SGM660
Buck-Boost Converter for Negative Output Voltage

GENERAL DESCRIPTION

The SGM660 is a synchronous inverting Buck-Boost converter. The device implements a multi-function digital input SWIRE pin which can be used to program the negative output voltage or device enable.

The SGM660 integrates a 810mA switch current power FET, which can be programmable down to 435mA. 1.8MHz switching frequency allows the use of small size inductor. The device has built-in soft-start and loop compensation network to reduce the external component counts. Output discharge function is also implemented.

Various protection features such as over-current protection, over-temperature protection and short circuit protection are implemented to protect the device against various fault conditions.

The SGM660 is available in a Green WLCSP-0.9×1.3-6B package.

FEATURES

- **Input Voltage Range: 2.8V to 5.5V**
- **Adjustable Output Voltage:**
  -0.8V to -5.2V, 0.1V/Step
- **Programmable Switching Current Limit:**
  810mA (Default)/620mA/435mA
- **Programmable Switching Frequency:**
  1.8MHz/1.6MHz (Default)/1.4MHz
- **Internal Soft-Start Function**
- **No External Compensation**
- **Shutdown Current: 1µA (MAX)**
- **Available in a Green WLCSP-0.9×1.3-6B Package**

APPLICATIONS

Sensor and Modulator Bias
Negative Bias Supply for Amplifiers and Data Converters
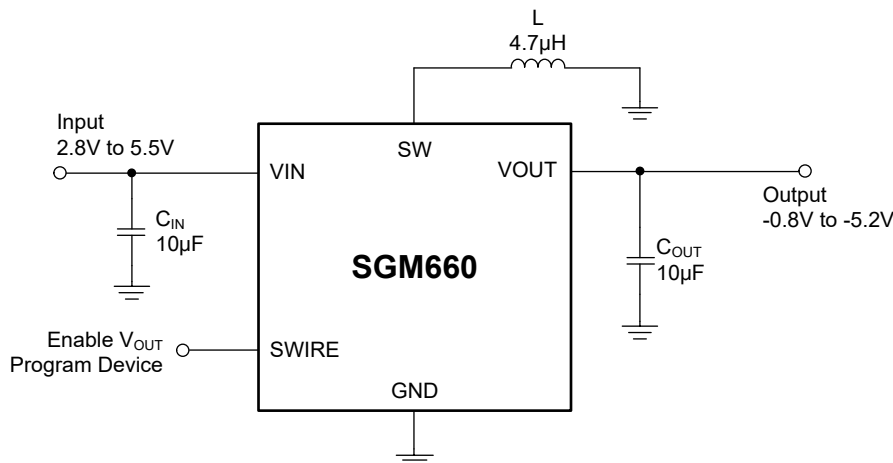Discrete LCD Biasing

TYPICAL APPLICATION

Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM660	WLCSP-0.9×1.3-6B	-40℃ to +125℃	SGM660XG/TR	XXX ORB	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXX = Date Code and Trace Code.

```
        ┌────── Date Code - Year
        │  ┌─── Trace Code
        │  │
        X  X X
        Y  Y Y ── Serial Number
```
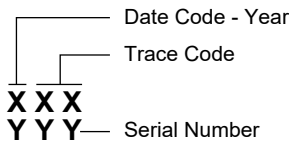
Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

VIN to GND Voltage.............................. -0.3V to 6V
VOUT to GND Voltage......................... -6V to 0.3V
SW to GND Voltage .... V_{OUT} - 0.3V to V_{IN} + 0.3V
SWIRE to GND Voltage .... -0.3V to 6V
Package Thermal Resistance
WLCSP-0.9×1.3-6B, θ_{JA} .... 192℃/W
Junction Temperature..+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s)...........................+260℃
ESD Susceptibility
HBM..4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range, V_{IN} ....2.8V to 5.5V
Output Voltage Range, V_{OUT} .... -0.8V to -5.2V
Operating Ambient Temperature Range ......-40℃ to +125℃
Operating Junction Temperature Range......-40℃ to +125℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

