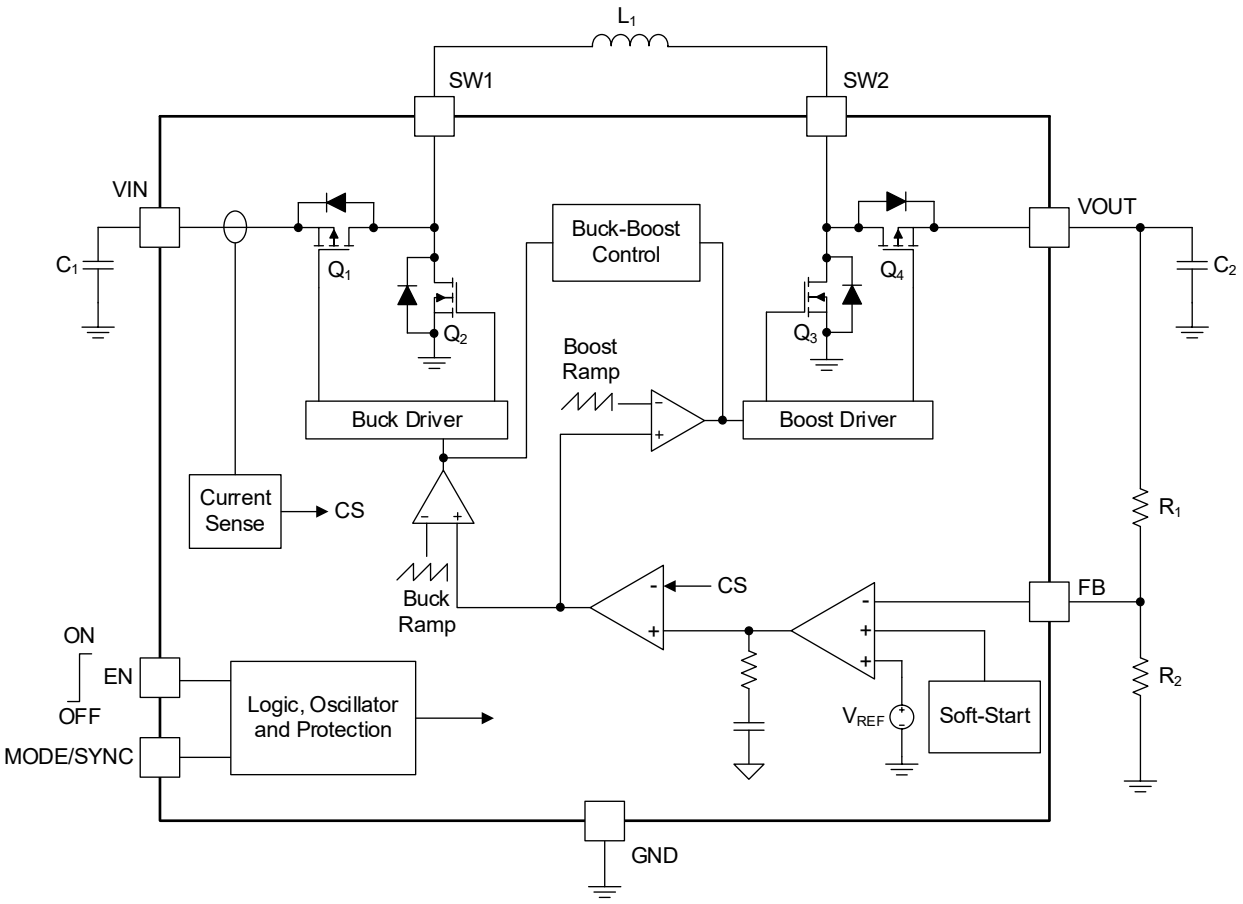


Figure 2. Block Diagram

DETAILED DESCRIPTION

The SGM62116 is a fully-integrated 4-switch synchronous Buck-Boost converter that maintains high efficiency across a wide range of input voltage and output power levels. The device is capable of changing mode automatically among Buck, Boost and Buck-Boost depending on the input and output condition. The SGM62116 utilizes a peak current mode topology in its controller circuit. The FB pin sends a feedback input signal to the voltage error amplifier, which requires connection to a resistive voltage divider. The feedback voltage is compared to the internal reference voltage to ensure a stable and precise output voltage.

