SGM6021
Programmable Output Voltage Ultra-Low Power Step-Down Converters with Up to 200mA Output Current

GENERAL DESCRIPTION

The SGM6021 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 SGM6021 family provides the system with an externally programmable regulated supply to preserve the overall efficiency of the power-management stage compared to a linear step-down converter. 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 (<10μA) to high currents (200mA).

The SGM6021 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.

The output regulator levels are programmed through VS pin.

All the capabilities of SGM6021 are packed into a small UTDFN-1.5×2-6L package. It operates over an ambient temperature range of -40℃ to +85℃.

FEATURES

- **Industry's Highest Efficiency at Low Output Currents: Up to 90% with I_{OUT} = 0.1mA**
- **Ultra-Low Power Step-Down Converters**
- **200mA Maximum Output Current**
- **Output Voltage Programmable in Operation**
- **1.8V to 5.5V Input Operating Range**
- **400nA Quiescent Current**
- **100% Duty Cycle (Pass Mode)**
- **Available in Green UTDFN-1.5×2-6L Package**
- **-40℃ to +85℃ Ambient Temperature Range**

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

TYPICAL APPLICATION

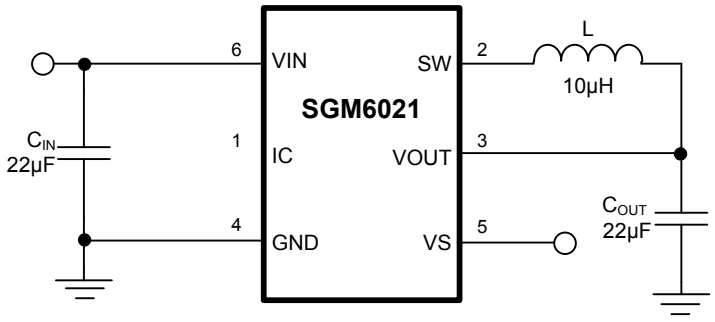


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	STATUS (1)	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM6021-1	PREVIEW	UTDFN-1.5×2-6L	-40℃ to +85℃	SGM6021-1YUDT6G/TR	G90 XXX	Tape and Reel, 3000
SGM6021-2	ACTIVE	UTDFN-1.5×2-6L	-40℃ to +85℃	SGM6021-2YUDT6G/TR	GFD XXX	Tape and Reel, 3000
SGM6021-3	ACTIVE	UTDFN-1.5×2-6L	-40℃ to +85℃	SGM6021-3YUDT6G/TR	GFE XXX	Tape and Reel, 3000
SGM6021-4	ACTIVE	UTDFN-1.5×2-6L	-40℃ to +85℃	SGM6021-4YUDT6G/TR	GFF XXX	Tape and Reel, 3000

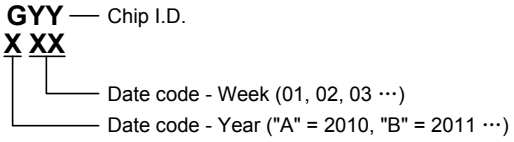
NOTES:
1. The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

2. XXX = Date Code.

MARKING INFORMATION



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.

SELECTABLE MODEL

MODEL	I_{OUT} (mA)	V_{OUT} (V)	V1 (V)	V2 (V)	V3 (V)
SGM6021-1	200	1.25	1.20	1.10	1.02
SGM6021-2	200	3.3	3.0	2.7	2.4
SGM6021-3	200	3.0	2.5	2.0	1.8
SGM6021-4	200	2.4	1.8	1.5	1.3

ABSOLUTE MAXIMUM RATINGS

Input Voltage Range on VIN, VS, VOUT, SW
.....-0.3V to 6V
Peak Currents VIN, VOUT..... 510mA
Junction Temperature .....+150℃
Storage Temperature Range..... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .....+260℃
ESD Susceptibility
HBM..... 7000V
MM..... 400V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range..... 1.8V to 5.5V
Input Capacitance, C_{IN} .....22μF (MIN)
Output Capacitance, C_{OUT} ..... 10μF (MIN), 22μF (TYP)
Inductance, L.....10μH (MIN)
Operating Junction Temperature Range.....-40℃ to +125℃
Operating Ambient Temperature Range .....-40℃ to +85℃

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

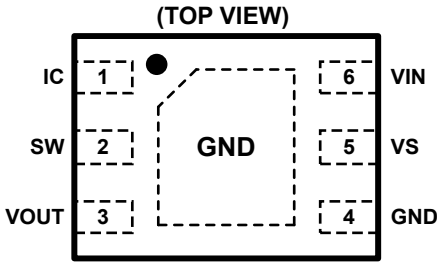
ESD SENSITIVITY CAUTION

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, specification or other related things if necessary without notice at any time.