DISCLAIMER

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

PIN CONFIGURATION

(TOP VIEW)

```
         1        2

   A    GND      VIN

   B   SWIRE      SW

   C    GND      VOUT
```

WLCSP-0.9×1.3-6B
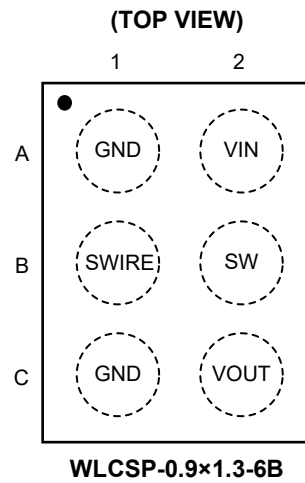
PIN DESCRIPTION

PIN	NAME	FUNCTION
A1, C1	GND	Ground.
B1	SWIRE	Enable Inverting Buck-Boost Converter and Digital Programming. Active high.
A2	VIN	Power Supply Input Pin. Connect to the internal high-side MOSFET and supply power to the internal circuit.
B2	SW	Switching Node Pin. Connect to the internal high-side MOSFET and low-side MOSFET.
C2	VOUT	Output Voltage. The output filter capacitor should be connected to this pin.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, T_J = -40℃ to +125℃, typical values are at T_J = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		2.8		5.5	V
Shutdown Current	I_{SD}	V_{SWIRE} = 0V, V_{IN} = 5.5V, T_J = +25℃		0.1	1.0	µA
Quiescent Current	I_Q	V_{SWIRE} = 1.8V, V_{IN} = 5.5V, non-switching, T_J = +25℃		270	350	µA
Input Under-Voltage Lockout Threshold	V_{UVLO}	V_{IN} rising, T_J = +25℃		2.55	2.70	V
Input Under-Voltage Lockout Hysteresis	V_{UVLO_HYS}	T_J = +25℃	0.08	0.13		V
Power-Up Blanking Time	t_{BLANK}			10		ms
Logic High Level Voltage	V_{IH}	V_{IN} = 3.3V, SWIRE rising	1.4			V
Logic Low Level Voltage	V_{IL}	V_{IN} = 3.3V, SWIRE falling			0.4	V
SWIRE Pin Leakage Current	I_{SWIRE}	V_{SWIRE} = 1.8V		10		nA
	I_{SWIRE_PD}	Before the input is recognized as logic high		2		µA
Negative Output Voltage	V_{OUT}		-5.2	-2.5	-0.8	V
Negative Output Voltage Accuracy		V_{OUT} = -2.5V, no load	-2.0		2.0	%
MOSFET On-Resistance	R_{DSP}	I_{DS} = 100mA		435		mΩ
MOSFET Rectifier On-Resistance	R_{DSN}	I_{DS} = 100mA		235		mΩ
Switch Current Limit	I_{SW}	T_J = +25℃	700	810	920	mA
		T_J = +25℃	530	620	710	mA
		T_J = +25℃	370	435	500	mA
Switching Frequency	f_{SW}		1.65	1.8	1.95	MHz
			1.45	1.6	1.75	MHz
			1.25	1.4	1.55	MHz
VOUT Negative Comparator at Start-Up	$V_{OUT\_SCP\_ST}$			-500		mV
VOUT Discharge Resistance	R_{VOUT_DCG}	V_{SWIRE} = GND, I_{VOUT} = ±1mA		150		Ω
Minimum High-side Switch On-Time	t_{ON_MIN}	I_{LOAD} = 0A		110		ns
Thermal Shutdown Threshold	T_{SD}			160		℃
Thermal Shutdown Hysteresis	T_{SD_HYS}			20		℃

TYPICAL PERFORMANCE CHARACTERISTICS

T_J = +25℃, V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, C_{IN} = 10μF, C_{OUT} = 10μF, L = 4.7μH, unless otherwise noted.