The 4-switch topology ensures that the load is always disconnected from the input during converter shutdown. There is an internal temperature sensor to prevent the IC from overheating.

Control Loop Description

The SGM62116 adopts the peak current mode control architecture where the peak current of the Buck high-side MOSFET is sensed to provide the current information for the control loop. The sensed current is compared with a voltage loop formed by the FB network and internal reference voltage. The voltage loop outputs the amplifier error information between the FB voltage and reference voltage which ultimately determines the proper inductor current level to maintain output voltage regulation. The FB pin sends a feedback input signal to the voltage error amplifier, which requires connection to a resistive voltage divider. Figure 3 is a simplified drawing of the internal control loop, which consists of an error amplifier, a type-2 compensation network of the voltage loop and a PFM control block.

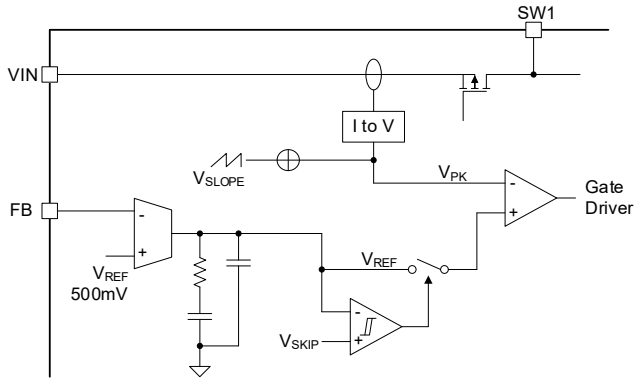


Figure 3. Control Loop Architecture Scheme

Enable

Pulling the EN pin logic high starts up the SGM62116, while a logic low shuts down the device. When in shutdown mode, the regulator stops switching, all internal control circuitry is turned off, and the load is disconnected from the input. During startup, the device limits the peak current to control the inrush current being pulled from the input supply.

Under-Voltage Lockout (UVLO)

To protect the device from malfunctioning when the input voltage is insufficient, an under-voltage lockout function is implemented. The device will not operate until the input voltage exceeds UVLO rising threshold of 1.8V (TYP), and will lockout if the input voltage falls below the UVLO falling threshold 1.5V (TYP).

Soft-Start and Short-Circuit Protection

The SGM62116 implements soft-start function to prevent output voltage overshoot and minimize the inrush current during startup. The initial peak current limit is set to 500mA to raise the output voltage from 0V. Once the output voltage reaches about 25% of V_{OUT}, the device allows the current limit to return to its nominal value. The current limit will not increase if the output voltage does not increase as well. To ensure controlled ramp-up of the output voltage, the device can handle large capacitors connected at the output. In case the output voltage does not increase above 25% of V_{OUT}, the device assumes a short-circuit at the output and lowers the current limit to prevent damage. During operation, if a short circuit occurs at the output, the current limit is clamped at 500mA peak current limit.

Over-Voltage Protection

In the event that the output voltage is not properly feed back to the input of the voltage amplifier, the control of the output voltage will fail. The device includes over-voltage protection to prevent the output voltage from exceeding critical values for both the device and the application system. This over-voltage protection circuit also internally monitors the output voltage. In the event that the output voltage reaches the over-voltage threshold (5.8V, TYP), the voltage amplifier regulates the output voltage to this value.

DETAILED DESCRIPTION (continued)

Over-Temperature Protection

The device features an integrated temperature sensor that continuously monitors the junction temperature. In the event that the temperature exceeds the shutdown level (T_{SD} = +140℃), the device will stop operating. Once the IC temperature drops below the programmed threshold, the device will automatically resume operation. To prevent unstable operation at IC temperatures close to the over-temperature threshold, a built-in hysteresis is implemented.

