



# SGM6031

## Ultra-Low Power Step-Down Converters with Up to 200mA Output Current

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### GENERAL DESCRIPTION

The SGM6031 family provides a highly integrated ultra-low power step-down converter solution that is well suited for meeting the special needs of ultra-low power applications such as energy harvesting. The regulators are intended to step-down the voltage from an energy storage element such as a battery or super capacitor to supply the rail to low-voltage electronics. The regulated output has been optimized to provide high efficiency across low output currents ( $<10\mu\text{A}$ ) to high currents (200mA).

The SGM6031 family integrates an optimized hysteretic controller for low-power applications. The internal circuitry uses a time-based sampling system to reduce the average quiescent current.

All the capabilities of SGM6031 are packed into a small WLCSP-0.90x0.88-5B package. It operates over an ambient temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

### FEATURES

- **Industry's Highest Efficiency at Low Output Currents: Up to 90% with  $I_{\text{OUT}} = 0.1\text{mA}$**
- **Ultra-Low Power Step-Down Converters**
- **200mA Maximum Output Current**
- **1.8V to 5.5V Input Operating Range**
- **Fixed Output Voltages: 1.0V, 1.2V, 1.5V, 1.8V, 2.5V and 2.8V**
- **Output Adjustable from 1.0V to 3.3V**
- **450nA Quiescent Current**
- **100% Duty Cycle (Pass Mode)**
- **$-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  Ambient Temperature Range**
- **Available in Green WLCSP-0.90x0.88-5B Package**

### APPLICATIONS

Ultra-Low Power Applications  
2-Cell and 3-Cell Alkaline-Powered Applications  
Energy Harvesting  
Solar Chargers  
Thermal Electric Generator (TEG) Harvesting  
Wireless Sensor Networks (WSN)  
Low-Power Wireless Monitoring  
Environmental Monitoring  
Bridge and Structural Health Monitoring (SHM)  
Smart Building Controls  
Portable and Wearable Health Devices  
Entertainment System Remote Controls

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### PACKAGE/ORDERING INFORMATION

MODEL	V <sub>OUT</sub> (V)	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM6031-1.0	1.0	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-1.0YG/TR	F1	Tape and Reel, 3000
SGM6031-1.2	1.2	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-1.2YG/TR	F2	Tape and Reel, 3000
SGM6031-1.5	1.5	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-1.5YG/TR	F3	Tape and Reel, 3000
SGM6031-1.8	1.8	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-1.8YG/TR	CF	Tape and Reel, 3000
SGM6031-2.5	2.5	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-2.5YG/TR	F4	Tape and Reel, 3000
SGM6031-2.8	2.8	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-2.8YG/TR	F5	Tape and Reel, 3000
SGM6031-ADJ	ADJ	WLCSP-0.90×0.88-5B	-40°C to +85°C	SGM6031-ADJYG/TR	F7	Tape and Reel, 3000

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 Voltage Range on VIN, EN, VOUT, FB, SW  
 .....-0.3V to 6V  
 Peak Currents VIN, VOUT ..... 510mA  
 Typical Thermal Resistance  
 WLCSP-0.90×0.88-5B,  $\theta_{JA}$  ..... 180°C/W  
 Junction Temperature ..... +150°C  
 Storage Temperature Range..... -65°C to +150°C  
 Lead Temperature (Soldering, 10s) ..... +260°C  
 ESD Susceptibility  
 HBM..... 7000V  
 MM..... 400V  
 CDM ..... 1000V

#### RECOMMENDED OPERATING CONDITIONS

Input Voltage Range ..... 1.8V to 5.5V  
 Input Capacitance, C<sub>IN</sub>.....22 $\mu$ F (MIN)  
 Output Capacitance, C<sub>OUT</sub> ..... 10 $\mu$ F (MIN), 22 $\mu$ F (TYP)  
 Inductance, L ..... 4.7 $\mu$ H (MIN)  
 Operating Ambient Temperature Range..... -40°C to +85°C  
 Operating Junction Temperature Range ..... -40°C to +125°C

#### 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.

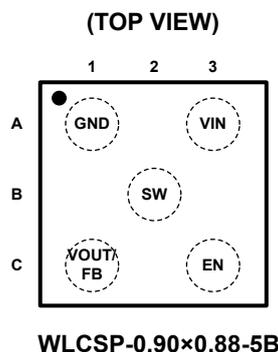
#### ESD SENSITIVITY CAUTION

This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. 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 very small parametric changes could cause the device not to meet its published specifications.