PIN CONFIGURATION



UTDFN-1.5×2-6L

PIN DESCRIPTION

PIN	NAME	FUNCTION
1	IC	For Internal Connection.
2	SW	Switching Node. Connect to output inductor.
3	VOUT	Step-Down Regulator Output.
4	GND	Ground. Power and IC ground. All signals are referenced to this pin.
5	VS	Programming Regulator Output Voltage Input. Pull this pin up for period > (t_{BLANK} + t_{SS}) to start from shutdown state to output a default voltage or a programmable voltage, and pull this pin down for period > t_{STOP} to select the default voltage or shut down its operation. This pin internally ties to a bias that is slightly higher than logic low threshold unless in shutdown state, which keeps it stay as logic high even when the external control IO is in Hi-Z status.
6	VIN	Input Voltage. Connect to input power source.
Exposed Pad	GND	Connect to GND.

ELECTRICAL CHARACTERISTICS

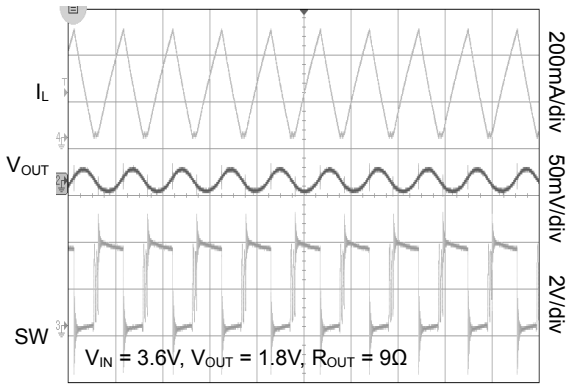
(V_{IN} = 3.6V, V_{OUT} = 1.25V, typical values are at T_A = +25℃. Full = -40℃ to +85℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
QUIESCENT CURRENT							
Buck Enabled State	I_Q	V_{IN} = 1.8V, no load, no switching	+25℃		400	700	nA
OUTPUT							
Output Accuracy			+25℃	-2		2	%
			Full	-3		3	
Output Line Regulation		V_{IN} = 1.8V to 5.5V, I_{OUT} = 100μA	+25℃		0.3		%/V
Output Load Regulation		I_{OUT} = 100μA to 200mA	+25℃		0.002		%/mA
Output Ripple		I_{OUT} = 1mA	+25℃		15		mV_{PP}
POWER SWITCH							
High-Side Switch ON Resistance	$R_{DS(ON)}$		+25℃		510	620	mΩ
Low-Side Switch ON Resistance			+25℃		530	690	
Cycle-by-Cycle Current Limit	I_{LIM}		+25℃	355	430	510	mA
Maximum Switching Frequency	f_{SW}		+25℃		1.4		MHz
INPUT							
Input Under Voltage Protection	V_{IN_UVLO}	V_{IN} falling	+25℃	1.19	1.3		V
VS							
VS Leakage Current	I_{VSH}	V_{VS} = 5.5V	+25℃		0.1	1	μA
Voltage for VS High Setting	V_{IH}		Full	1			V
Voltage for VS Low Setting	V_{IL}		Full			0.25	
Power-On Blanking Time	t_{BLANK}		+25℃		66		ms
VS Change Stop Time	t_{STOP}		+25℃	8	11	14	ms
Shutdown Delay	t_{OFF}		+25℃	99	135	170	ms
t_{OFF} Hold On Time	$t_{OFF-HOLD}$		+25℃	38	53	66	ms
Effective Pulse Time	t_{PULSE}		+25℃	1.5		2.5	ms
Soft Start Time	t_{SS}		+25℃		26		ms
THERMAL SHUTDOWN							
Thermal Shutdown	T_{TSD}				160		℃
Thermal Shutdown Hysteresis	T_{HYS}				20		℃

TYPICAL PERFORMANCE CHARACTERISTICS

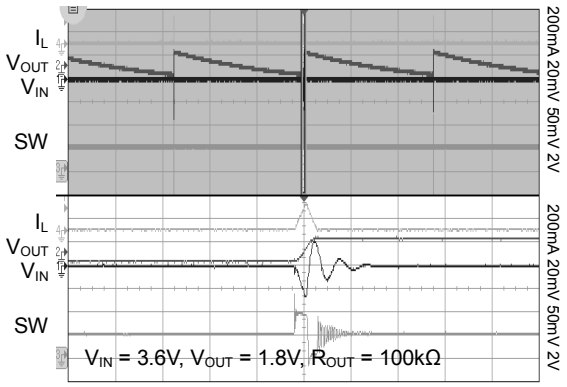
T_A = +25℃, unless otherwise noted.

