SGM6607
# 1.2A High Voltage Boost Converter in Small Packages

GENERAL DESCRIPTION

The SGM6607 is a monolithic high voltage switching regulator with integrated 1.2A, 40V power MOSFET. It can be configured in several standard switching-regulator topologies, including boost and SEPIC converter. The device has a wide input voltage range to support applications with input voltage from multi-cell batteries or regulated 5V, 12V power rails.

The SGM6607 uses a 1.2MHz switching frequency, allowing the use low-profile inductors and low-value ceramic input and output capacitors. The external loop compensation gives the user flexibility to optimize loop compensation and transient response. The device has built-in protection features, such as cycle-by-cycle over-current limit, output OVP, soft-start and thermal shutdown.

The SGM6607 is available in Green TDFN-2×2-6L and TSOT-23-6 packages and is rated over the -40℃ to +85℃ temperature range.
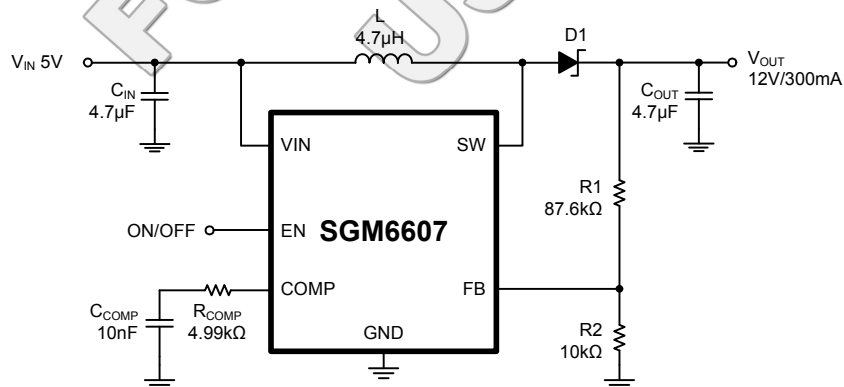
FEATURES

- 3V to 20V Input Voltage Range
- High Output Voltage: Up to 38V
- 41V Over-Voltage Protection
- 1.2A Integrated Switch
- 1.2MHz Fixed Switching Frequency
- 12V at 300mA and 24V at 150mA from 5V Input (TYP)
- Up to 93% Efficiency
- Skip-Switching for Light Load
- Built-In Soft-Start Function
- 500kΩ Pull-Down Resistor on EN Pin
- -40℃ to +85℃ Operating Temperature Range
- Available in Green TDFN-2×2-6L and TSOT-23-6 Packages
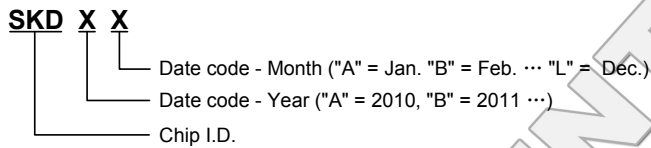
APPLICATIONS

Cell Phones
Portable Equipment

TYPICAL APPLICATION

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKAGE OPTION
SGM6607	TDFN-2×2-6L	-40℃ to +85℃	SGM6607YTDI6G/TR	6607 XXXX	Tape and Reel, 3000
	TSOT-23-6	-40℃ to +85℃	SGM6607YTN6G/TR	SKDXX	Tape and Reel, 3000

NOTE: **XX** = Date Code. **XXXX** = Date Code.

MARKING INFORMATION

SKD X X

— Date code - Month ("A" = Jan. "B" = Feb. ··· "L" = Dec.)
— Date code - Year ("A" = 2010, "B" = 2011 ···)
— Chip I.D.

For example: SKDCD (2012, April)

ABSOLUTE MAXIMUM RATINGS

Supply Voltage on VIN…....................................-0.3V to 20V
Voltage on EN….. -0.3V to 5V
Voltages on FB and COMP.................................. -0.3V to 3V
Voltage on SW..-0.3V to 40V
Operating Temperature Range........................ -40℃ to +85℃
Junction Temperature... 150℃
Storage Temperature Range............................-65℃ to +150℃
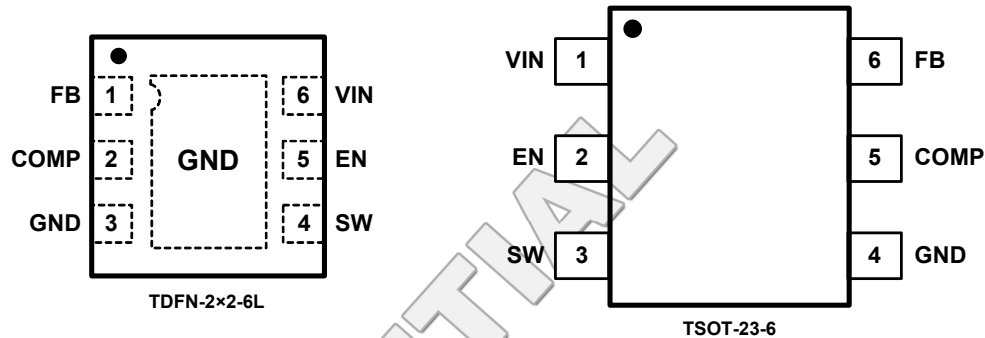Lead Temperature (Soldering, 10s) .... 260℃

NOTE:
Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

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.

SGMICRO reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time. Please contact SGMICRO sales office to get the latest datasheet.

