

GENERAL DESCRIPTION

The SGM6623 is a general-purpose miniature boost DC/DC switching regulator with high-efficiency for battery-backup and standby power systems. The acceptable input voltage range is between 0.8V and 12V that can be converted to a regulated 3.3V to 13V output voltage with efficiency as high as 90%. SGM6623 can be used as backup charger for systems with 1- to 4-cell batteries. It operates at a 600kHz nominal switching frequency, allowing the use of small and low-profile inductor for compact design. It also has several built-in protection features, such as cycle-by-cycle over-current limit, soft-start, thermal shutdown and open loop over-voltage protection.

The SGM6623 is available in a Green SOT-23-6 package.

FEATURES

- 0.8V to 12V Input Voltage Range
- 3.3V to 13V Wide Output Voltage Range
- 4.4A Current Limited Integrated Switch
- Up to 90% Efficiency
- 600kHz Nominal Fixed Switching Frequency with Pulse Skipping at Light Loads
- Built-In Soft-Start Function
- Open Loop Over-Voltage Protection
- Enable Input Pin
- 47µA Typical Quiescent Current (to VS Pin)
- 0.4µA Typical Supply Current in Shutdown
- Available in a Green SOT-23-6 Package

APPLICATIONS

- Cell Phones
- Portable Equipment
- Hand-Held Instruments
- 1-, 2-, 3- or 4-Cell Battery Systems

TYPICAL APPLICATION

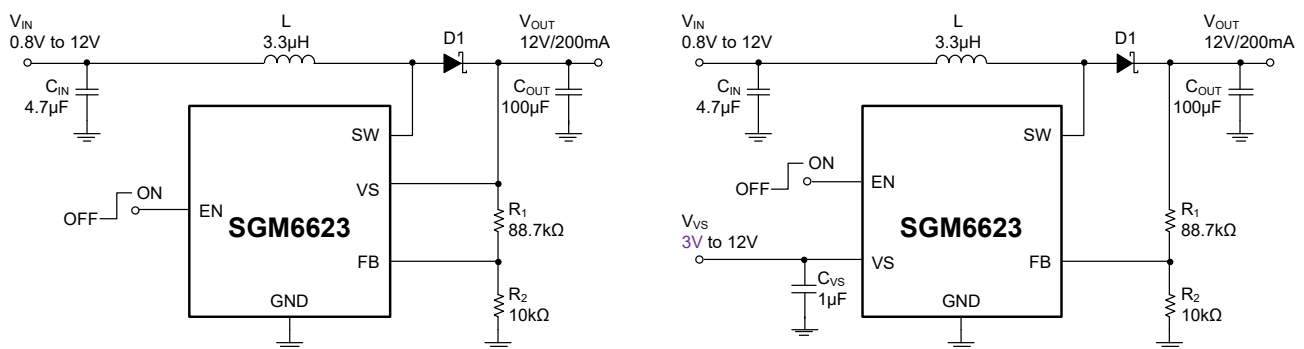


Figure 1. Typical Application Circuits

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM6623	SOT-23-6	-40°C to +85°C	SGM6623YN6G/TR	CB4XX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XX = Date Code.

YYY X X

└── Date Code - Week

└── Date Code - Year

└── Serial Number

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

- Voltages on EN and FB -0.3V to 6V
- Voltages on SW and VS -0.3V to 14.5V
- Package Thermal Resistance
- SOT-23-6, θ_{JA} 190°C/W
- Junction Temperature +150°C
- Storage Temperature Range..... -65°C to +150°C
- Lead Temperature (Soldering, 10s) +260°C
- ESD Susceptibility
- HBM..... 3000V
- CDM 1000V

RECOMMENDED OPERATING CONDITIONS

- 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.

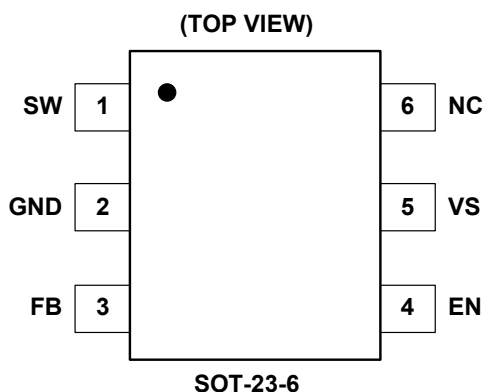
ESD SENSITIVITY CAUTION

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	I/O	FUNCTION
1	SW	I	Switching node of the IC. Connect to the input source through the boost inductor.
2	GND	O	Ground.
3	FB	I	Feedback input to the error amplifier for regulated output.
4	EN	I	Enable pin of the boost regulator. Logic low disables the chip and logic high enables it. It needs to be pulled up to enable the device, otherwise the weak internal pull-down will disable it. Two levels logic or analog bias with edge slope rate > 10V/ms is desired for stable on/off transition.
5	VS	O	Supply power input for internal circuit. Connect to the output of converter.
6	NC	—	Not connected. Recommend to solder it onto ground plane for better thermal dissipation.

NOTE: I = Input, O = Output.