Steady State Operation



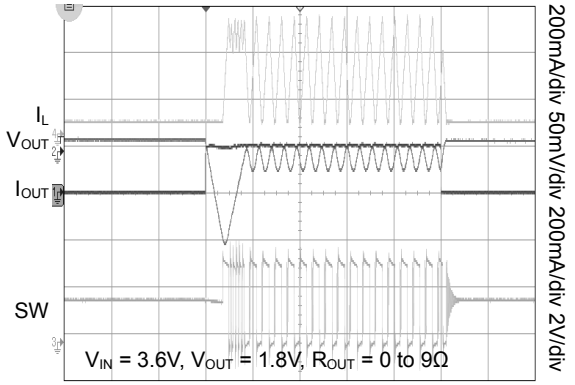
Time (5μs/div)

Steady State Operation



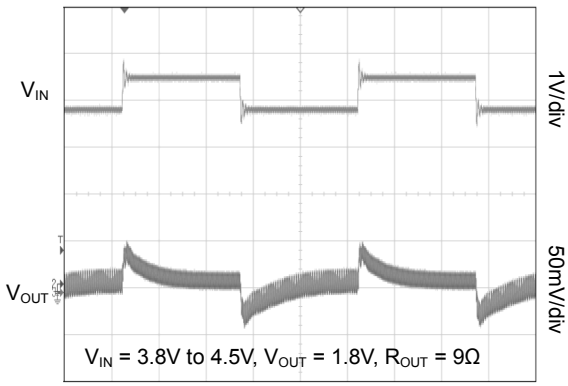
Time (5ms/div)

Load Transient



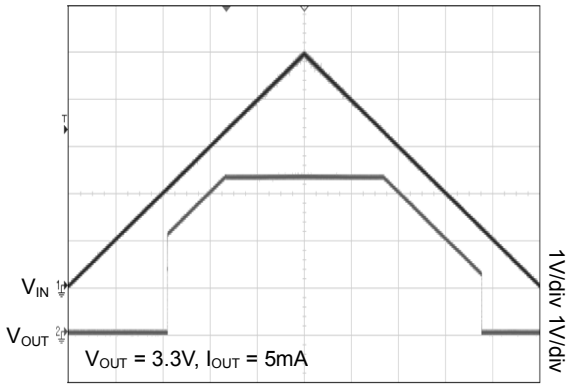
Time (20μs/div)

Line Transient



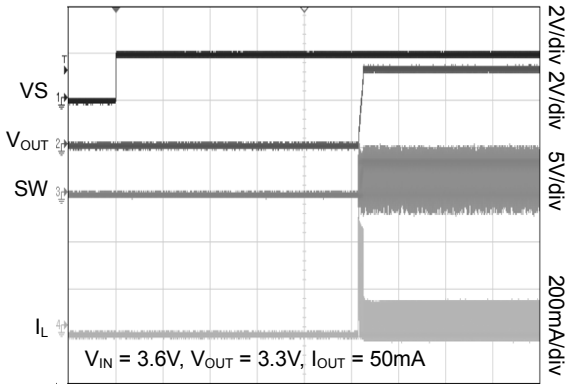
Time (200μs/div)

Power Management Response



Time (100ms/div)

Startup Behavior

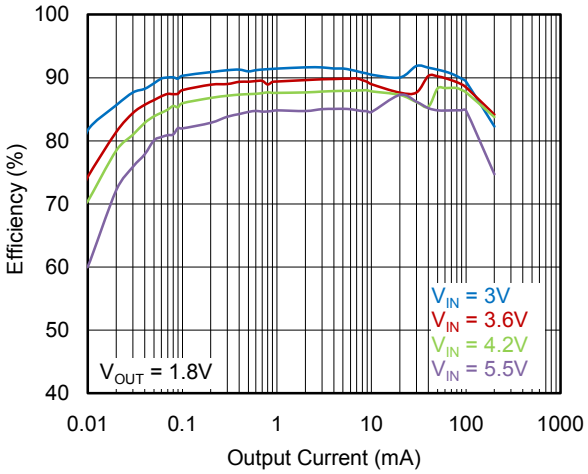


Time (5ms/div)

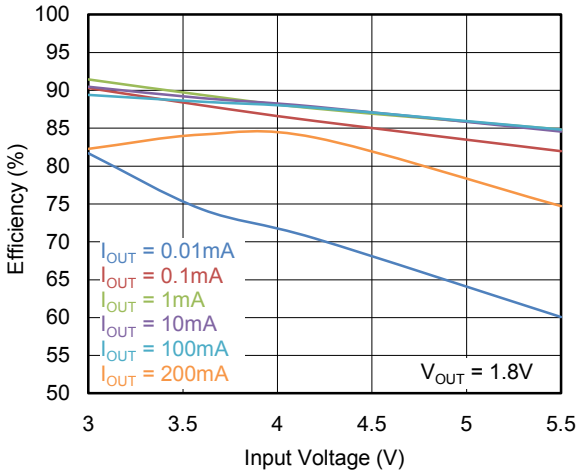
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, unless otherwise noted.