PIN CONFIGURATIONS (TOP VIEW)

TDFN-2×2-6L
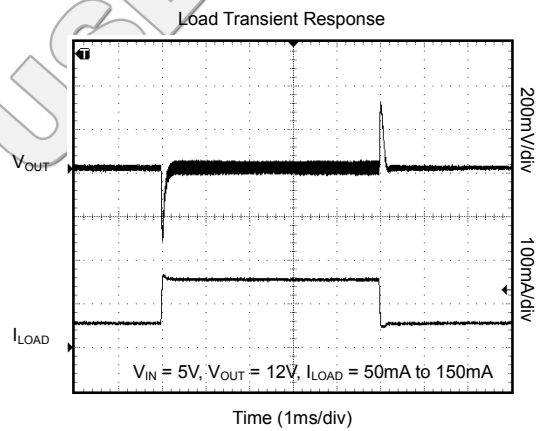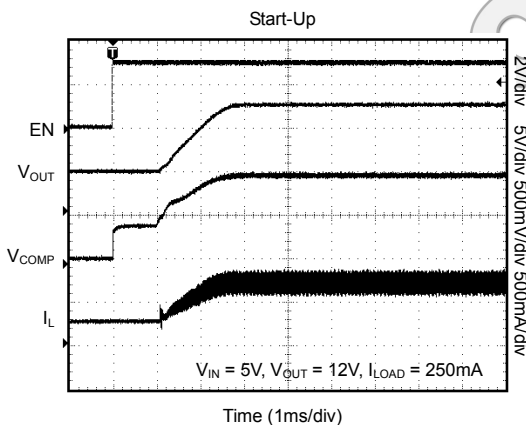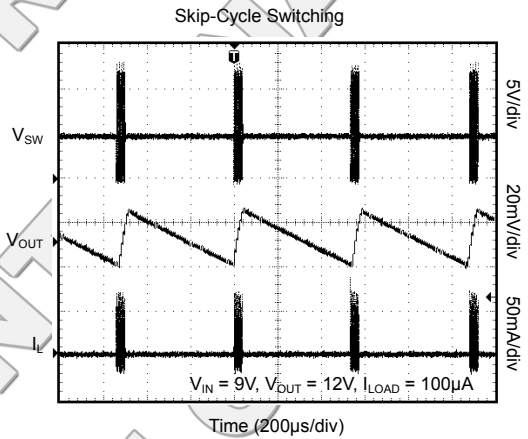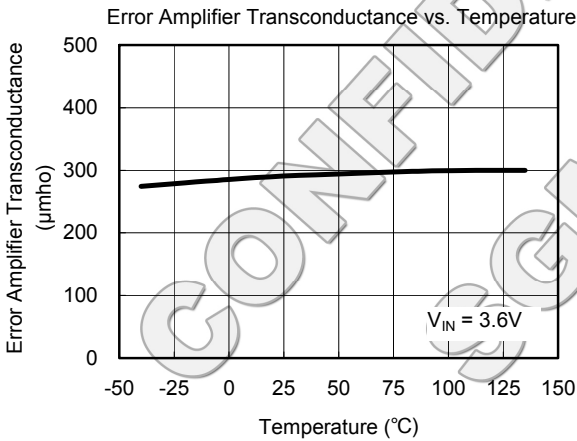

TSOT-23-6

PIN DESCRIPTION

PIN		NAME	I/O	FUNCTION
TDFN-2×2-6L	TSOT-23-6			
6	1	VIN	I	The Input Supply Pin for the IC. Connect VIN to a supply voltage between 3V and 20V.
4	3	SW	I	Switching Node of the IC. Connect SW to the switched side of the inductor.
3	4	GND	O	Ground.
1	6	FB	I	Feedback Pin for Current. Connect to the center tap of a resistor divider to program the output voltage.
2	5	COMP	O	Output of the Transconductance Error Amplifier. Connect an external RC network to this pin to compensate the regulator.
5	2	EN	I	Enable Pin of the Boost Regulator. Logic low disables the chip. Logic high enables the chip.
GND	—	Thermal Pad	—	The thermal pad should be soldered to the analog ground plane to avoid thermal issue. If possible, use thermal via to connect to ground plane for ideal power dissipation.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, EN = V_{IN}, T_A = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
SUPPLY CURRENT						
Input Voltage Range	V_{IN}		3		20	V
Operating Quiescent Current into VIN	I_Q	Device PWM switching no load		400		µA
Shutdown Current	I_{SD}	EN = GND, V_{IN} = 4.2V		0.3		µA
Under-Voltage Lockout Threshold	UVLO	V_{IN} falling		2.2		V
Under-Voltage Lockout Hysteresis	V_{HYS}			70		mV
ENABLE AND REFERENCE CONTROL						
EN Logic High Voltage	V_{ENH}	V_{IN} = 3V to 20V	1.5			V
EN Logic Low Voltage	V_{ENL}	V_{IN} = 3V to 20V			0.3	V
EN Pull-Down Resistor	R_{EN}			500		kΩ
VOLTAGE AND CURRENT CONTROL						
Voltage Feedback Regulation Voltage	V_{REF}			1.223		V
Voltage Feedback Input Bias Current	I_{FB}	V_{FB} = 1.3V		10		nA
Oscillator Frequency	f_S			1.2		MHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 1.1V		94		%
Minimum ON Pulse Width	t_{MIN_ON}			80		ns
COMP Pin Sink Current	I_{SINK}			55		µA
COMP Pin Source Current	I_{SOURCE}			55		µA
Error Amplifier Transconductance	G_{EA}			290		µmho
POWER SWITCH						
N-Channel MOSFET On-Resistance	$R_{DS(ON)}$	V_{IN} = 3.6V		0.36		Ω
		V_{IN} = 3.0V		0.4		
N-Channel Leakage Current	I_{LN_NFET}	V_{SW} = 35V, EN = GND, T_A = 25℃		0.01		µA
OC AND SS						
N-Channel MOSFET Current Limit	I_{LIM}			1.2		A
V_{REF} Ramp Up Time	t_{STEP}			2		ms
THERMAL SHUTDOWN						
Thermal Shutdown Threshold	T_{SHDN}			150		℃
Thermal Shutdown Threshold Hysteresis	T_{HYS}			25		℃

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, L = 10μH, D1 = ONsemi MBR0540T1, unless otherwise noted.