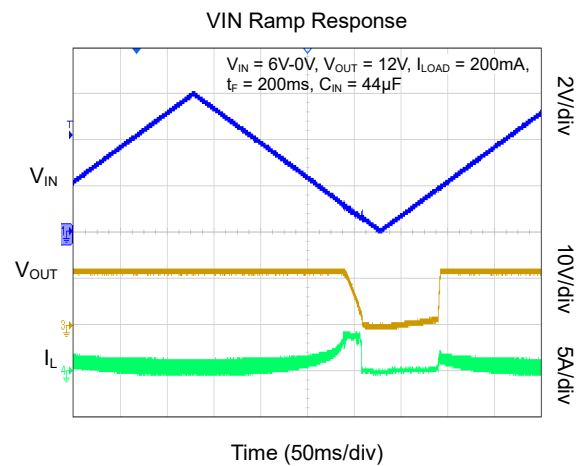
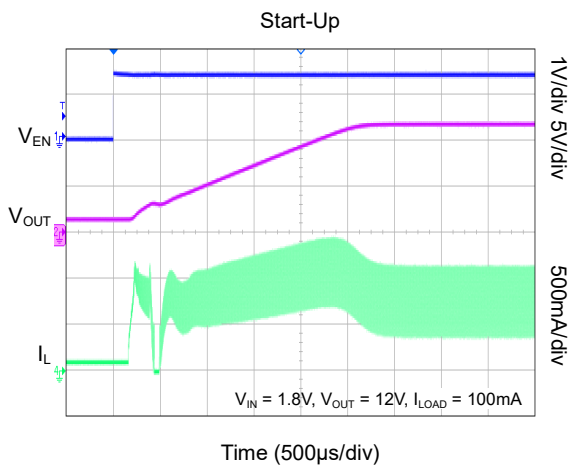
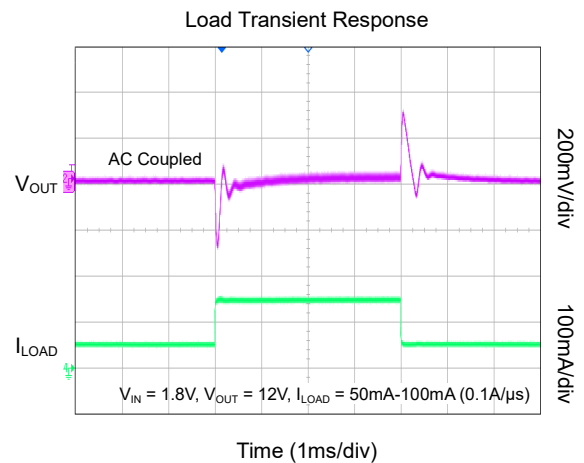
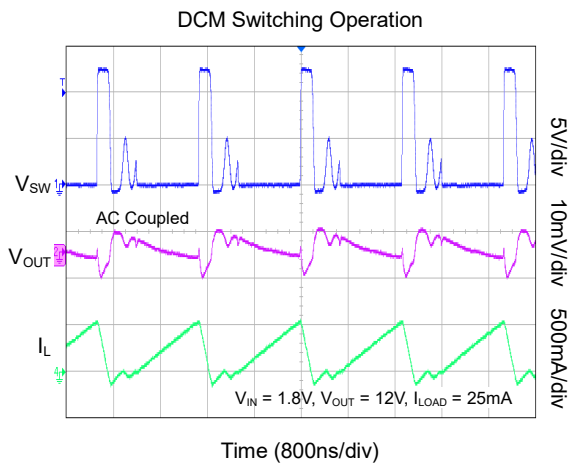
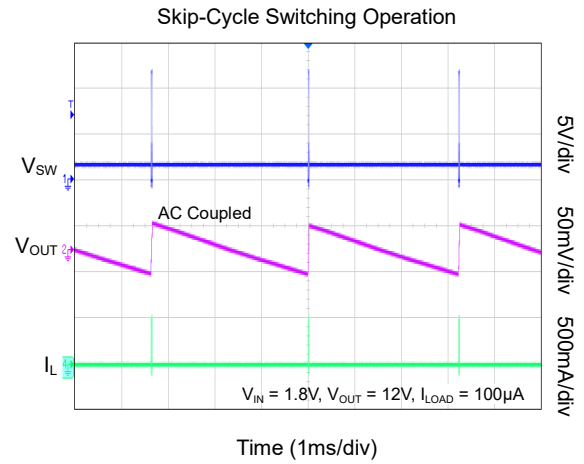
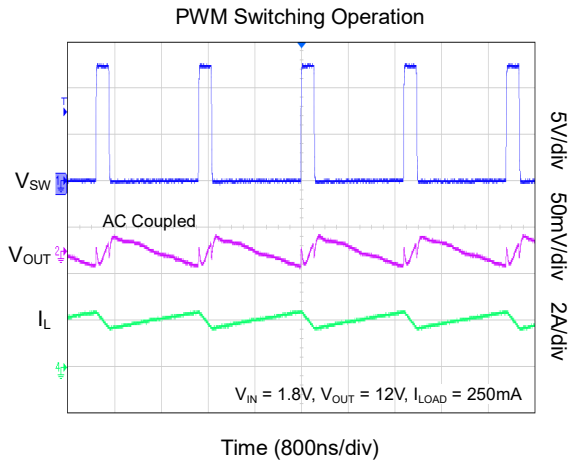
ELECTRICAL CHARACTERISTICS