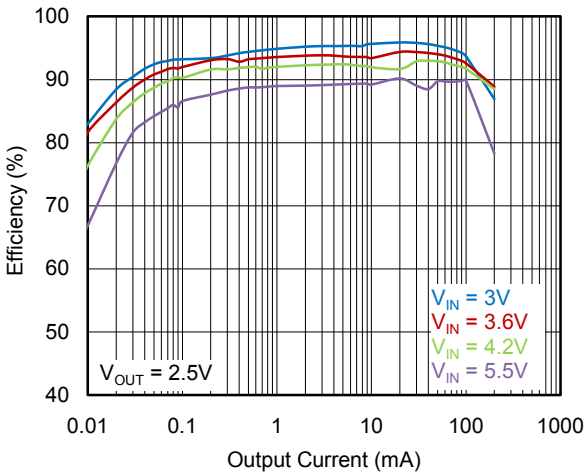
Efficiency vs. Output Current



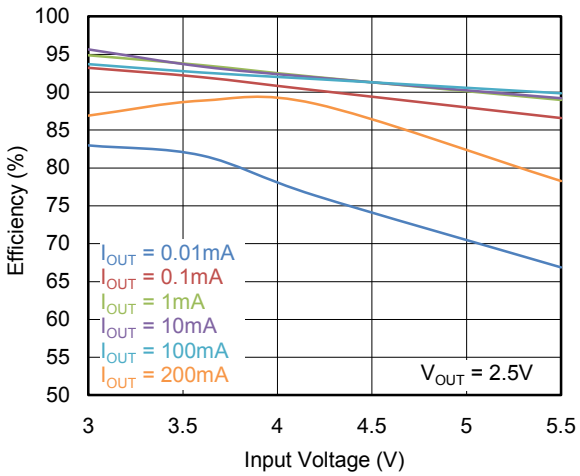
Efficiency vs. Input Voltage



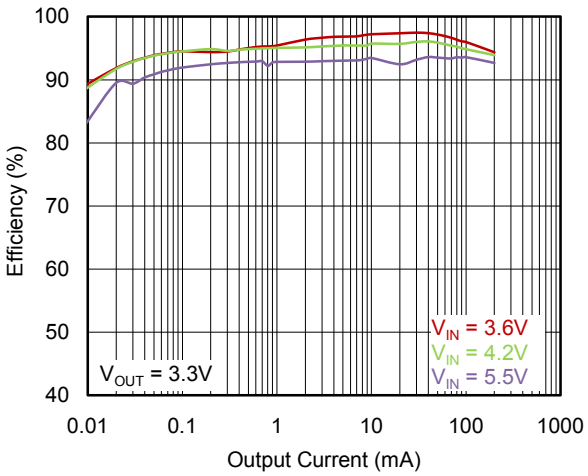
Efficiency vs. Output Current



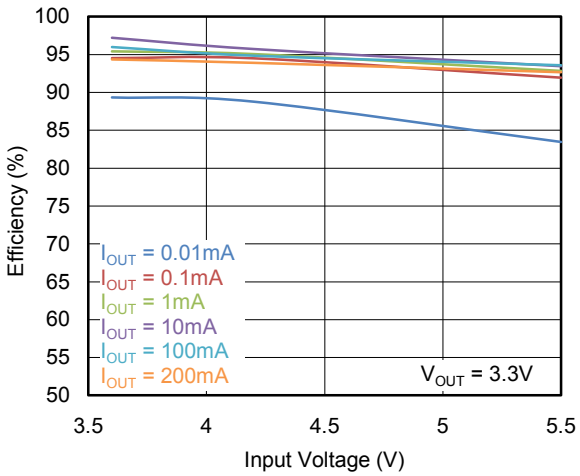
Efficiency vs. Input Voltage



Efficiency vs. Output Current



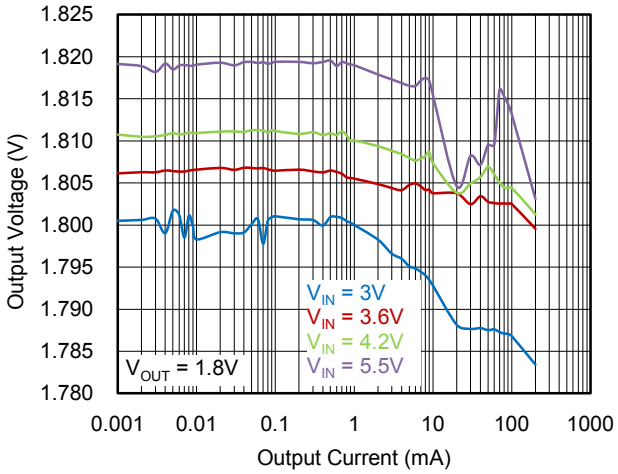
Efficiency vs. Input Voltage



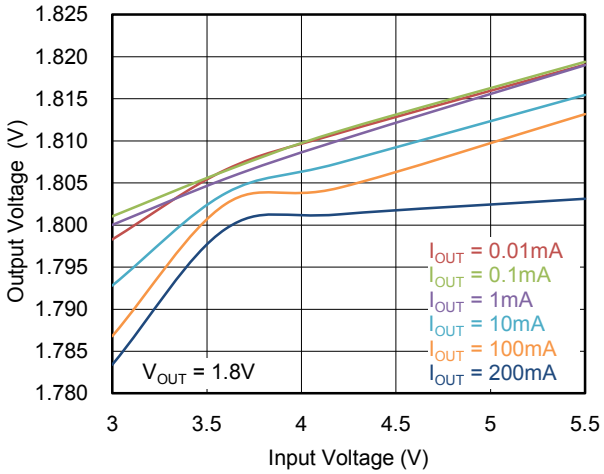
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, unless otherwise noted.