Efficiency vs. Output Current

Efficiency vs. Output Current

Error Amplifier Transconductance vs. Temperature

Skip-Cycle Switching

Start-Up

Load Transient Response

TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, L = 10µH, D1 = ONsemi MBR0540T1, unless otherwise noted.

PWM Switching Operation

V_{SW}

V_{OUT}

I_L

5V/div

100mV/div

500mA/div

V_{IN} = 5V, V_{OUT} = 12V, I_{LOAD} = 250mA

Time (400ns/div)
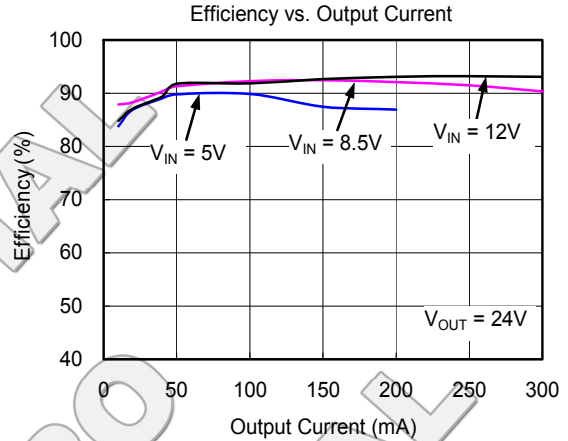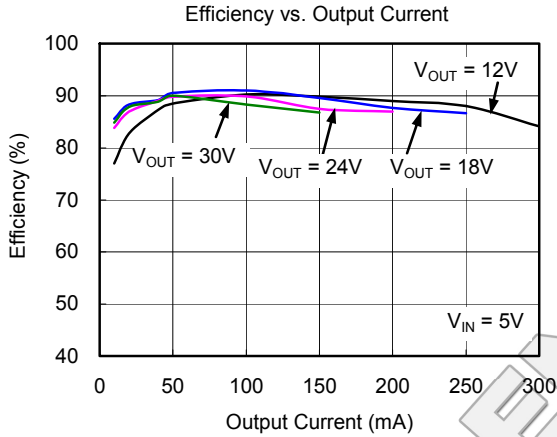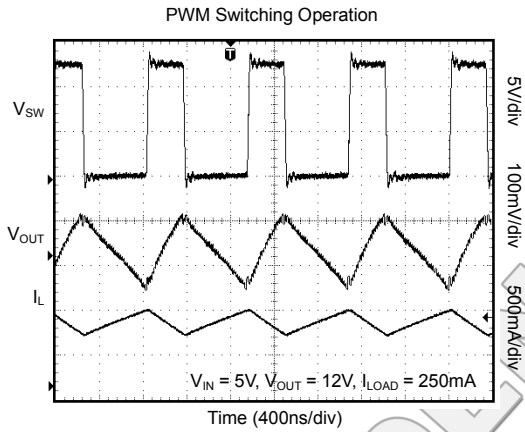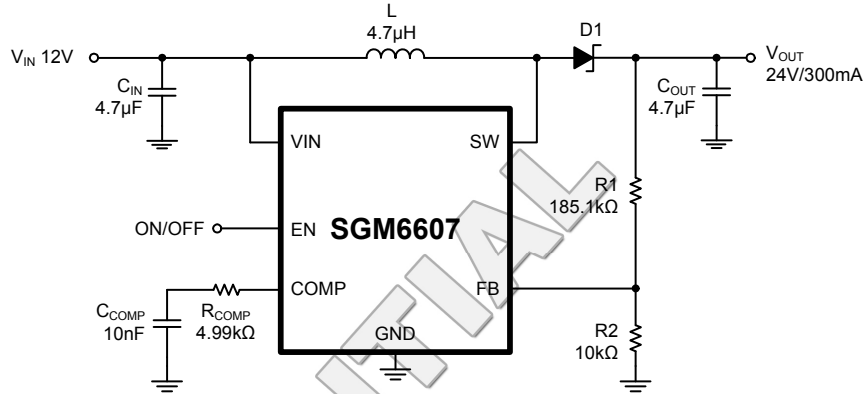
TYPICAL APPLICATIONS

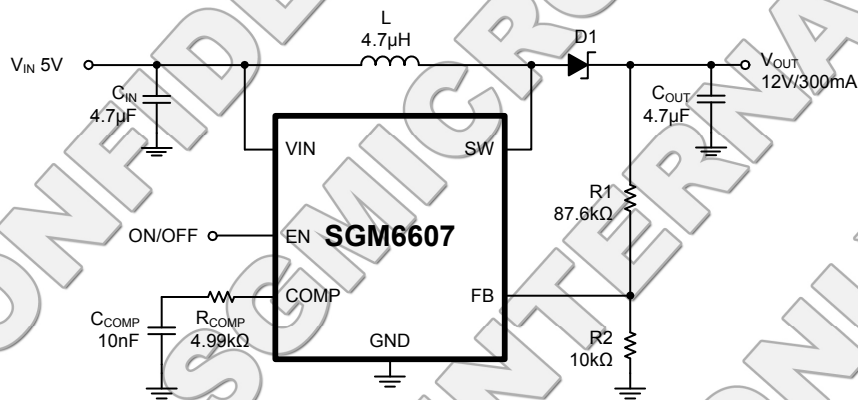Figure 1. 12V to 24V DC/DC Power Conversion