(V_{VS} = 3.6V, V_{EN} = 3.6V, Full = -40°C to +85°C, typical values are at T_J = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
Supply Current							
Sustainable Input Voltage Range	V _{IN}	The VS pin connects to output	+25°C	0.8		12	V
Minimum VS Voltage for Start-Up	V _{VS_START_MIN}	The VS pin connects to output	+25°C		1.5		V
VS Input Voltage Range	V _{VS}	V _{IN} is in 0.8V to 12.5V range	+25°C	3		13	V
Operating Quiescent Current into VS	I _Q	No switching, no load	Full		47	65	μA
Shutdown Current	I _{SHDN}	V _{EN} = GND	+25°C			1	μA
			Full			1.5	
Enable and Reference Control							
EN Logic High Voltage	V _{IH}		Full	1.1			V
EN Logic Low Voltage	V _{IL}		Full			0.3	V
EN Internal Pull-Down Resistor	R _{EN}		Full	400	570	740	kΩ
Voltage and Current Control							
Voltage Feedback Regulation Voltage	V _{REF}		Full	1.177	1.205	1.231	V
Voltage Feedback Input Bias Current	I _{FB}	V _{FB} = 1.3V	Full			170	nA
Switching Frequency	f _{SW}		Full	480	600	720	kHz
Maximum Duty Cycle	D _{MAX}		+25°C		96		%
Over-Voltage Protection Threshold	V _{OVP}		+25°C	13.3	13.8	14.3	V
Over-Voltage Protection Threshold Hysteresis	V _{OVP_HYS}		+25°C		0.43		V
Power Switch							
N-Channel MOSFET On-Resistance	R _{DSON}	V _{VS} = 3.6V	+25°C		70	90	mΩ
			Full			110	
N-Channel Leakage Current	I _{LN_NFET}	V _{SW} = 13.2V, V _{EN} = 0V	+25°C			1	μA
			Full			1.5	
N-Channel MOSFET Current Limit	I _{LIM}		+25°C	3.65	4.4	5.25	A
Thermal Shutdown							
Thermal Shutdown Threshold	T _{SHDN}				165		°C
Thermal Shutdown Threshold Hysteresis	T _{HYS}				15		°C