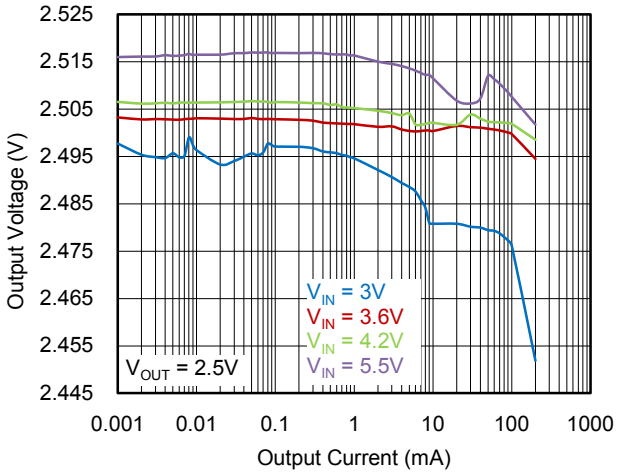
Output Voltage vs. Output Current



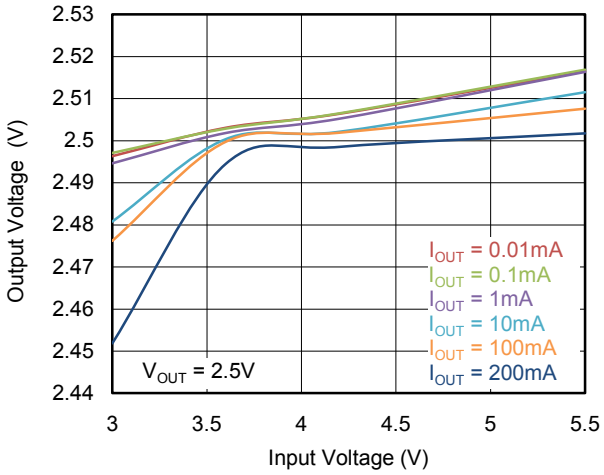
Output Voltage vs. Input Voltage



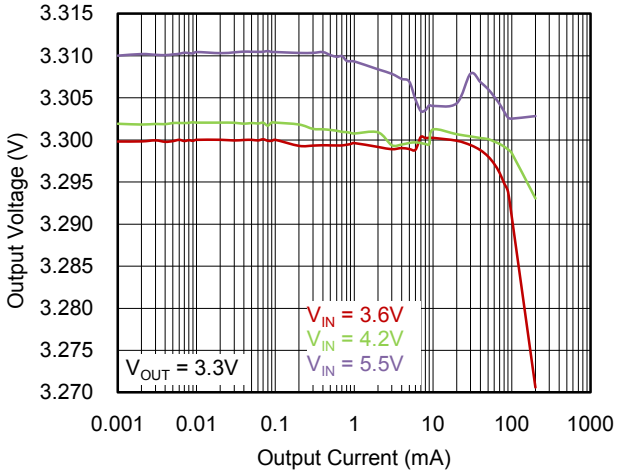
Output Voltage vs. Output Current



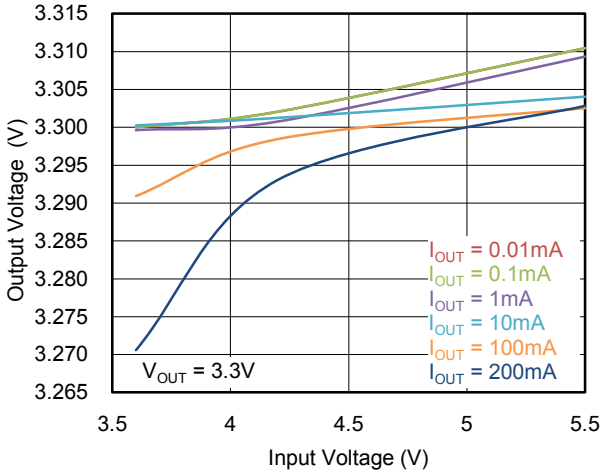
Output Voltage vs. Input Voltage



Output Voltage vs. Output Current



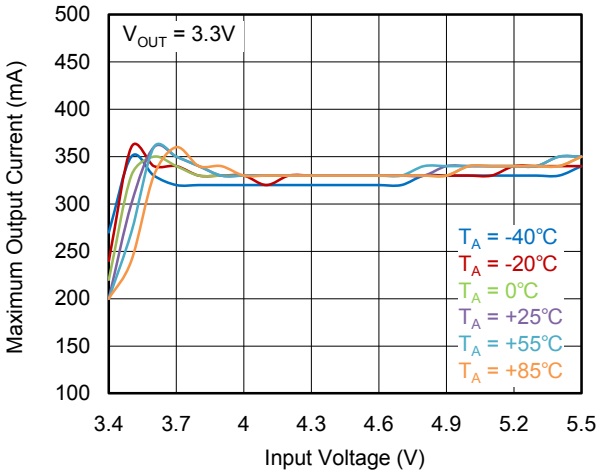
Output Voltage vs. Input Voltage



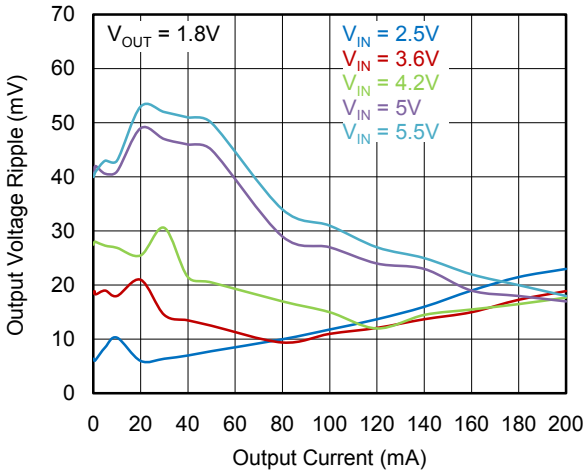
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, unless otherwise noted.

Maximum Output Current vs. Input Voltage



Output Voltage Ripple vs. Output Current



FUNCTIONAL BLOCK DIAGRAM

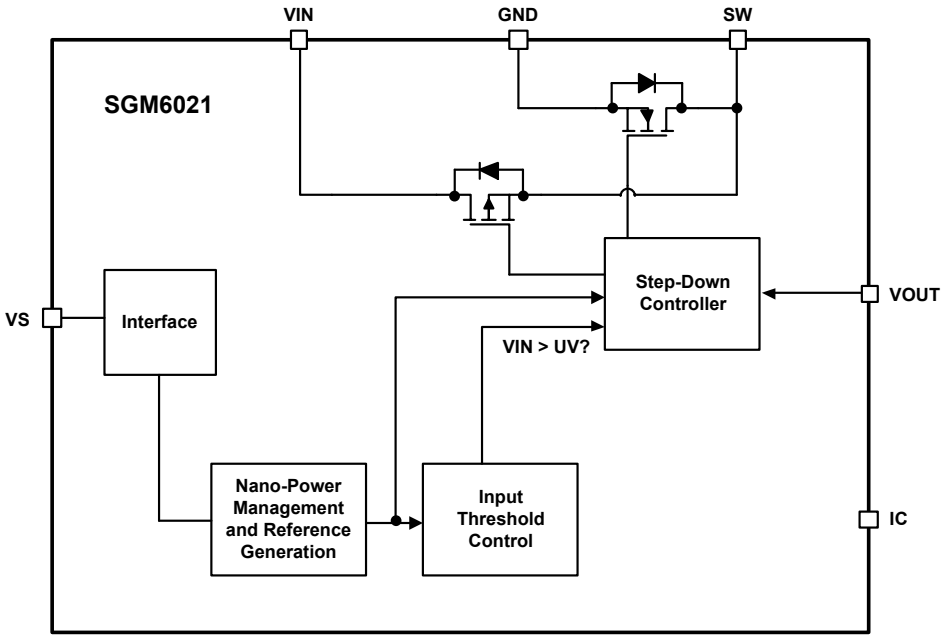


Figure 2. Block Diagram

OPERATION DESCRIPTION

The SGM6021 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 SGM6021 family provides the system with an externally programmable regulated supply in order to preserve the overall efficiency of the power-management stage compared to a linear step-down converter. 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 10μA) to high currents (200mA).

The SGM6021 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 SGM6021 family takes input power from VIN, steps it down and provides a regulated voltage at the VOUT pin. It employs pulse frequency modulation (PFM) control to regulate the voltage close to the desired reference voltage. The reference voltage is set by VS pin. 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 SGM6021 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 VIN 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} × $R_{DS(ON)-HS}$). 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 VS pin for systems that desire to turn off the regulated output.