#### DISCLAIMER

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

## PIN CONFIGURATION



## PIN DESCRIPTION

PIN	NAME	FUNCTION
A1	GND	Ground. Power and IC ground. All signals are referenced to this pin.
A3	VIN	Input Voltage. Connect to input power source.
B2	SW	Switching Node. Connect to output inductor.
C1	VOUT	Step-Down Regulator Output.
	FB	Feedback Input (adjustable voltage version only). The voltage at this pin is regulated to 1.0V. Connected to the resistor divider between output and ground to set output voltage.
C3	EN	Enable Input. Input logic high to enable this circuit and logic low to shut down. Do not leave this pin unconnected. EN is recommended to be effective 10ms later than VIN.

**ELECTRICAL CHARACTERISTICS**(V<sub>IN</sub> = 3.6V, V<sub>OUT</sub> = 1.2V, Full = -40°C to +85°C, typical values are at T<sub>A</sub> = +25°C, unless otherwise noted.)

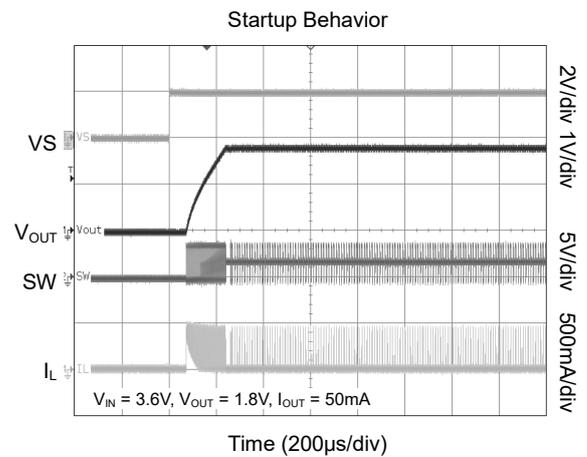
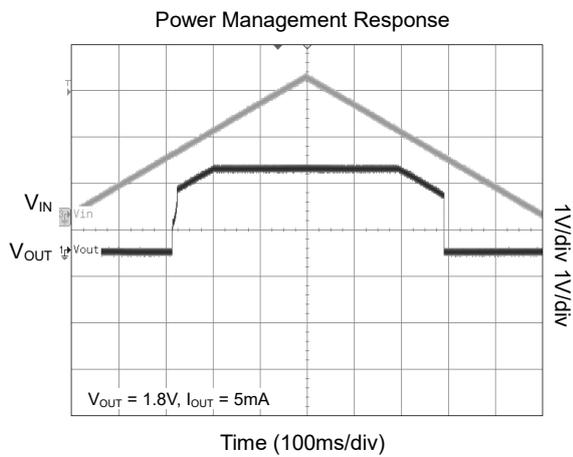
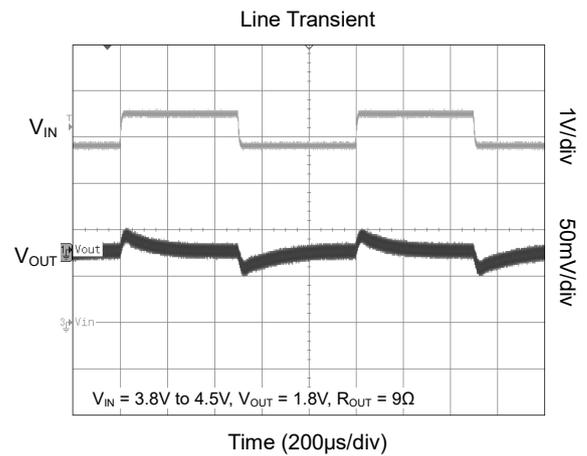
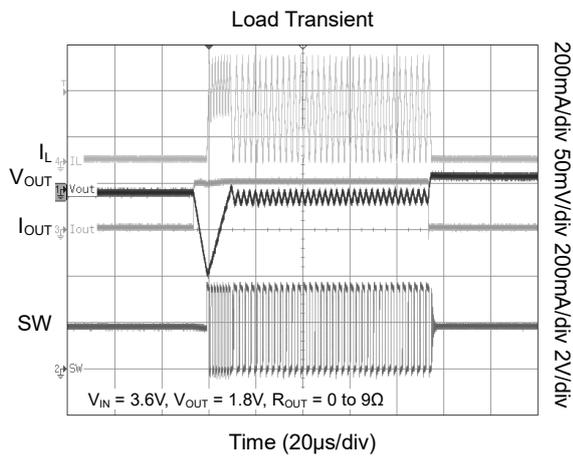
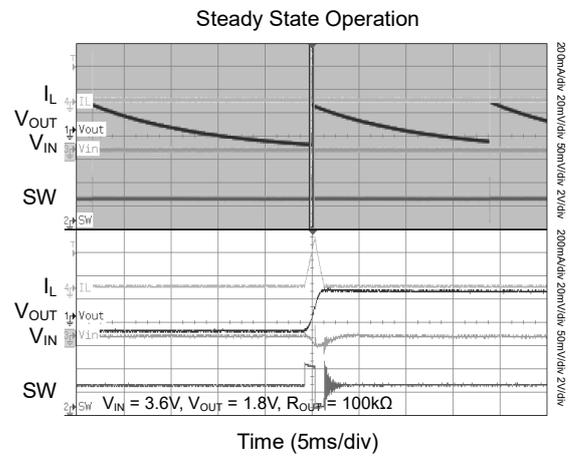