Automatic Mode Transition

The device seamlessly switches among Buck, Buck-Boost, and Boost modes of operation as required by the configuration to regulate the output voltage across all possible input voltage conditions. When V_{IN} >> V_{OUT}, the device operates as a Buck converter. Q_1 is the active switch, Q_2 is the synchronous rectifier, Q_3 is off and Q_4 is always on. If V_{IN} << V_{OUT}, the device operates as a Boost converter. In the Boost mode, Q_1 is always on, Q_2 is off, Q_3 is the active switch, and Q_4 acts as the synchronous rectifier. When V_{OUT} ~ V_{IN}, all four switches are controlled in a continuous on manner. The internal control loop controls all four switches adaptively based on the load, input voltage and output voltage. The inductor current is regulated to ensure output voltage regulation and load current delivery. The converter's overall efficiency is enhanced by minimizing the RMS current passing through the switches and inductor.

Pulse Frequency Modulation (PFM) and Synchronization

The MODE/SYNC pin in this device has two functions: enabling PFM or FPWM mode and synchronizing the device to an external clock frequency.

When MODE/SYNC is set low, PFM mode is enabled, which improves efficiency at light load. In this mode, switching loss is reduced due to the reduced switching cycles. Some of the internal blocks are turned off in PFM mode to further improve the light load efficiency. In the PFM mode, a sequence of burst switching cycles occur to maintain the output voltage followed by an off period as shown in Figure 4.

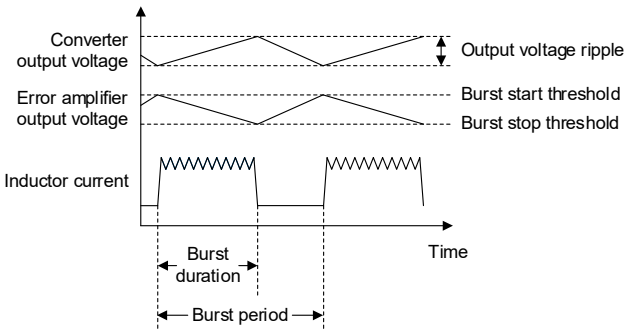


Figure 4. PFM Mode

The output voltage is monitored with a comparator by the burst start/stop threshold. The burst sequence is issued when the output of the error amplifier exceeds the burst start threshold voltage and the output voltage ramps up. As the error amplifier falls below the burst stop threshold, the device stops switching and the output voltage drops. The device dynamically adjusts the burst mode switching frequency based on the load to ensure the output voltage regulation accuracy. When load increases to above medium load condition, the device will automatically switch to FPWM mode.

MODE/SYNC can also be used to synchronize the device to an external clock frequency. When a clock signal is connected to MODE/SYNC, the device synchronizes to the connected clock frequency using a phase-locked loop (PLL). The PLL is designed to withstand missing clock pulses and synchronize to both lower and higher frequencies than the internal clock frequency without any complications.

Note that the PFM mode can be disabled by programming high at the MODE/SYNC pin.

DETAILED DESCRIPTION (continued)

Forced Pulse Width Modulation (FPWM)

FPWM mode is enabled via MODE/SYNC = High. In the FPWM mode, in light load condition, the synchronous switches are not turned off when the inductor current goes negative to maintain a constant switching frequency. FPWM operation has lower output voltage ripple and better transient response compared to PFM. However, in the lower output current, FPWM results in higher switching and conduction loss thus lowering efficiency.

Current Limit Operation

The SGM62116 implements peak current limit to protect the device from over-current scenarios. Switching is terminated immediately when the peak current sensed from the Buck high-side MOSFET reaches the current limit threshold.