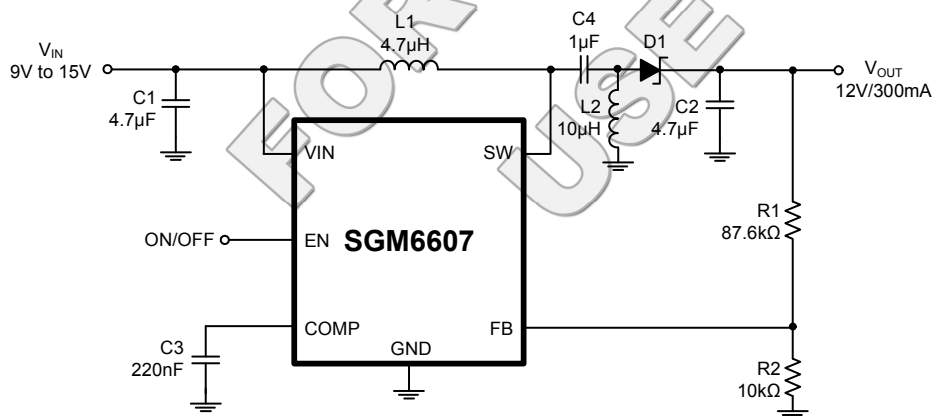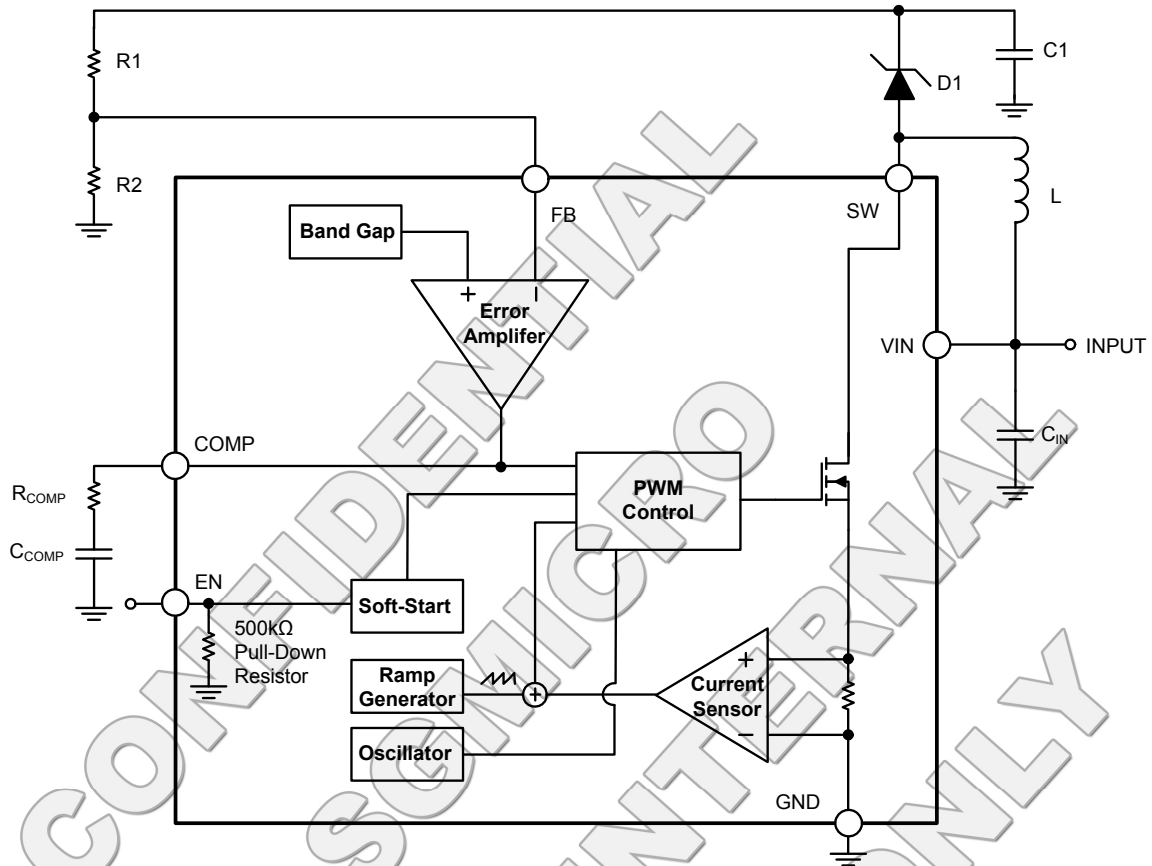Figure 2. 5V to 12V DC/DC Power Conversion

Figure 3. 12V SEPIC (Buck-Boost) Converter

FUNCTIONAL BLOCK DIAGRAM

DETAILED DESCRIPTION

Operation

The SGM6607 integrates a 40V low-side FET for up to 38V output voltages. The device regulates the output with current mode PWM (pulse width modulation) control. The switching frequency of PWM is fixed at 1.2MHz. The PWM control circuitry turns on the switch at the beginning of each switching cycle. The input voltage is applied across the inductor and stores the energy as inductor current ramps up. During this portion of the switching cycle, the load current is provided by the output capacitor. When the inductor current rises to the threshold set by the error amplifier output, the power switch turns off and the external Schottky diode is forward biased. The inductor transfers stored energy to replenish the output capacitor and supply the load current. This operation repeats in every switching cycle. As shown in the block diagram, the duty cycle of the converter is determined by the PWM control comparator which compares the error amplifier output and the current signal.