OPERATION DESCRIPTION (continued)

Effective Pulse at VS Pin

A pulse with width less than t_{PULSE} is treated as an effective pulse. Consecutive pulses will be counted if delay between adjacent pulses is within the t_{STOP}. Please refer to Figure 3 for a graphical explanation.

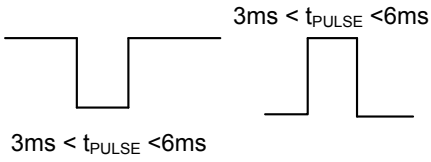


Figure 3. Effective Pulse at VS Pin

VS Pin Interface Functions

In order to enable the IC from shutdown mode, two conditions must be met:

1. VIN voltage is higher than UVLO threshold.

2. VS pin is floating or VS pin stays logic high for at least t_{BLANK} + t_{SS} time.

After that, the pulses at VS pin become effective and can be used to shut down the IC or program the output voltage. The following are the three cases that the VS pin affects the regulator:

1. 1 pulse followed by VS pin being low for longer than t_{OFF} will shut down the regulator.

During the $t_{OFF-HOLD}$ time after shutdown, the pulses applied to VS Pin are ignored.

To restart the regulator, the VS pin must be pulled high for at least t_{SS} time.

2. 2~5 pulses followed by VS pin being high for longer than t_{OFF} will set the output voltage to the default, V1, V2 and V3 respectively.

3. 2 or more pulses followed by VS pin being low for longer than t_{OFF} will set the output voltage to the default value.

Other pulse patterns will have no effects on the IC.

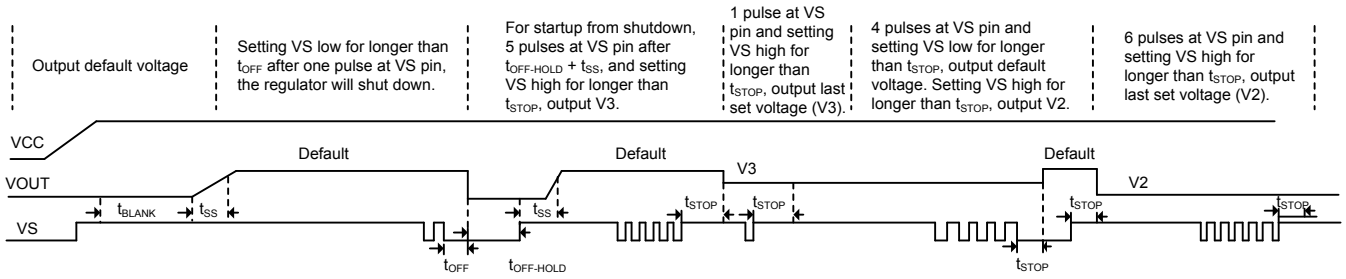


Figure 4. Program Output Voltage via VS Pin

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.

Thermal Shutdown (TSD)

A thermal shutdown function is implemented to prevent damage caused by excessive heat and power dissipation. Once a temperature of typically +160°C is exceeded, the device is shut down. The device is released from shutdown automatically when the junction temperature decreases by +20°C.

OPERATION DESCRIPTION (continued)

Nano-Power Management and Efficiency

The high efficiency of the SGM6021 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 SGM6021 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 SGM6021 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.

Detailed Design Procedure

The recommended 10μH inductor (Toko DFE2520- 12C) 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 ΔV_{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 10μH ±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
10	2.0 × 2.5 × 1.2	DFE252012C-H-100M	Toko
10	4.0 × 4.0 × 1.7	LPS4018-103M	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.

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.

REVISION HISTORY

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

AUGUST 2017 – REV.A to REV.A.1

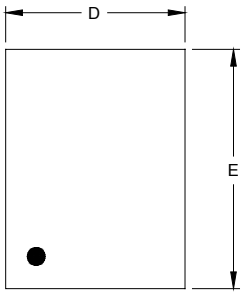
Changed SGM6021-4 STATUS from PREVIEW to ACTIVE 2

Changes from Original (JUNE 2017) to REV.A

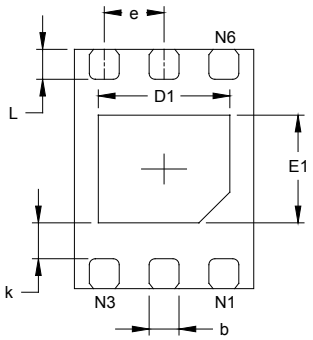
Changed from product preview to production data ..... All