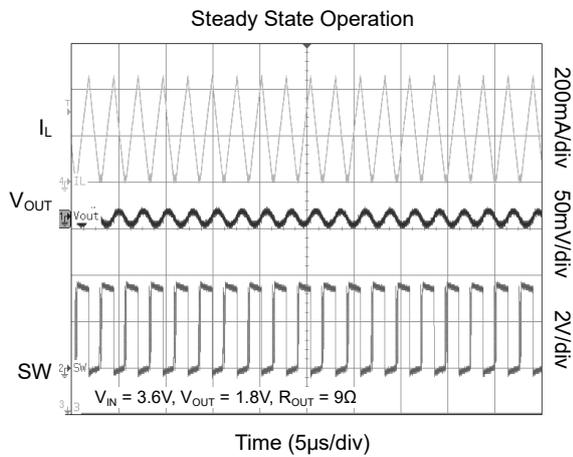
PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
<b>Quiescent Current</b>							
Buck Enabled State	I <sub>Q</sub>	V <sub>IN</sub> = 1.8V, no load, no switching	+25°C		450	730	nA
<b>Output</b>							
Feedback Voltage	V <sub>FB</sub>		+25°C	0.98	1.0	1.02	V
Output Accuracy			+25°C	-2		2	%
			Full	-3		3	
Output Line Regulation		V <sub>IN</sub> = 1.8V to 5.5V, I <sub>OUT</sub> = 100μA	+25°C		0.3		%/V
Output Load Regulation		I <sub>OUT</sub> = 100μA to 200mA	+25°C		0.002		%/mA
Output Ripple		I <sub>OUT</sub> = 1mA	+25°C		15		mV <sub>PP</sub>
<b>Power Switch</b>							
High-side Switch On-Resistance	R <sub>DS(ON)</sub>		+25°C		360	480	mΩ
Low-side Switch On-Resistance			+25°C		380		
Cycle-by-Cycle Current Limit	I <sub>LIM</sub>		+25°C	320	400	480	mA
Maximum Switching Frequency	f <sub>SW</sub>		+25°C		1.4		MHz
<b>Input</b>							
Input Under Voltage Protection	V <sub>IN_UVLO</sub>	V <sub>IN</sub> falling	+25°C	1.14	1.3		V
<b>EN</b>							
Voltage for EN High Setting	V <sub>IH</sub>		Full	1.1			V
Voltage for EN Low Setting	V <sub>IL</sub>		Full			0.4	V