Soft-Start and Soft-Off Waveform

V_{IN} = 3.3V, V_{OUT} = -2.5V, R_{LOAD} = 0Ω
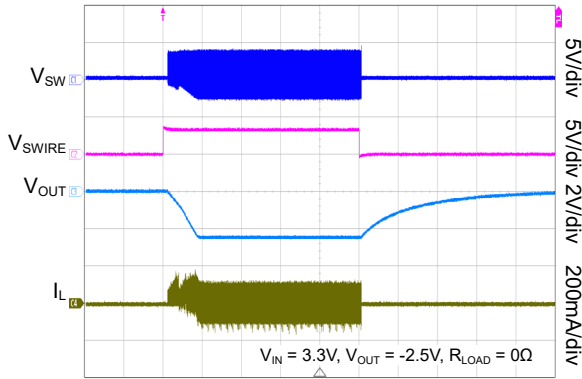
Time (1ms/div)

Soft-Start and Soft-Off Waveform

V_{IN} = 3.3V, V_{OUT} = -2.5V, R_{LOAD} = 25Ω
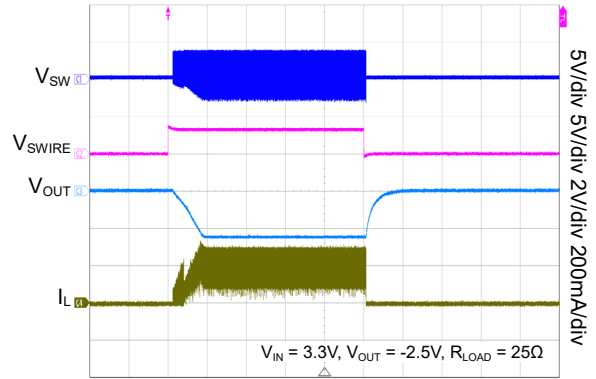
Time (1ms/div)

Typical Switching Waveform

V_{IN} = 3.3V, V_{OUT} = -2.5V, I_{LOAD} = 0A
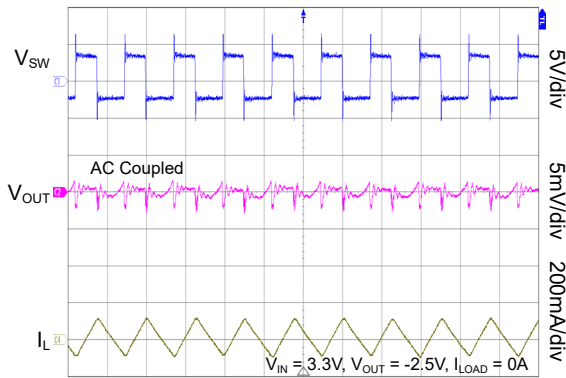
Time (500ns/div)

Typical Switching Waveform

V_{IN} = 3.3V, V_{OUT} = -2.5V, I_{LOAD} = 100mA
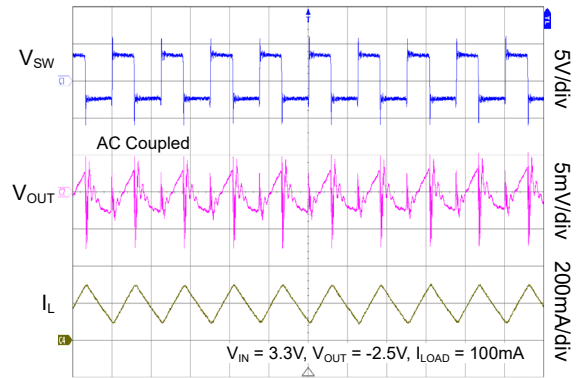
Time (500ns/div)