APPLICATION INFORMATION

Application Information

The SGM62116 is a non-inverting Buck-Boost converter that supports regulated output voltages from 1.2V to 5.5V. It is designed to operate over a wide input voltage range from 1.8V to 5.5V, making it suitable for a variety of applications where the input voltage can be higher or lower than the desired output voltage. The average input current limit is typically 900mA.

Typical Application

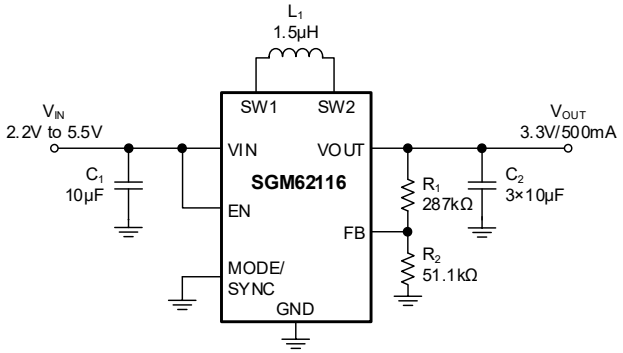


Figure 5. Typical Operating Circuit

Parameters of this design example are shown in Table 1.

Table 1. Design Parameters

Parameter	Symbol	Recommended Value
Input Voltage	V_{IN}	2.2V to 5.5V
Output Voltage	V_{OUT}	3.3V
Output Current	I_{OUT}	500mA

Design Procedure

Setting the Output Voltage

To set the output voltage of the SGM62116, an external resistor divider connected among VOUT, FB, and GND is used. The typical voltage at the FB pin is 500mV when the output voltage is regulated. The maximum recommended output voltage is 5.5V. The leakage current into the FB pin is 0.01μA (TYP), and the internal reference voltage is typically 500mV. The selected bottom FB resistor R_2 is 51.1kΩ for 3.3V output. Use Equation 1 to calculate the top feedback resistor R_1, which 287kΩ is used to provide a 3.3V output.

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right) \quad (1)$$

Inductor Selection

A 1.5μH inductor is recommended for use with SGM62116. Lower DCR inductors are recommended for better efficiency. The rated saturation current (I_{SAT}) must be at least 20% above the maximum peak current in the worst cases including transients. Usually the worst cases occur in the Boost mode when operating at the lowest input voltage, highest output voltage and with the maximum load. Use Equation 2 to calculate the maximum duty cycle in Boost mode (corresponds to the maximum inductor current).

$$D_{MAX} = \frac{V_{OUT\_MAX} - V_{IN\_MIN}}{V_{OUT\_MAX}} \quad (2)$$

where:
D_{MAX} is the maximum duty cycle in Boost mode.
V_{IN_MIN} is the minimum input voltage which is possible to have in Boost mode.
V_{OUT_MAX} is the maximum output voltage.

The maximum inductor current in steady-state operation can be calculated by:

$$I_{LM} = \frac{I_{OUT\_MAX}}{\eta(1 - D_{MAX})} + \frac{D_{MAX} \times V_{IN\_MIN}}{2 \times f \times L} \quad (3)$$

where:
I_{LM} is the peak inductor current.
I_{OUT_MAX} is the maximum output current.
η is the converter efficiency (use application curves or choose 80%).
f is the switching frequency (2.4MHz).
L is the inductance (1.5μH).

To avoid saturation of the inductor, choose the I_{SAT} value at least 20% higher than the calculated I_{LM} value.

Capacitor Selection

Input Capacitor

The total input capacitance after considering the DC bias de-rating is recommended to be above 5μF. It is recommended to use a 10μF, 6.3V ceramic capacitor in most applications. If the source is far away from the device, it is recommended to use additional bulk capacitance (such as a 47μF electrolytic or tantalum capacitor) for better stability.

APPLICATION INFORMATION (continued)

Output Capacitor

A combination of 30μF capacitor is recommended in the application. To reduce high frequency noise, a 100nF ceramic capacitor in 0201 or 0402 package is recommended to place as close to the VOUT and GND pins as possible in parallel to the other output capacitors.