# Ultra-Low Power Step-Down Converters with Up to 200mA Output Current

## SGM6031

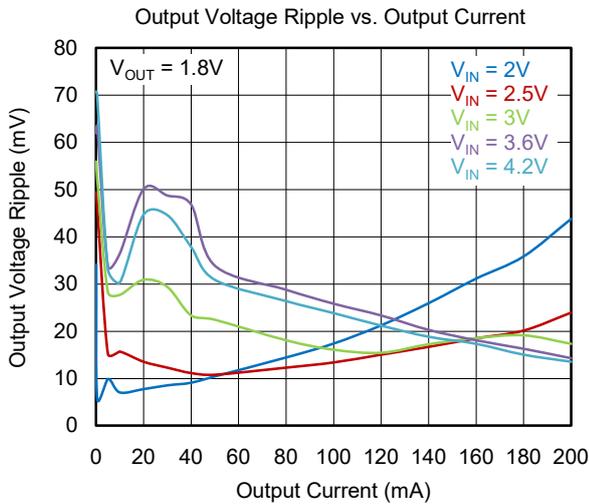
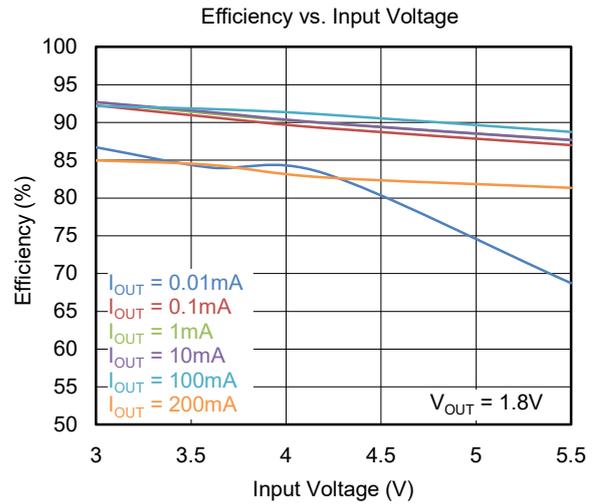
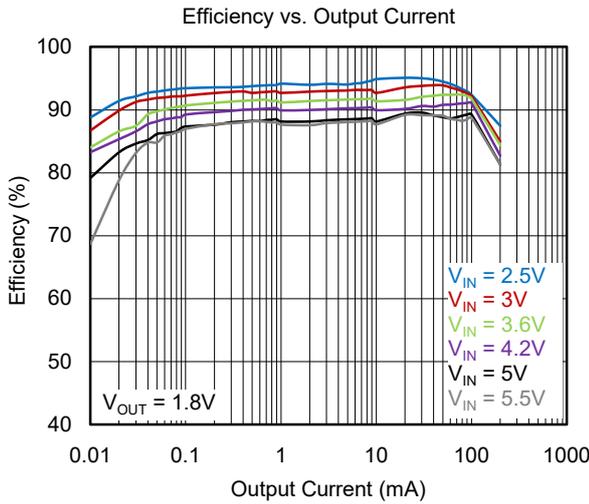
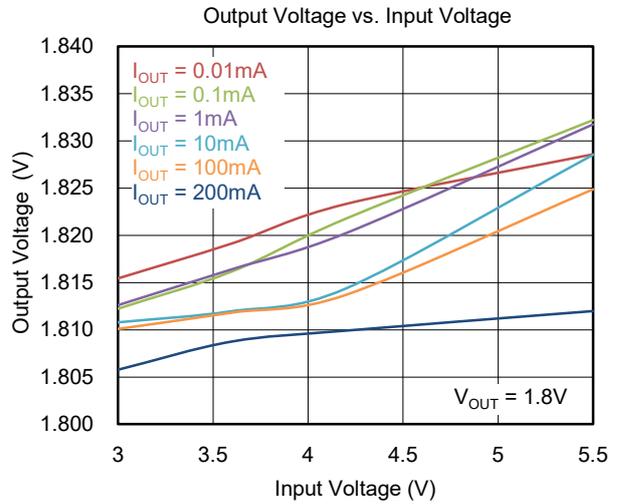
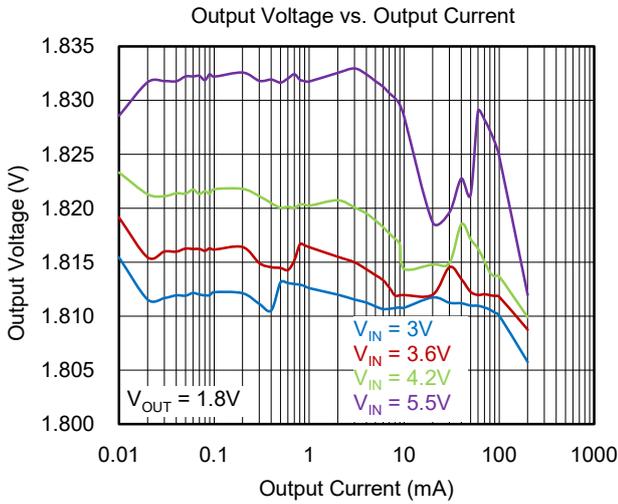
### TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = +25^\circ\text{C}$ , unless otherwise noted.



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T<sub>A</sub> = +25°C, unless otherwise noted.