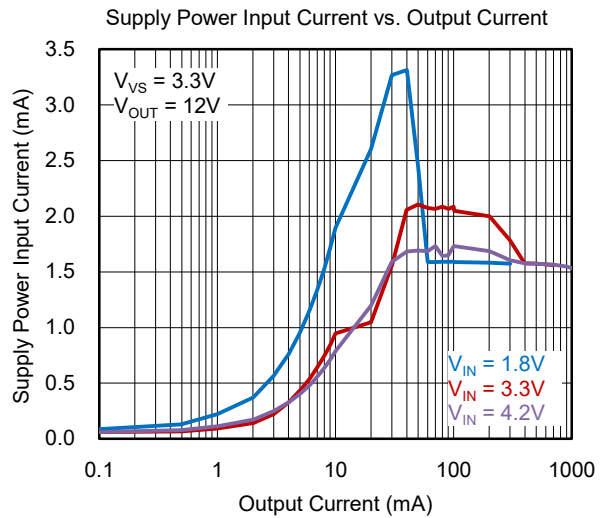
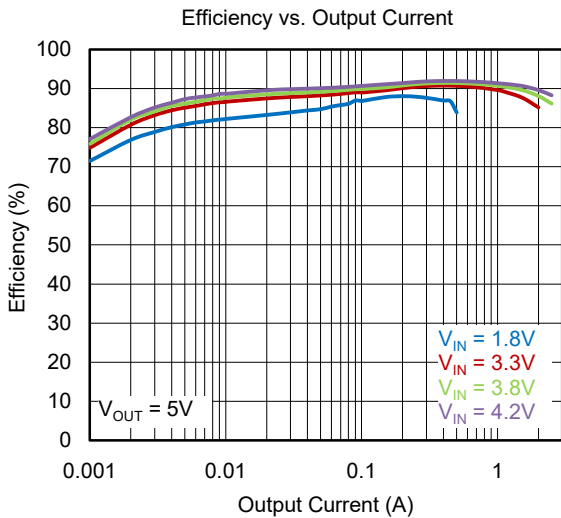
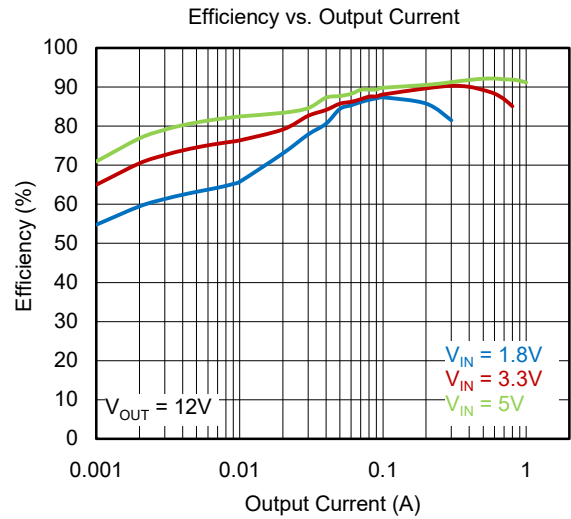
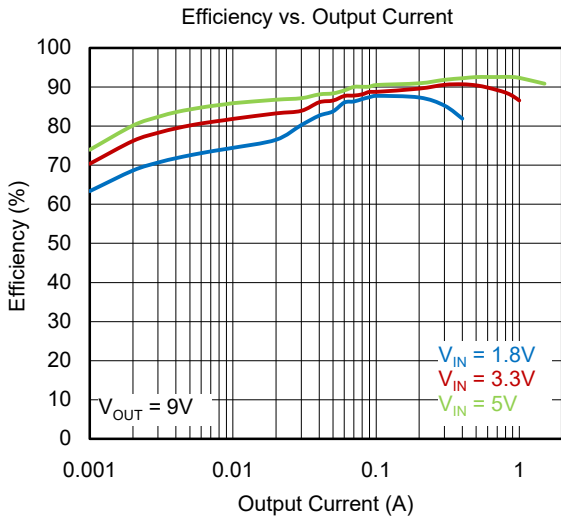
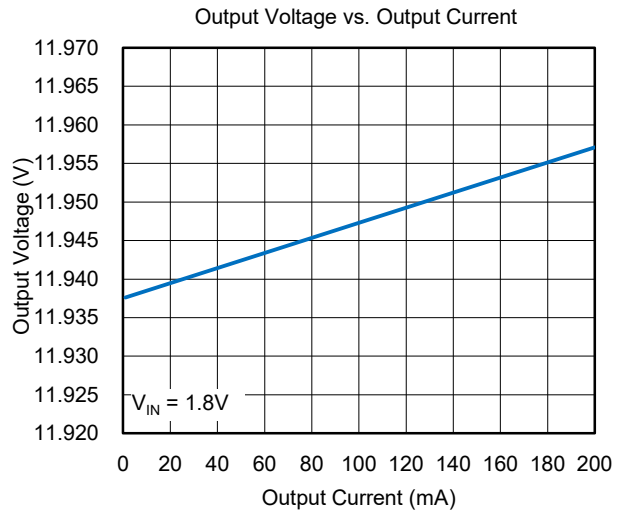
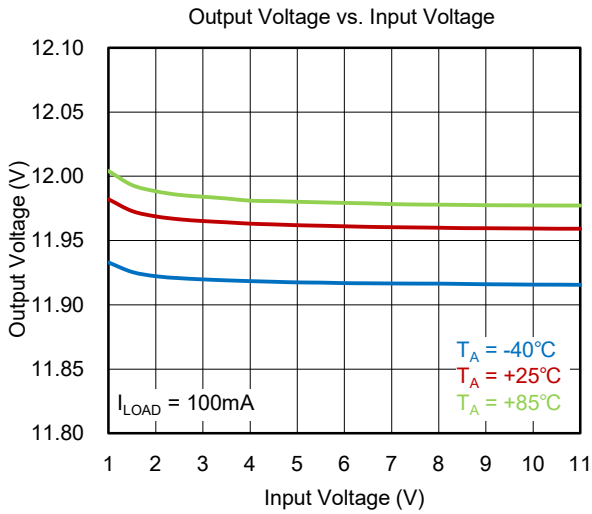
TYPICAL PERFORMANCE CHARACTERISTICS

$T_J = +25^\circ\text{C}$, $C_{IN} = 4.7\mu\text{F}$, $C_{OUT} = 100\mu\text{F}$, $L = 3.3\mu\text{H}$ and $V_{VS} = V_{OUT}$, unless otherwise noted.



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_J = +25°C, C_{IN} = 4.7µF, C_{OUT} = 100µF, L = 3.3µH and V_{VS} = V_{OUT}, unless otherwise noted.