Load Transient

V_{IN} = 3.3V, V_{OUT} = -2.5V, I_{LOAD} = 2mA to 50mA
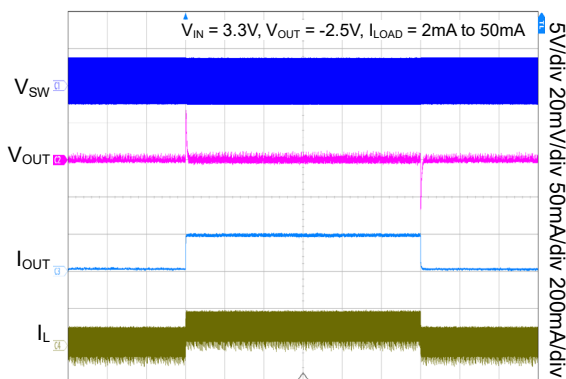
Time (2ms/div)

Short Circuit Waveform
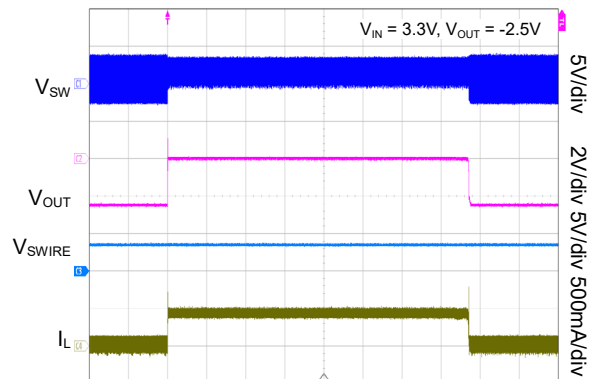
V_{IN} = 3.3V, V_{OUT} = -2.5V

Time (10ms/div)

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_J = +25℃, V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, C_{IN} = 10µF, C_{OUT} = 10µF, L = 4.7µH, unless otherwise noted.