TYPICAL APPLICATION CIRCUITS

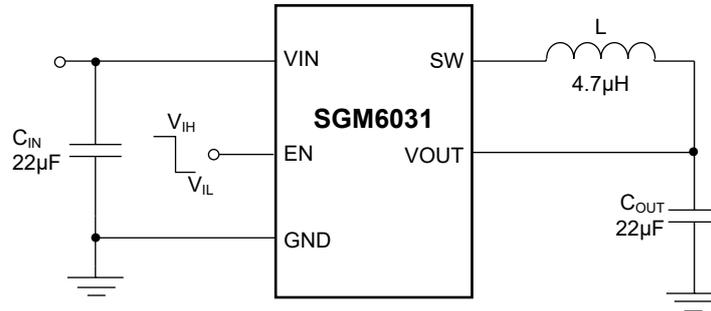


Figure 1. Fixed Voltage Typical Application Circuit

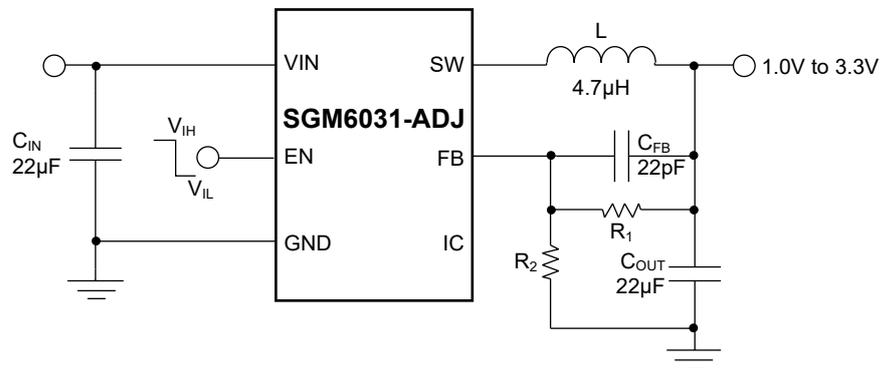


Figure 2. Adjustable Voltage Typical Application Circuit

FUNCTIONAL BLOCK DIAGRAM

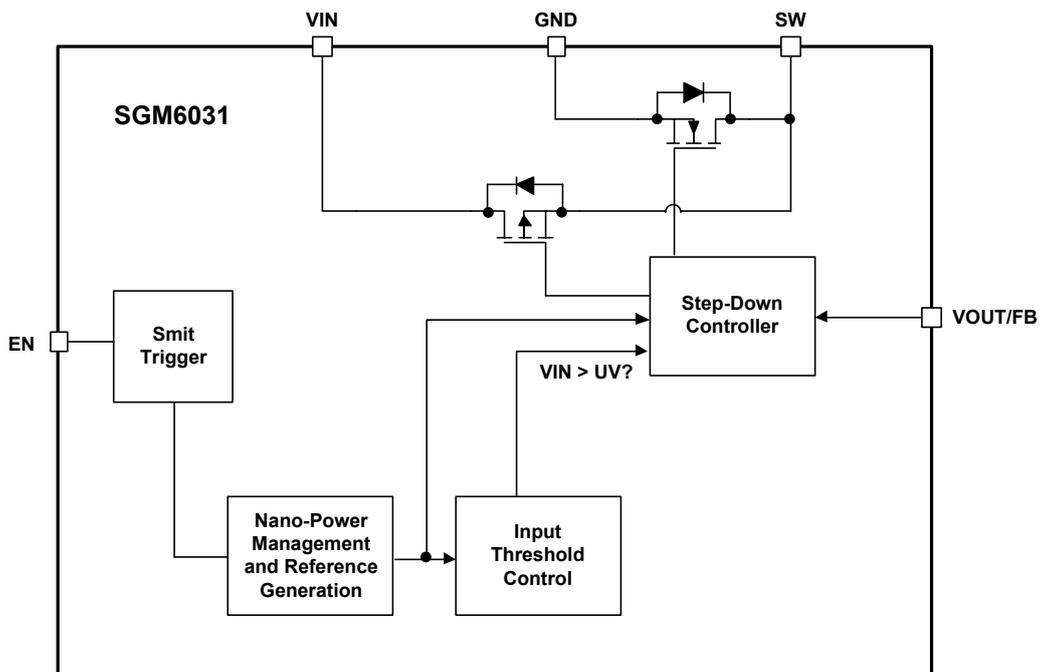


Figure 3. Block Diagram

### DETAILED DESCRIPTION

The SGM6031 family provides a highly integrated ultra-low power step-down converter solution that is well suited for meeting the special needs of ultra-low power applications such as energy harvesting. The regulators are intended to step-down the voltage from an energy storage element such as a battery or super capacitor in order to supply the rail to low-voltage electronics. The regulated output has been optimized to provide high efficiency across low output currents (less than 10 $\mu$ A) to high currents (200mA).