FUNCTIONAL BLOCK DIAGRAM

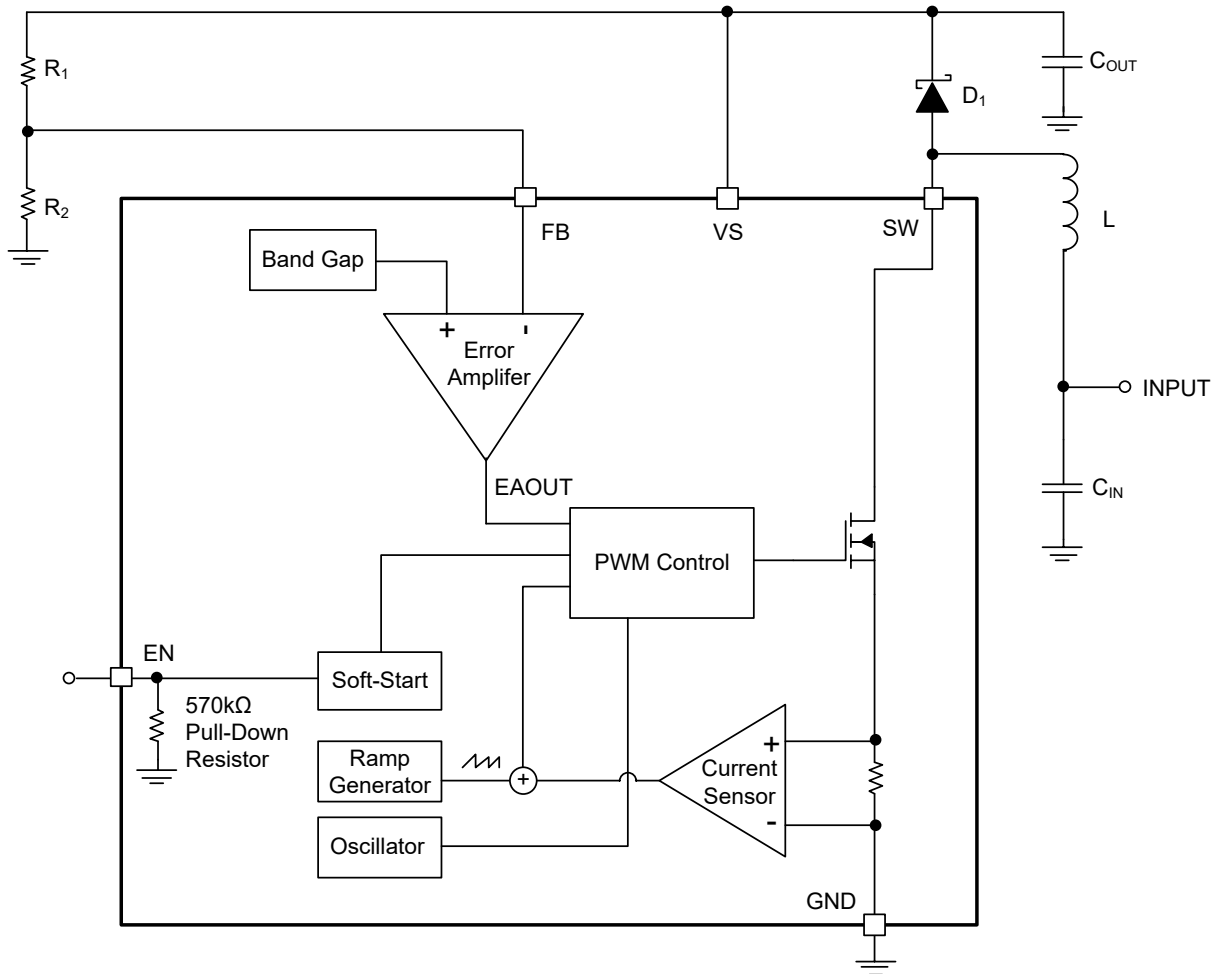


Figure 2. Block Diagram

DETAILED DESCRIPTION

Operation

The SGM6623 is a miniature boost converter with integrated low-side MOSFET switch able to provide output voltages up to 13V that are typically used in battery operated portable devices. Current mode PWM control is used to regulate the output voltage as shown in Figure 2. The switching frequency of the PWM is fixed at 600kHz (TYP). The PWM controller turns on the switch at the beginning of each switching cycle. During the ON time, the input voltage is applied across the inductor and stores the energy as the inductor current ramps up. During this portion of the switching cycle, the load current is provided by the output capacitor. When the inductor current reaches to the threshold set by the error amplifier output, the power switch turns off and the external Schottky diode is

forward biased and takes over the inductor current. The inductor releases the stored energy to replenish the output capacitor and supply the load current during this period. This operation repeats in each switching cycle. As shown in the Functional 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 the oscillator is added to the current ramp. This slope compensation ramp is necessary to avoid sub-harmonic oscillations that are intrinsic to current mode control at duty cycles higher than 40%. The feedback loop regulates the FB pin voltage to the internal reference voltage using the error amplifier.

DETAILED DESCRIPTION (continued)

Soft-Start

A soft-start circuit is integrated in the device to avoid high inrush currents during start-up. After the chip is enabled by a logic high signal on the EN pin, the FB pin reference voltage ramps up to the final reference value of 1.205V in about $t_{SS} = 2.5\text{ms}$. The reference voltage ramping ensures that the output voltage tracks it similarly, starting from V_{FB} and going up slowly, and reduces the inrush current to the output capacitors and the load.

As showed in Figure 1, the VS pin is the power input for the device itself and is powered from the converter output or a voltage source in proper range. When the VS pin is powered from the converter output, before enabling the chip, the bias to VS comes from the input through the inductor and Schottky diode. The SGM6623 can start up from input voltage as low as 1.5V. On start-up, the controller switches the N-channel MOSFET continuously until the V_{OUT} reaches 2.7V. When 2.7V is reached, the normal boost regulator feedback takes over the control. Once the device is in regulation, it can operate with input voltage down to 0.8V.

When the VS is not self-biased with its own output but from an independent power source, enable the device after the VS is biased $> 3\text{V}$ stably to avoid continuous switching without output voltage regulation, in which the output voltage may trigger the over-voltage protection and hiccups to output the maximum possible voltage decided by the OVP threshold.