The output capacitance of the SGM62116 has no upper limit. Selecting higher output capacitance can provide tighter transient response and lower output voltage ripple.

Application Example

Table 2 lists the component values and part numbers used for the tests and measurements outlined in the characteristic curves.

Table 2. Components used for Characteristic Curves

Reference	Description	Part Number	Manufacturer
C_1	Capacitor, 10μF, 6.3V, 0603, ceramic	GRM188R60J106KME84D	Murata
C_2	Capacitor, 10μF, 6.3V, 0603, ceramic	GRM188R60J106KME84D	Murata
L_1	Inductor, 1.5μH	MHCD252010B-1R5M-A8L	Chilisin
U_1	Integrated circuit	SGM62116	SGMICRO

LAYOUT

Layout Guidelines

Layout plays a significant role for all switch mode DC/DC power supplies. Improper layout could result in poor EMI performance, device instability, and potential device damage. To ensure proper layout, employ short and wide traces for the main current path and ground tracks. It is also essential to place the input capacitor, output capacitor, and inductor as close as possible to the IC to minimize parasitic effects. Furthermore, the feedback divider should be positioned in close proximity to the ground pin of the IC to reduce noise and improve accuracy. Figure 6 is an example layout which is also the PCB layout used to collect the data in the Typical Performance Characteristics section.

Layout Example

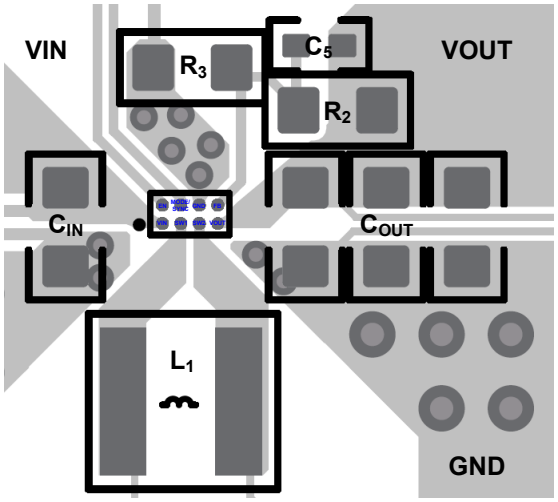


Figure 6. Recommended PCB Layout

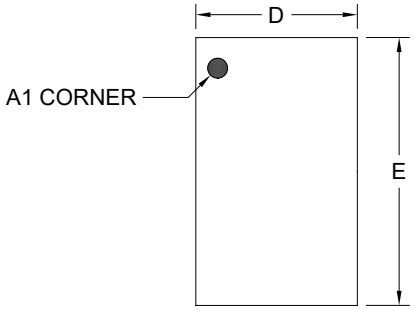
REVISION HISTORY

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

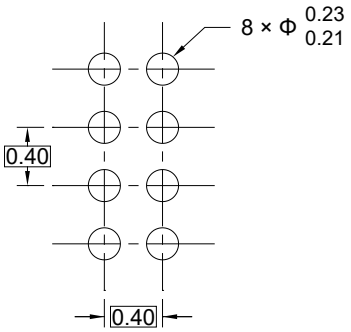
Changes from Original (MAY 2023) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

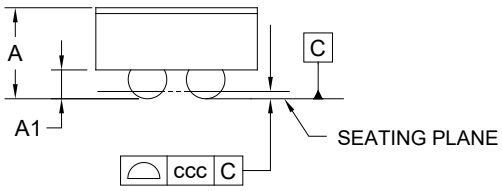
WLCSP-1.11×1.84-8B



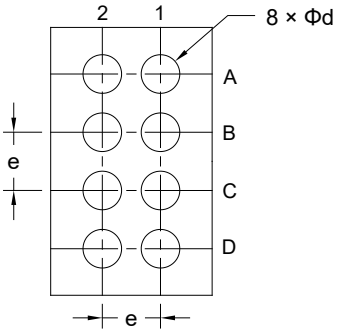
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