The SGM6031 family integrates an optimized hysteretic controller for low-power applications. The internal circuitry uses a time-based sampling system to reduce the average quiescent current.

#### Step-Down Converter Operation

The step-down regulator in the SGM6031 family takes input power from  $V_{IN}$ , steps it down and provides a regulated voltage at the  $V_{OUT}$  pin. It employs pulse frequency modulation (PFM) control to regulate the voltage close to the desired reference voltage. The current through the inductor is controlled through internal current sense circuitry. The peak current in the inductor is controlled to maintain high efficiency of the converter across a wide input current range. The SGM6031 converter delivers an average output current of 200mA with a peak inductor current of 430mA. The step-down regulator is disabled when the voltage on  $V_{IN}$  reaches the UVLO condition. The UVLO level is continuously monitored. The step-down regulator continues to operate in pass (100% duty cycle) mode, passing the input voltage to the output, as long as  $V_{IN}$  is greater than UVLO and less than  $V_{IN}$  minus  $I_{OUT}$  times

$R_{DS(ON)}$  of the high-side FET (that is,  $V_{IN} - I_{OUT} \times R_{DS(ON)-HS}$ ). In order to save power from being dissipated through other ICs on this supply rail, the step-down regulator can be enabled and disabled through the EN pin for systems that desire to turn off the regulated output.

#### Under-Voltage Lockout (UVLO)

When the input voltage is below the UVLO threshold, the device is shut down. If the input voltage rises above the UVLO threshold plus hysteresis, the IC will restart.

#### Nano-Power Management and Efficiency

The high efficiency of the SGM6031 family is achieved through the nano-power management circuitry and algorithm. This feature essentially samples and holds all references in order to reduce the average quiescent current. That is, the internal circuitry is only active for a short period of time and then off for the remaining period of time at the lowest feasible duty cycle.

The efficiency versus output current and efficiency versus input voltage are plotted for three different output voltages for SGM6031 device in Typical Characteristics. All data points were captured by averaging the overall input current. This must be done, due to the periodic biasing scheme implemented through the nano-power management circuitry. The input current efficiency data was gathered using a source meter set to average over at least 25 samples and at the highest accuracy sampling rate. Each data point takes a long period of time to gather in order to properly measure the resulting input current when calculating the efficiency.

### APPLICATION INFORMATION

The SGM6031 family is step-down converters. Their low quiescent currents make them ideal for battery powered systems that are operated at low duty cycles in order to achieve low total power levels.

#### Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R_2}{R_1 + R_2}$$

where  $V_{FB}$  is the feedback voltage and  $V_{OUT}$  is the output voltage. Thus the output voltage is:

$$V_{OUT} = 1.0 \times \frac{R_1 + R_2}{R_2}$$

The value for  $R_2$  can be as high as 1MΩ.

For example, for a 2V output voltage,  $R_2$  is 1MΩ, and  $R_1$  is 1MΩ.

#### Detailed Design Procedure

The recommended 4.7μH inductor and 22μF input capacitor are used. Since no large load transients are expected, the minimum 22μF output capacitor is used. Had a large load transient been expected, we would have sized the capacitor using  $I_{TRAN} = C_{OUT} \times \Delta V_{OUT} / \Delta TIME$  where  $\Delta V_{OUT}$  is amount of  $V_{OUT}$  droop allowed for the time of the transient.

#### Inductor Selection

The internal-control circuitry is designed to control the switching behavior with a nominal inductance of 4.7μH ±20%. The saturation current of the inductor should be at least 25% higher than the maximum cycle-by-cycle

current limit per the electrical specs table ( $I_{LIM}$ ) in order to account for load transients. Because this device is a hysteretic controller, it is a naturally stable system (single order transfer function). However, the smaller the inductor value is, the faster the switching currents are.

A list of inductors recommended for this device is shown in Table 1.