Over-Current Protection

SGM6623 has a cycle-by-cycle 4.4A (TYP) over-current limit feature that turns off the power switch once the inductor current (sensed in the internal switch) reaches the limit. The PWM controller turns on the power switch at the beginning of each switch cycle. During an over-current event, the early turn off of the switch results in a reduced duty cycle that leads to a decreased output voltage. The maximum available output current is determined by the current limit threshold, input voltage, output voltage, switching frequency and inductor value. Larger inductance values typically increase the current output capability because

of the reduced current ripple. See the Application Information section for the output current calculation.

Over-Voltage Protection (OVP)

Over-voltage protection circuitry prevents IC damage as the result of output resistor divider disconnection. The SGM6623 monitors the voltage at the SW pin during each switching cycle. The circuitry turns off the switch FET when the SW voltage exceeds the OVP threshold. The switch FET remains in shutdown mode until SW pin voltage is lower than 13.37V for 100ms. The OVP threshold of SGM6623 is 13.8V.

Pulse-Skipping Mode

The SGM6623 integrates a pulse-skipping mode at the light load. When a light load condition occurs, the EAOUT voltage naturally decreases and reduces the peak current. When the EAOUT voltage further goes down with the load lowered and reaches the pre-set low threshold, the output of the error amplifier is clamped at this threshold and does not go down any more. If the load is further lowered, the output voltage of SGM6623 exceeds the nominal voltage and the device skips the switching cycles. The pulse-skipping mode reduces the switching losses and improves efficiency at the light load condition by reducing the average switching frequency.

Thermal Shutdown

The internal thermal shutdown protection turns off the device when the junction temperature exceeds 165°C. The chip will resume operation when the junction temperature drops by at least 15°C (TYP).

Enable and Shutdown

If the EN input voltage falls below 0.3V, the SGM6623 enters into shutdown state in which the input supply current for the device is less than 1 μA . The EN pin has a weak internal pull-down resistor (570k Ω TYP) to disable the device when the pin is left unconnected. Apply two levels logic or analog bias with edge slope rate $> 10\text{V/ms}$ to enable/shutdown the device stably. Quick toggles during the enabling may cause false over-voltage hiccup if the bias voltage ramps slowly.

APPLICATION INFORMATION

Supply to Internal Circuit

The internal circuit is biased from the VS pin. The bias voltage could be from 3V to 12V, but not higher than the output voltage + 1V, which could be connected to the VOUT or to any supply rail whose voltage is in the range as mentioned above. But when the supply rail is less than 3V, the voltage of EN must be less than 0.3V. When the VS pin is connected to the VOUT, a 50Ω resistor inserted between VS to VOUT is recommended to isolate the VS from potential voltage surge at the VOUT.

Output Voltage Programming

To program the output voltage, select the values of R1 and R2 (see Figure 3) according to Equation 1.

$$V_{OUT} = 1.205 \times \left(\frac{R_1}{R_2} + 1 \right)$$

or

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{1.205} - 1 \right) \tag{1}$$

Considering the leakage current to the FB pin and noise decoupling from FB, smaller resistor values around 10kΩ are recommended for R2. The output voltage tolerance depends on the accuracy of the reference voltage and the tolerances of R1 and R2. Thermally stable resistors with 1% or better accuracy and of same type are recommended for R1 and R2. Mount them close to each other for the same thermal variations.

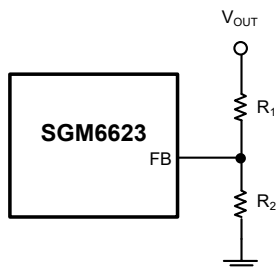


Figure 3. Output Voltage Programming

Maximum Output Current

The over-current limit in a boost converter basically limits the maximum input current, and in turn the maximum input power (for a given input voltage) is limited by the over-current limit. Therefore, the maximum output power is also limited to the maximum input power minus losses. So, the actual maximum output current depends on the input current limit, input voltage, output voltage and efficiency. The input current

limit clamps the peak inductor current. The maximum input DC current can be calculated by subtracting half of the inductor ripple current from the current limit value. The inductor ripple current is a function of the switching frequency, inductor value and duty cycle. In summary the following two equations show the impact of all the above factors on the maximum output current.

$$\Delta I_L = \frac{1}{L \times f_{SW} \times \left(\frac{1}{V_{OUT} + V_F - V_{IN}} + \frac{1}{V_{IN}} \right)} \tag{2}$$

where:

ΔI_L = Inductor peak-to-peak ripple current.

L = Inductor value.

V_F = Schottky diode forward voltage.

f_{SW} = Switching frequency.

V_{OUT} = Output voltage.

V_{IN} = Input voltage.

$$I_{OUT_MAX} = \frac{V_{IN} \times \left(I_{LIM} - \frac{\Delta I_L}{2} \right) \times \eta}{V_{OUT}} \tag{3}$$

where:

I_{OUT_MAX} = Maximum output current of the boost converter.

I_{LIM} = Over-current limit (typically 4.4A for SGM6623).

η = Efficiency.