A ramp signal from oscillator is added to the current ramp. This slope compensation is to avoid sub-harmonic oscillation that is intrinsic to the current mode control at duty cycle higher than 40%. The feedback loop regulates the FB pin to a reference voltage through an error amplifier. The output of the error amplifier is connected to the COMP pin. An external RC compensation network is connected to the COMP pin to optimize the feedback loop for stability and transient response.

Soft-Start

Soft-start circuitry is integrated into the IC to avoid a high inrush current during start-up. After the device is enabled by a logic high signal on the EN pin, the FB pin reference voltage ramps up to 1.223V with about 2ms. This ensures that the output voltage rises slowly to reduce inrush current.

Over-Current Protection

SGM6607 has a cycle-by-cycle over-current limit feature that turns off the power switch once the inductor current reaches the over-current limit. The PWM circuitry resets itself at the beginning of the next switch cycle. During an over-current event, this results in a decrease of output voltage with respect to load. The current limit threshold as well as input voltage, output voltage, switching

frequency and inductor value determine the maximum available output current. Larger inductor values increases the current output capability because of the reduced current ripple. See the application information section for the output current calculation.

Under-Voltage Lockout (UVLO)

An under-voltage lockout prevents mis-operation of the device at input voltages below typical 2.2V. When the input voltage is below the under-voltage threshold, the device remains off and the internal switch FET is turned off. The under-voltage lockout threshold is set below minimum operating voltage of 3V to avoid any transient V_{IN} dip triggering the UVLO and causing the device to reset. For the input voltages between UVLO threshold and 3V, the device maintains its operation, but the specifications are not ensured.

Over-Voltage Protection (OVP)

Over-voltage protection circuitry prevents IC damage as the result of output resistor divider disconnection. The SGM6607 monitors the voltage at the SW pin during each switching cycle. The circuitry turns off the switch FET and shuts down the IC when the following condition persists for 8 switching clock cycles: the SW voltage exceeds the V_{OVP} threshold. As a result, the output voltage falls to the level of the input supply. The device remains in shutdown mode until it is enabled by toggling the EN pin logic. The V_{OVP} threshold of SGM6607 is set at 41V.

Thermal Shutdown

An internal thermal shutdown turns off the device when the typical junction temperature of 150℃ is exceeded. The IC restarts when the junction temperature drops by 25℃.

Enable and Shutdown

The SGM6607 enters shutdown when the EN pin voltage is less than 0.3V. In shutdown, the input supply current for the device is less than 1μA (MAX). The EN pin has an internal 500kΩ pull-down resistor to disable the device when the pin is left unconnected.

APPLICATION INFORMATION

Program Output Voltage

To program the output voltage, select the values of R1 and R2 (see Figure 4) according to Equation 1.

$$V_{OUT} = 1.223V \times \left(\frac{R1}{R2} + 1 \right)$$

$$R1 = R2 \times \left(\frac{V_{OUT}}{1.223V} - 1 \right) \quad (1)$$

Considering the leakage current through the resistor divider and noise decoupling to FB pin, an optimum value for R2 is around 10kΩ. The output voltage tolerance depends on the V_{FB} accuracy and the tolerance of R1 and R2.
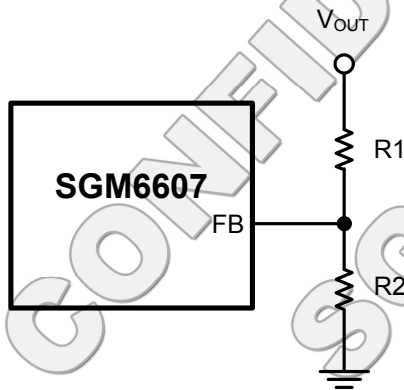

Figure 4. Program Output Voltage

Maximum Output Current

The over-current limit in a boost converter limits the maximum input current, and thus the maximum input power for a given input voltage. The maximum output power is less than the maximum input power due to power conversion losses. Therefore, the current-limit setting, input voltage, output voltage and efficiency can all affect the maximum output current. The current limit clamps the peak inductor current; therefore, the ripple must be subtracted to derive the maximum DC current. The ripple current is a function of the switching frequency, inductor value and duty cycle. The following equations take into account of all the above factors for maximum output current calculation.

$$I_P = \frac{1}{\left[L \times f_S \times \left(\frac{1}{V_{OUT} + V_F - V_{IN}} + \frac{1}{V_{IN}} \right) \right]} \quad (2)$$

Where:
I_P = Inductor peak to peak ripple
L = Inductor value
V_F = Schottky diode forward voltage
f_S = Switching frequency
V_{OUT} = Output voltage

$$I_{OUT\_MAX} = \frac{V_{IN} \times \left(I_{LIM} - \frac{I_P}{2} \right) \times \eta}{V_{OUT}} \quad (3)$$

Where:
I_{OUT_MAX} = Maximum output current of the boost converter
I_{LIM} = Over-current limit
η = Efficiency

For instance, when V_{IN} is 5V, V_{OUT} is 12V, the inductor is 10µH, the Schottky forward voltage is 0.2V; and then the maximum output current is 300mA in typical operation.

Switch Duty Cycle

The maximum switch duty cycle (D) of the SGM6607 is 94% (TYP). The duty cycle of a boost converter under continuous conduction mode (CCM) is given by:

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} \quad (4)$$

For a 5V to 12V application, the duty cycle is 58.3%, and for a 5V to 24V application, the duty cycle is 79.2%. The duty cycle must be lower than the maximum specification of 90% in the application; otherwise, the output voltage can not be regulated.