**Table 1. Recommended Inductors**

Inductance (μH)	Dimensions (mm)	Part Number	Manufacturer
4.7	2.0 × 2.5 × 1.2	DFE252012C-H-4R7M	Toko
4.7	4.0 × 4.0 × 1.7	LPS4018-472ML	Coilcraft

#### Output Capacitor Selection

The output capacitor is chosen based on transient response behavior and ripple magnitude. The lower the capacitor value, the larger the ripple will become and the larger the droop will be in the case of a transient response. It is recommended to use at least a 22μF output capacitor for most applications. In addition, the output voltage ripple may increase when  $V_{IN} > 4.5V$ , and this may need larger output capacitor for better output ripple.

#### Input Capacitor Selection

The bulk input capacitance is recommended to be a minimum of 22μF ±20%. This bulk capacitance is used to suppress the lower frequency transients produced by the switching converter. There is no upper bound to the input-bulk capacitance. In addition, a high-frequency bypass capacitor of 0.1μF is recommended in parallel with the bulk capacitor. The high-frequency bypass is used to suppress the high-frequency transients produced by the switching converter.

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## SGM6031

### REVISION HISTORY

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

<b>NOVEMBER 2020 – REV.A.1 to REV.A.2</b>	<b>Page</b>
Updated Fixed Output Voltages .....	All

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<b>JULY 2020 – REV.A to REV.A.1</b>	<b>Page</b>
Updated Electrical Characteristics, Typical Performance Characteristics and Detailed Description.....	4, 7, 9, 10

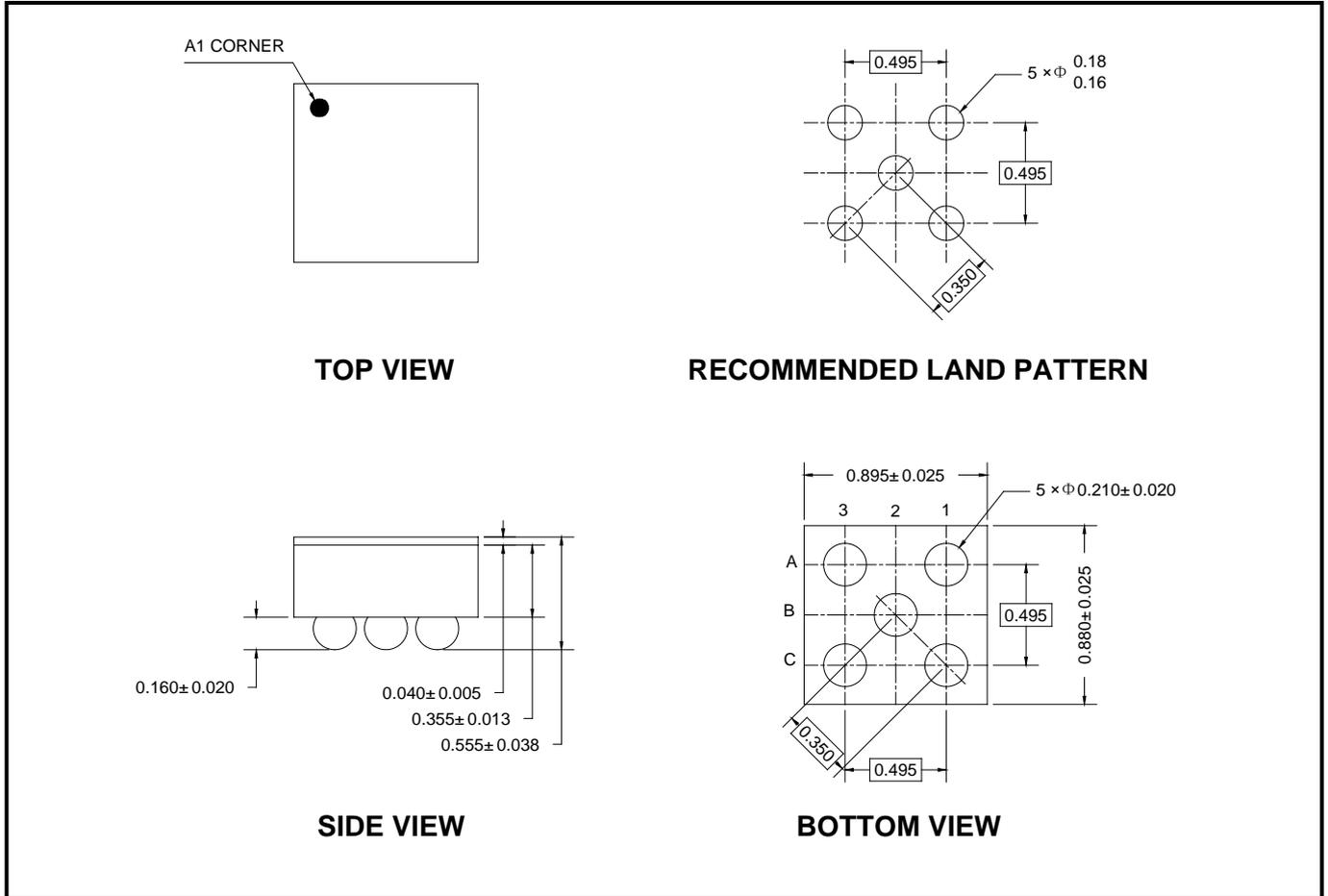
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<b>Changes from Original (MARCH 2019) to REV.A</b>	<b>Page</b>
Changed from product preview to production data.....	All

# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### WLCSP-0.90x0.88-5B

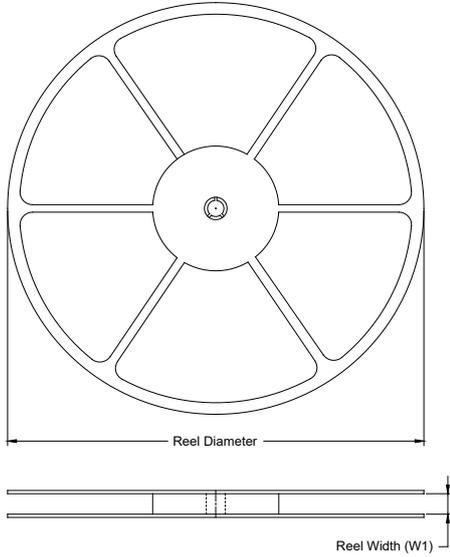


NOTE: All linear dimensions are in millimeters.

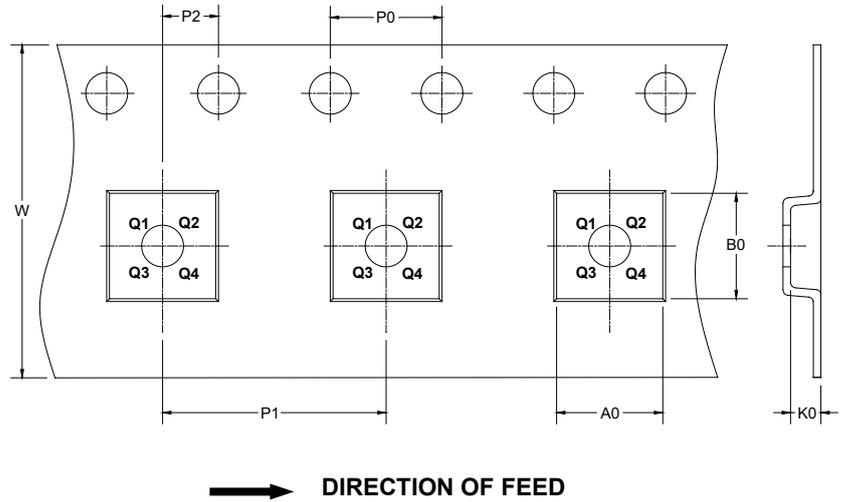
# PACKAGE INFORMATION

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS



### TAPE DIMENSIONS



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

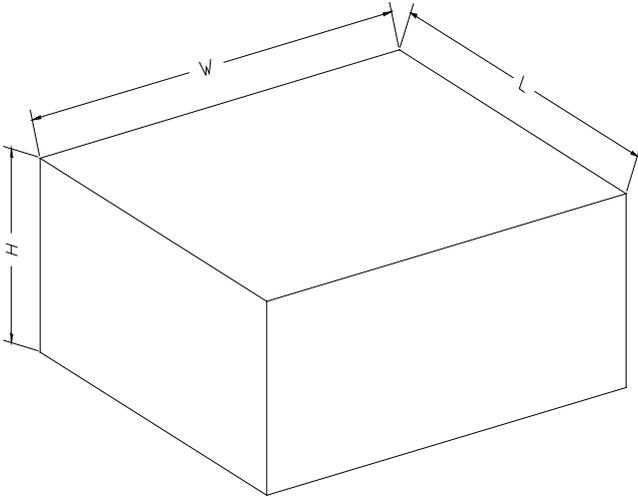
### KEY PARAMETER LIST OF TAPE AND REEL

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-0.90×0.88-5B	7"	9.2	1.00	1.00	0.73	4.0	4.0	2.0	8.0	Q1

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# PACKAGE INFORMATION

## 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