Efficiency vs. Load Current

Output Regulation

Maximum Load Current vs. Input Voltage

No Load Supply Current vs. Input Voltage

No Load Supply Current vs. Input Voltage
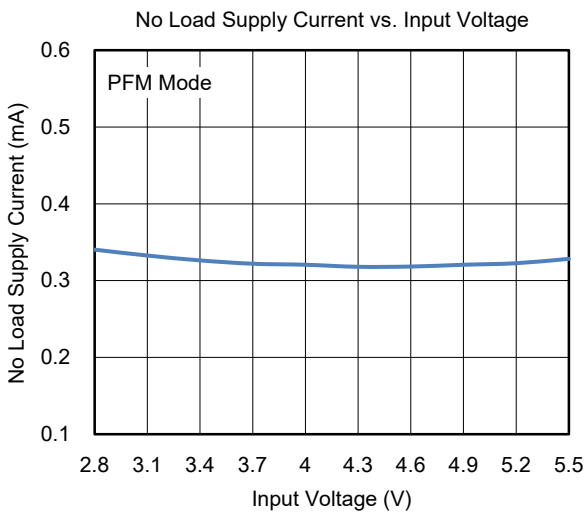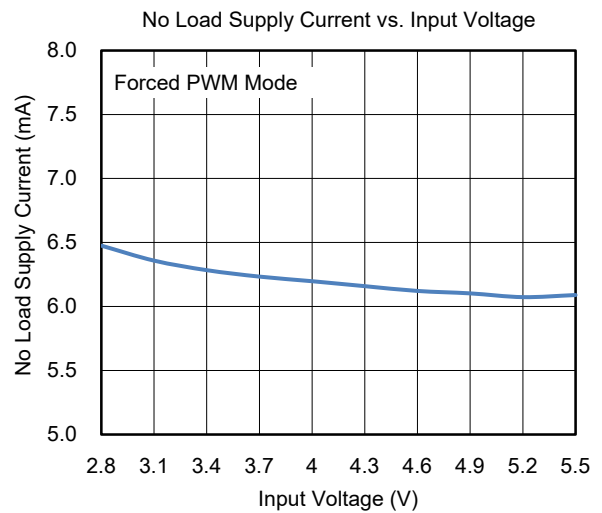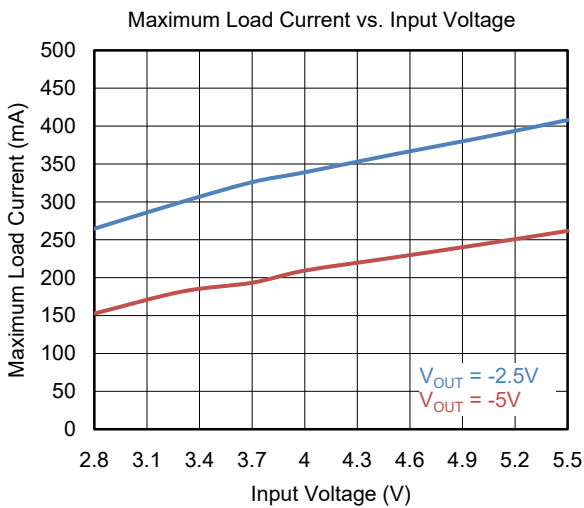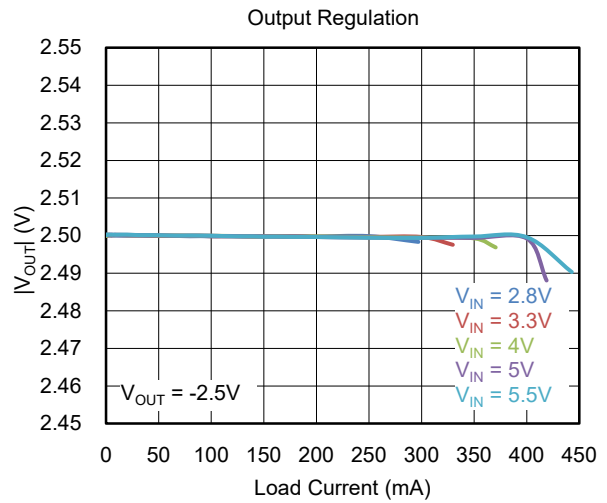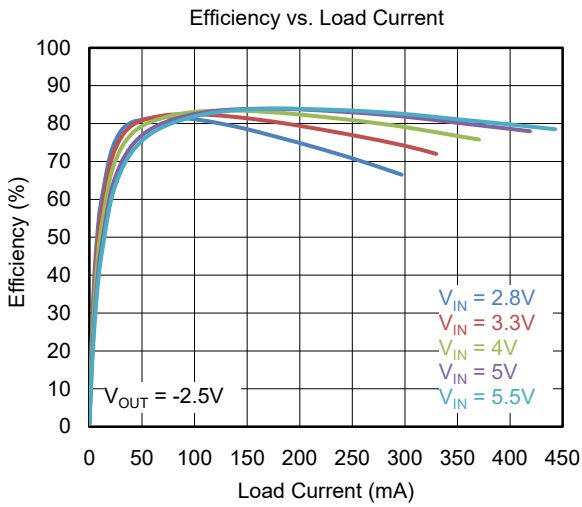
TIMING REQUIREMENTS

(T_J = +25℃, unless otherwise noted.)

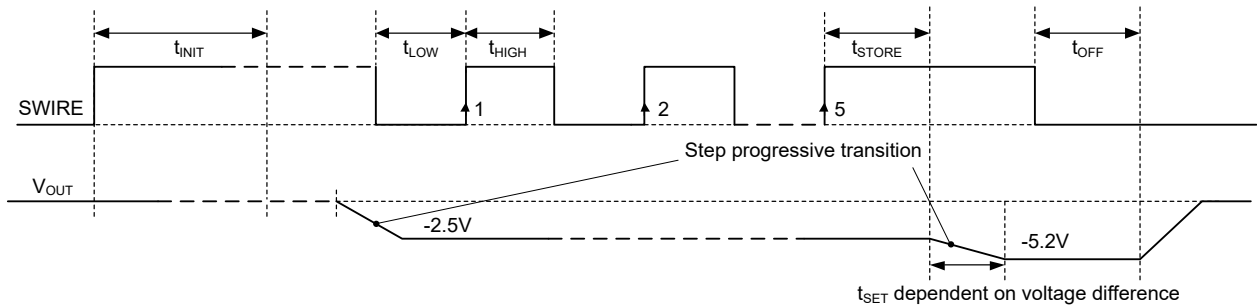| PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS
SWIRE Interface					
Initialization Time	t_{INIT}		300	400	μs
Shutdown Time Period	t_{OFF}	30	55	80	
Pulse High Level Time Period	t_{HIGH}	4	10	25	
Pulse Low Level Time Period	t_{LOW}	4	10	25	
Data Storage/Accept Time Period	t_{STORE}	30	55	80	