Switch Duty Cycle

The maximum duty cycle (D) of the internal power switch in the SGM6623 is 96% (TYP). The duty cycle of an ideal boost converter under continuous conduction mode (CCM) is given by:

$$D = \frac{V_{OUT} - V_{IN}}{V_{OUT}} \tag{4}$$

For example, in a 5V to 12V application, the duty cycle is almost 58.3%. The duty cycle must always be lower than 96% with sufficient margin to consider the transients and voltage drops in a real application; otherwise, the output voltage will not be regulated.

The SGM6623 has also a minimum ON time switching pulse width. This sets a limit on the minimum duty cycle. When operating at low duty cycles, the SGM6623 can enter the pulse-skipping mode. In this mode, the device turns the power switch off for several switching cycles to prevent the output voltage from rising above regulation. This operation typically occurs in light load condition when the converter operates in discontinuous conduction mode (DCM).

APPLICATION INFORMATION (continued)

Inductor Selection

Inductor is the most critical component in the design of a boost converter with SGM6623 because it affects steady state operation, transient behavior and loop stability (sub-harmonic oscillations). Four parameters of the inductor must be considered in the design: nominal inductance value, DC resistance (DCR), saturation current (or 20%~30% inductance-drop currents) and maximum RMS current (DC plus AC) for a certain temperature rise.

The inductance of the inductor determines the ripple current. It is recommended to choose a peak-to-peak ripple current (given by Equation 2) that is in the 30%~40% range of the maximum DC current of the inductor in the application. Such ripple factor usually gives a good compromise between inductor core and converter conduction losses (due to the ac ripple) and the inductor size. Inductor DC current can be calculated based on input-output power balance as given in Equation 5:

$$I_{IN_DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \quad (5)$$

Typically, the inductor value can have a $\pm 20\%$ initial tolerance. On top of that the inductance may drop another 20%~30% when the inductor current approaches to the maximum (saturation or 20%~30% drops) at maximum current. This drop is usually given by manufacturer. Note that the powder iron core inductors do not have a sharp saturation like ferrite inductors and show a gradual inductance drop even if the current peaks much higher than their maximum rated currents that is an important advantage. The manufacturer specifies the 20%~30% drop current level for them instead of saturation. However, they are usually slightly bigger than the similar ferrite inductor. Finally, the total RMS current of the inductor must be limited to keep the total inductor losses low and prevent excessive temperature rise in the inductor. The DCR of an inductor may increase around 50% if the temperature is increased from +25°C to +125°C. Such temperature rises need to be considered in the evaluation of the I^2R losses of the inductor.

Using an inductor with a smaller inductance in a boost converter results in having discontinuous conduction mode (DCM) range extended to the higher load currents due to larger ripple. Small inductance can also result in reduced maximum output current, increased input voltage ripple and reduced efficiency. In general,

inductors with large inductance and low DCR values provide better output current and higher conversion efficiency. However, smaller inductance usually provides better load transient response. For these reasons, an inductance with 30%~40% current ripple (of the peak load current) is recommended.

SGM6623 has a built-in slope compensation to avoid sub-harmonic oscillation associated with current mode control. If the inductor value is too small, the slope compensation may not be adequate, and the loop can become unstable for larger duty cycles. Therefore, the designer must verify the selected inductor for the application with the maximum and minimum margins of the input and output voltages if it is not chosen based on the recommended values.

Schottky Diode Selection

The high switching frequency of the SGM6623 demands for a high-speed rectifier for optimum efficiency. Ensure that the average and peak current ratings of the diode exceed the average output current and the peak inductor current respectively. In addition, the diode's reverse breakdown voltage must exceed the maximum output voltage (13V) with a reasonable margin. Schottky diodes with lower rated voltages can be used for lower output voltages to reduce the size and cost. A 20V diode is a good choice for 12V output.

Input and Output Capacitor Selection

The output capacitor is selected to meet the requirements for the output voltage ripple and loop stability. The ripple voltage depends on the capacitance itself and the equivalent series resistance (ESR) of the capacitor. Assuming a capacitor with zero ESR, the minimum capacitance needed for a given output ripple can be calculated using Equation 6.

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times V_{RIPPLE}} \quad (6)$$

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

$$V_{RIPPLE_ESR} = \Delta I_L \times ESR \quad (7)$$

For ceramic capacitors the ESR is usually small and V_{RIPPLE_ESR} can be neglected, but for tantalum or electrolytic capacitors the capacitive and ESR components of the ripple must be added to estimate the total output voltage ripple.