PACKAGE OUTLINE DIMENSIONS

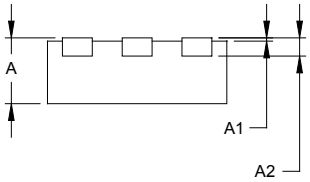
UTDFN-1.5×2-6L



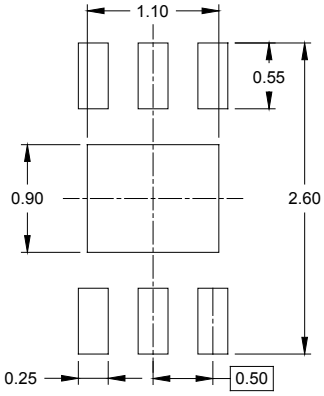
TOP VIEW



BOTTOM VIEW



SIDE VIEW

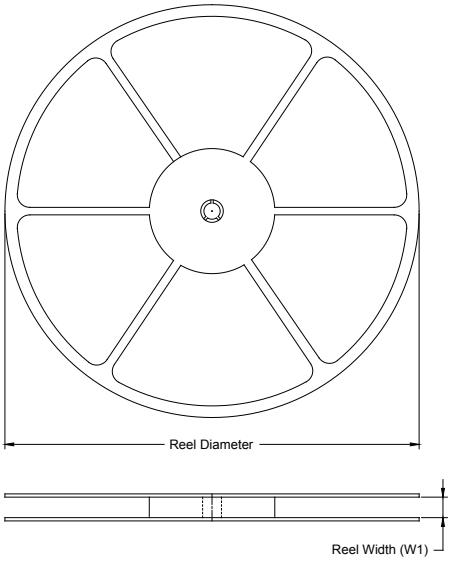


RECOMMENDED LAND PATTERN (Unit: mm)

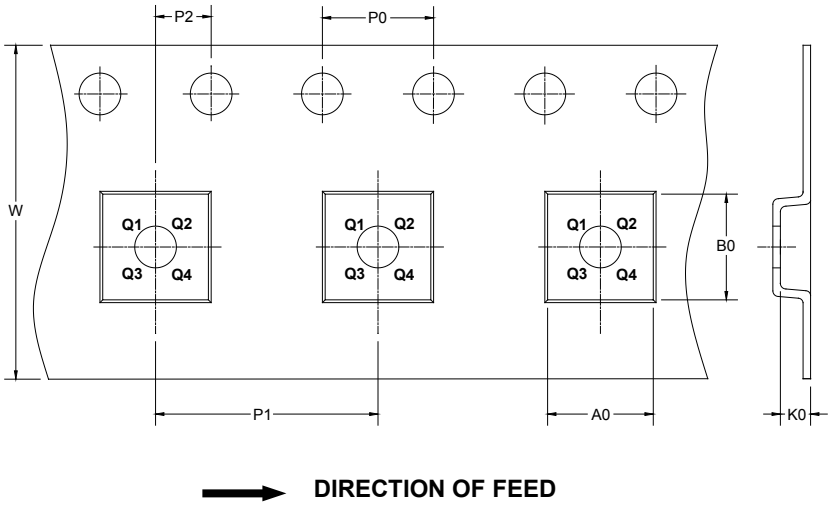
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.500	0.600	0.020	0.024
A1	0.000	0.050	0.000	0.002
A2	0.152 REF		0.006 REF	
D	1.400	1.600	0.055	0.063
D1	1.000	1.200	0.039	0.047
E	1.900	2.100	0.075	0.083
E1	0.800	1.000	0.031	0.039
k	0.300 REF		0.012 REF	
b	0.200	0.300	0.008	0.012
e	0.500 BSC		0.020 BSC	
L	0.200	0.300	0.008	0.012

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



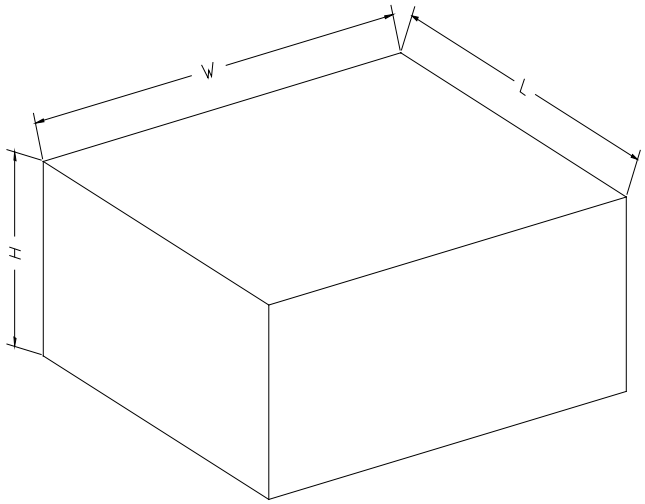
NOTE: The picture is only for reference. Please make the object as the standard.

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
UTDFN-1.5×2-6L	7″	9.5	1.70	2.30	0.75	4.0	4.0	2.0	8.0	Q2

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