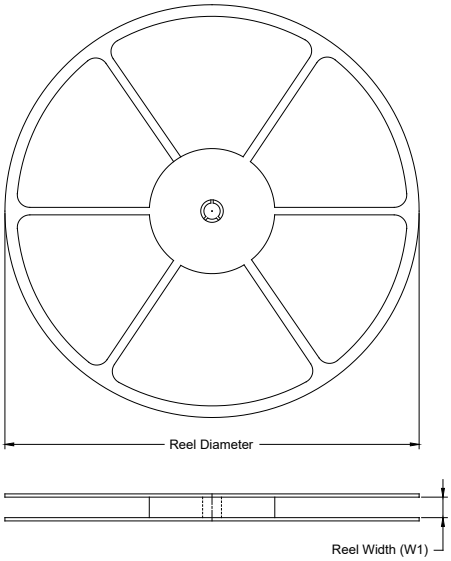
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	-	-	0.663
A1	0.178	-	0.218
D	1.081	-	1.141
E	1.809	-	1.869
d	0.235	-	0.295
e	0.400 BSC		
ccc	0.050		

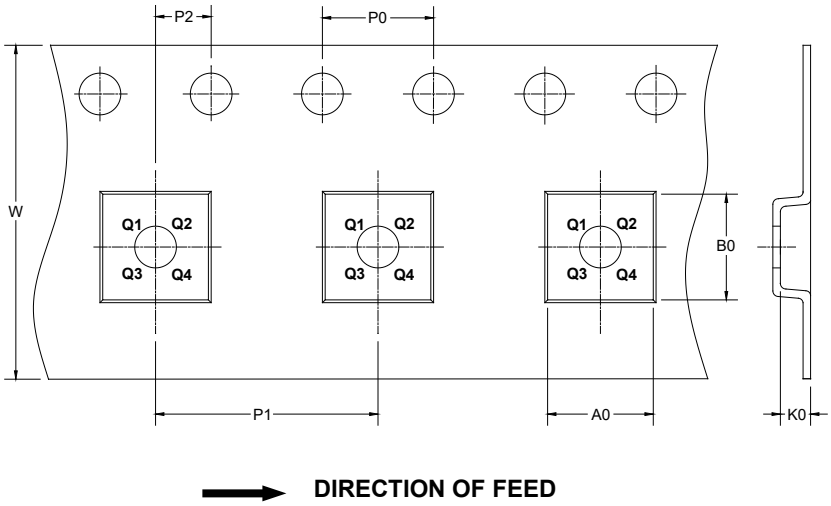
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



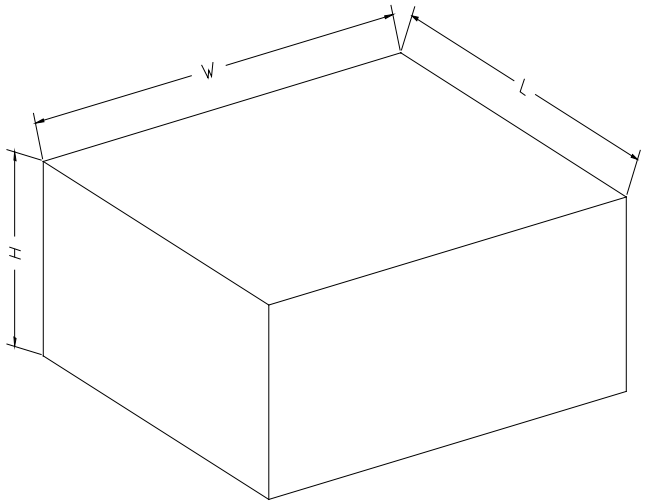
NOTE: The picture is only for reference. Please make the object as the standard.

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-1.11×1.84-8B	7"	9.5	1.23	1.98	0.76	4.0	4.0	2.0	8.0	Q1

DD0001

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

DD0002