REVISION HISTORY

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

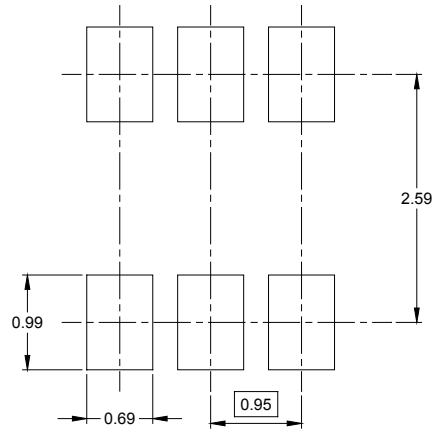
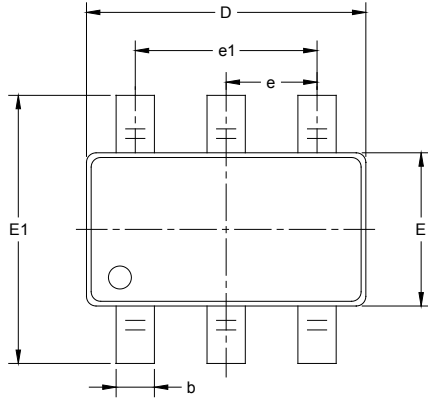
JULY 2020 – REV.A.1 to REV.A.2	Page
Updated switching frequency.....	1, 4, 7

FEBRUARY 2020 – REV.A to REV.A.1	Page
Updated Pin Description section.....	3
Updated Detailed Description section	8

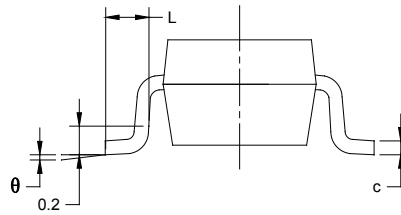
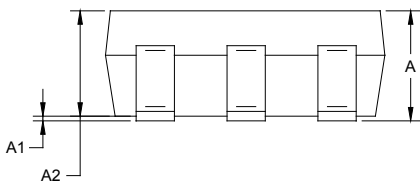
Changes from Original (SEPTEMBER 2019) to REV.A	Page
Changed from product preview to production data.....	All

PACKAGE OUTLINE DIMENSIONS

SOT-23-6



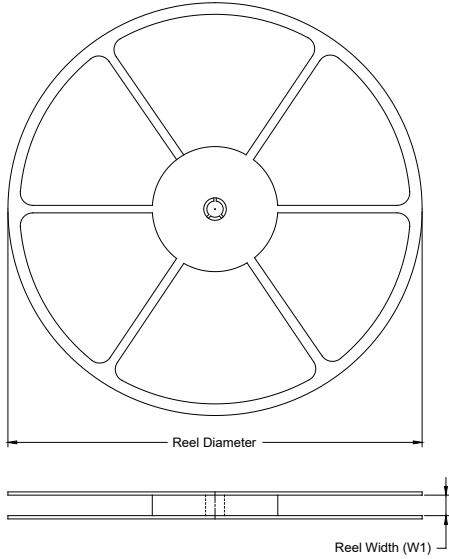
RECOMMENDED LAND PATTERN (Unit: mm)



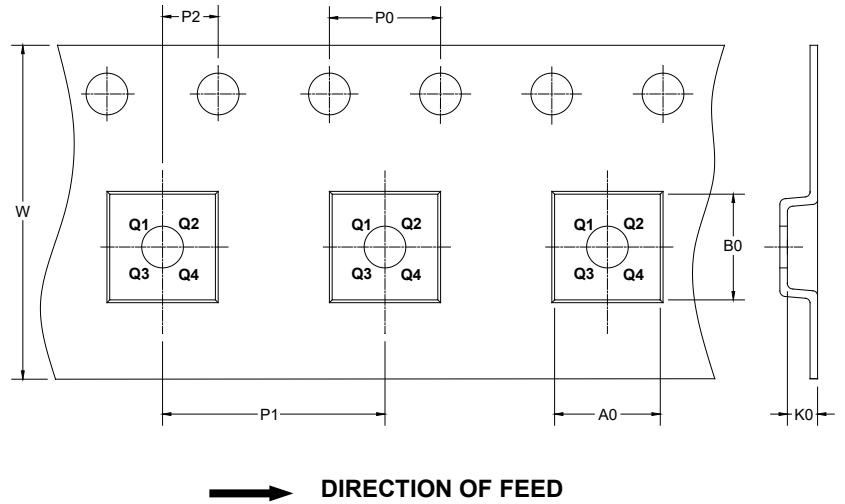
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950 BSC		0.037 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



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

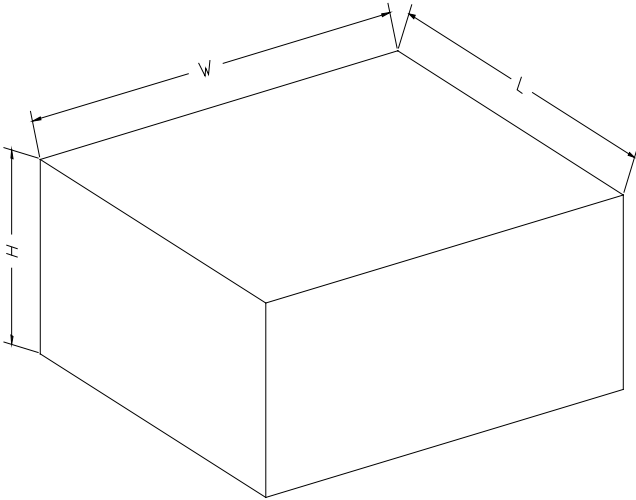
KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT-23-6	7"	9.5	3.17	3.23	1.37	4.0	4.0	2.0	8.0	Q3

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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

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