Once the PWM switch is turned on, the SGM6607 has minimum ON pulse width. This sets the limit of the minimum duty cycle. For operating low duty cycle, the SGM6607 enters pulse-skipping mode. In this mode, the device keeps the power switch off for several switching cycles to keep the output voltage in regulation. This operation typically occurs in light load condition when the PWM operates in discontinuous mode.

APPLICATION INFORMATION

Inductor Selection

The selection of the inductor affects steady state operation as well as transient behavior and loop stability. These factors make it the most important component in power regulator design. There are three important inductor specifications, inductor value, DC resistance and saturation current. Considering inductor value alone is not enough.

The inductor's value determines the inductor ripple current. It is recommended that the peak-to-peak ripple current given by Equation 2 be set to 30% - 40% of the DC current. Also, the inductor value should not be beyond the range in the recommended operating conditions table. It is a good compromise of power losses and inductor size. Inductor DC current can be calculated as

$$I_{IN\_DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \qquad (5)$$

Inductor values can have ±20% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the 0A value depending on how the inductor vendor defines saturation current. Using an inductor with a smaller inductance value forces discontinuous PWM where the inductor current ramps down to zero before the end of each switching cycle. This reduces the boost converter's maximum output current, causes large input voltage ripple and reduces efficiency. In general, large inductance value provides much more output and higher conversion efficiency. Small inductance value can give better the load transient response. For these reasons, a 6.8µH to 22µH inductor value range is recommended.

SGM6607 has built-in slope compensation to avoid sub-harmonic oscillation associated with current mode control. If the inductor value is lower than 6.8µH, the slope compensation may not be adequate, and the loop can be unstable. Therefore, customers need to verify the inductor in their application if it is different from the recommended values.

Compensation Capacitor Selection

The SGM6607 has an external compensation, COMP pin, which allows the loop response to be optimized for each application. The COMP pin is the output of the internal error amplifier. An external resistor R_{COMP} and ceramic capacitor C_{COMP} are connected to COMP pin to provide a pole and a zero. This pole and zero, along with the inherent pole an zero in a current mode control boost converter, determine the close loop frequency response. This is important to a converter stability and transient response.

The following equations summarize the poles, zeros and DC gain in SGM6607, as shown in the block diagram. They include the dominant pole (f_{P1}), the output pole (f_{P2}) of a boost converter, the right-half-plane zero (f_{RHPZ}) of a boost converter, the zero (f_Z) generated by R_{COMP} and C_{COMP} and the DC gain (A).

$$f_{P1} = \frac{1}{2\pi \times 140M\Omega \times C_{COMP}} \qquad (6)$$

$$f_{P2} = \frac{2}{2\pi \times R_{OUT} \times C_{OUT}} \qquad (7)$$

$$f_{RHPZ} = \frac{R_{OUT}}{2\pi \times L} \times \left(\frac{V_{IN}}{V_{OUT}}\right)^2 \qquad (8)$$

$$f_Z = \frac{1}{2\pi \times R_{COMP} \times C_{COMP}} \qquad (9)$$

$$A = \frac{1.223V}{V_{OUT}} \times G_{EA} \times 140M\Omega \times \frac{V_{IN}}{V_{OUT} \times R_{SENSE}} \times R_{OUT} \times \frac{1}{2} \qquad (10)$$

Where R_{OUT} is the load resistance, G_{EA} is the error amplifier transconductance located in the electrical characteristics table, R_{SENSE} (200mΩ) is a sense resistor in the current control loop. These equations helps generate a simple bode plot for SGM6607 loop analysis.

APPLICATION INFORMATION

Increasing R_{COMP} or reducing C_{COMP} increases the close loop bandwidth which improves the transient response. Adjusting R_{COMP} and C_{COMP} toward opposite direction increase the phase, and help loop stability. For most of the applications, the recommended value of 4.99kΩ and 10nF makes an ideal compromise between transient response and loop stability. To optimize the compensation, use C_{COMP} in the range of 1nF to 22nF, and R_{COMP} of 4.99kΩ.

Schottky Diode Selection

The high switching frequency of the SGM6607 demands a high-speed rectification for optimum efficiency. Ensure that the diode's average and peak current rating exceeds the average output current and peak inductor current. In addition, the diode's reverse breakdown voltage must exceed the switch FET rating voltage of 40V. However, Schottky diode of low rating voltage can be used for low output to save the solution size and cost. For example, 12V output with 20V diode is a good choice.

Input and Output Capacitor Selection

The output capacitor is mainly selected to meet the requirements for the output ripple and loop stability. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). Assuming a capacitor with zero ESR, the minimum capacitance needed for a given ripple can be calculated using Equation 11.

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \times I_{OUT}}{V_{OUT} \times f_S \times V_{RIPPLE}} \qquad (11)$$

Where, V_{RIPPLE} = peak-to-peak output ripple. The additional output ripple component caused by ESR is calculated using:

$$V_{RIPPLE\_ESR} = I_{OUT} \times R_{ESR}$$

Due to its low ESR, V_{RIPPLE_ESR} can be neglected for ceramic capacitors, but must be considered if tantalum or electrolytic capacitors are used.

Care must be taken when evaluating a ceramic capacitor's derating under DC bias, aging and AC signal. For example, larger form factor capacitors (in 1206 size) have a resonant frequency in the range of the switching frequency. So, the effective capacitance is significantly lower. The DC bias can also significantly reduce capacitance. Ceramic capacitors can loss as much as 50% of its capacitance at its rated voltage. Therefore, choose a ceramic capacitor with a voltage rating at least 1.5× its expected DC bias voltage.

The capacitor in the range of 1μF to 4.7μF is recommended for input side. The output requires a capacitor in the range of 1μF to 10μF. The output capacitor affects the loop stability of the boost regulator. If the output capacitor is below the range, the boost regulator can potentially become unstable.

Thermal Considerations

The maximum IC junction temperature should be restricted to 150℃ under normal operating conditions. This restriction limits the power dissipation of the SGM6607. Calculate the maximum allowable dissipation, $P_{D(MAX)}$, and keep the actual dissipation less than or equal to $P_{D(MAX)}$. The maximum-power-dissipation limit is determined using Equation 12:

$$P_{D(MAX)} = \frac{150℃ - T_A}{\theta_{JA}} \qquad (12)$$

Where, T_A is the maximum ambient temperature for the application. θ_{JA} is the package thermal resistance.

The SGM6607 comes in TDFN and TSOT packages. Compared with the TSOT package, the TDFN package has better heat dissipation. This package includes a thermal pad that improves the thermal capabilities of the package. The θ_{JA} of the TDFN package greatly depends on the PCB layout and thermal pad connection. The thermal pad must be soldered to the analog ground on the PCB. Using thermal vias underneath the thermal pad as illustrated in the layout example.
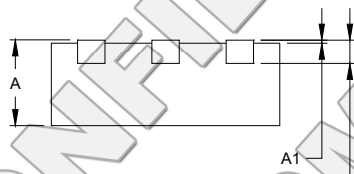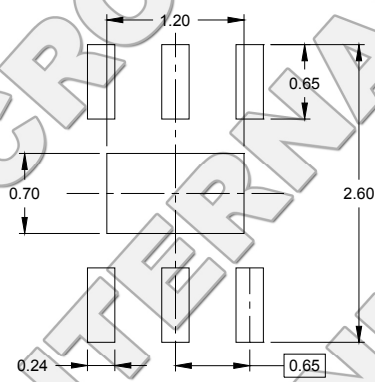
PACKAGE OUTLINE DIMENSIONS

TDFN-2×2-6L
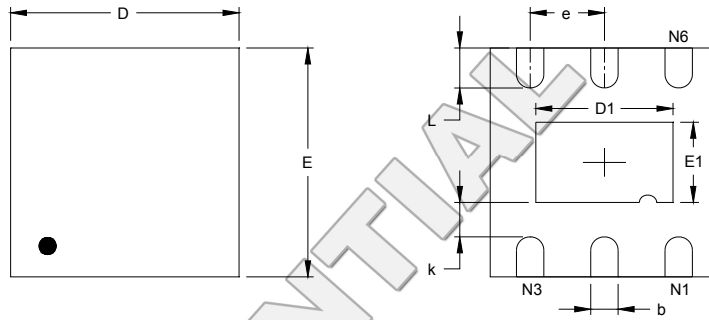
TOP VIEW

BOTTOM VIEW

SIDE VIEW

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	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	1.100	1.300	0.043	0.051
E	1.900	2.100	0.075	0.083
E1	0.600	0.800	0.024	0.031
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.650 TYP		0.026 TYP	
L	0.250	0.450	0.010	0.018

PACKAGE OUTLINE DIMENSIONS

TSOT-23-6

RECOMMENDED LAND PATTERN (Unit: mm)
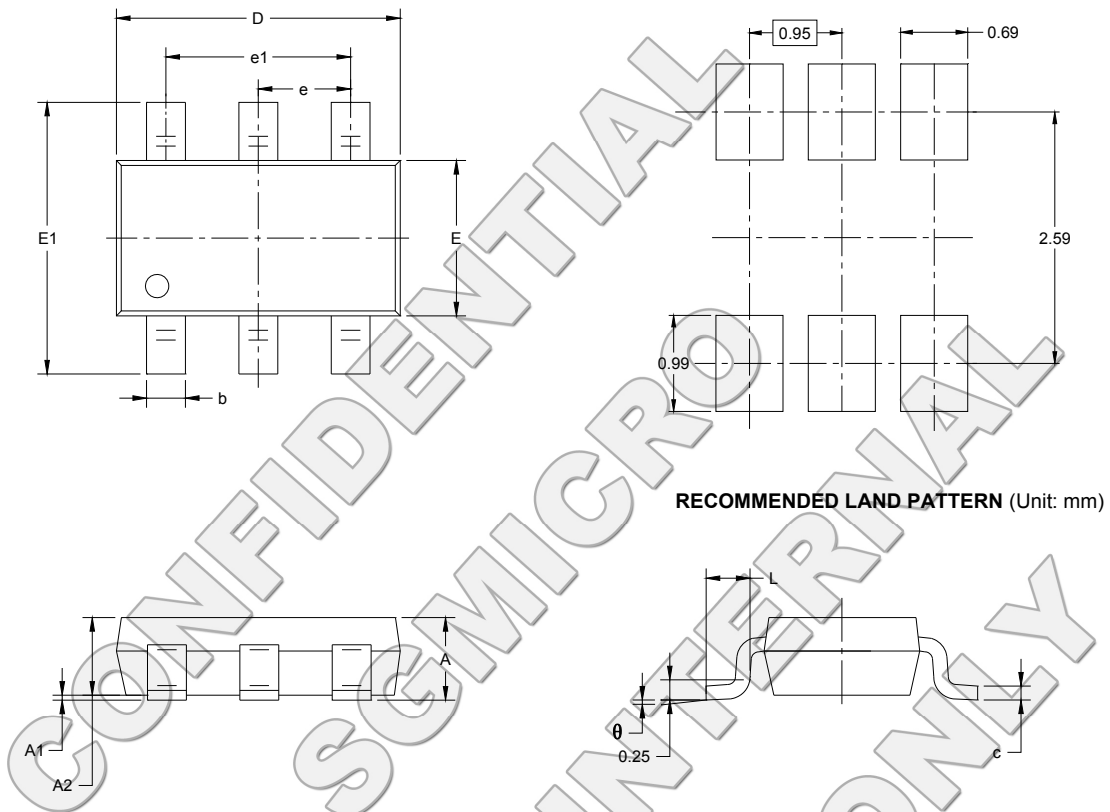
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	**MAX**	**MIN**	**MAX**
A	0.700	0.900	0.028	0.035
A1	0.000	0.100	0.000	0.004
A2	0.700	0.800	0.028	0.031
b	0.350	0.500	0.014	0.020
c	0.080	0.200	0.003	0.008
D	2.820	3.020	0.111	0.119
E	1.600	1.700	0.063	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 BSC	
e1	1.900 BSC		0.075 BSC	
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

TAPE AND REEL INFORMATION
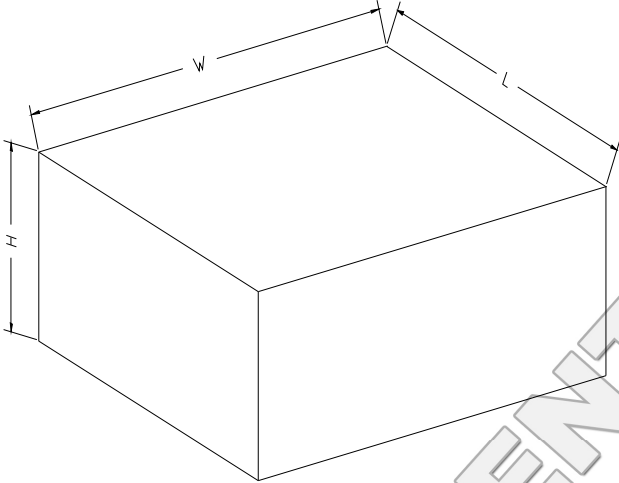
REEL DIMENSIONS

TAPE DIMENSIONS
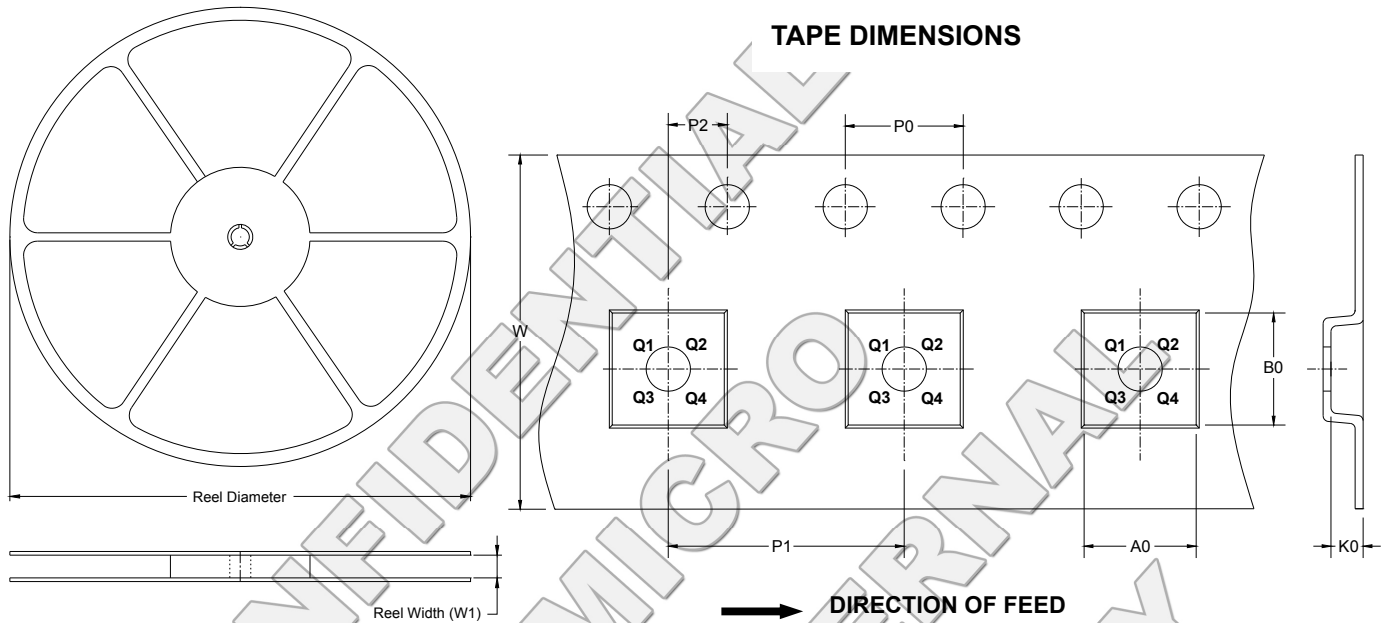
DIRECTION OF FEED

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
TDFN-2×2-6L	7″	9.5	2.30	2.30	1.10	4.00	4.00	2.00	8.00	Q1
TSOT-23-6	7″	9.5	3.2	3.1	1.1	4.0	4.0	2.0	8.0	Q3

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

REVISION HISTORY

VERSION	DATE	PAGE	LOCATION	REMARK