Figure 2. Timing Diagram
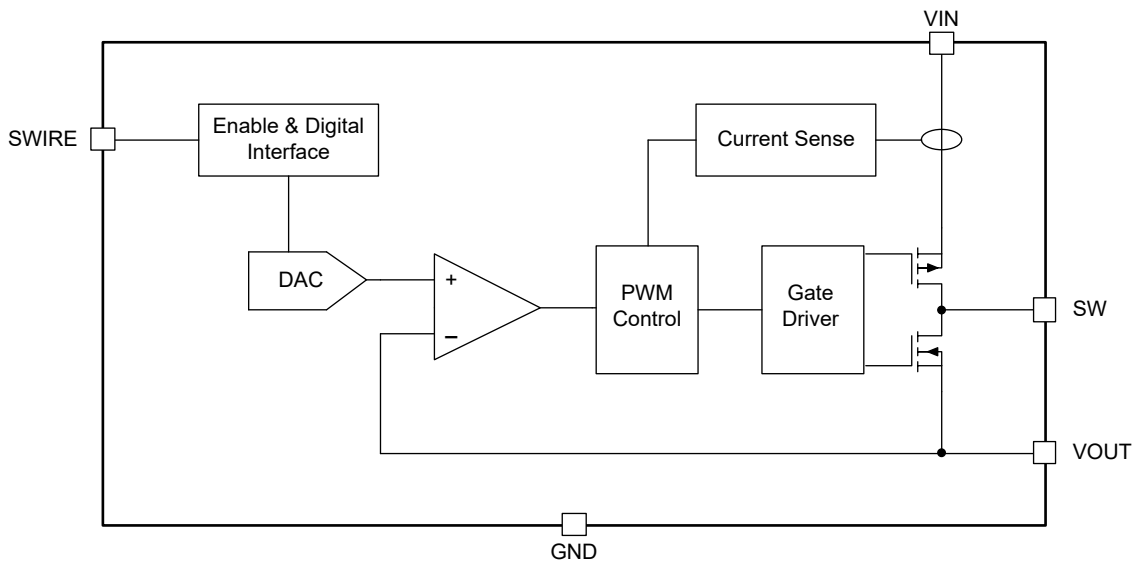
FUNCTIONAL BLOCK DIAGRAM

Figure 3. Block Diagram

DETAILED DESCRIPTION

The SGM660 adopts the peak current mode control scheme, which provides excellent line and load transient responses with minimal output capacitance. But in that case, the duty cycle will be limited by the minimum on-time. So the ripple of V_{OUT} will get bigger when that happens.

Under-Voltage Lockout
The built-in under-voltage lockout function (UVLO) monitors the input voltage and disables the device when the input voltage is too low to operate.

Thermal Shutdown
The device implements thermal shutdown, which prevents the device from damage due to overheating and excessive power dissipation. The device stops switching and shuts down all the outputs when the junction temperature exceeds +160℃ (TYP), and restarts with the same programmed voltages and sequences when the temperature decreases to +140℃ (TYP).

Soft-Start
The device implements an internal soft-start to limit the inrush current.

Input Power Supply
The input power supply voltage is recommended between 2.8V and 5.5V. To achieve full performance, a stable and noise-free input source is needed. In case the distance between input source and SGM660 is long, additional capacitors are suggested to place as close to the device as possible. Please refer to Figure 1 for the suggested input capacitance.

Short Circuit Protection
Peak current mode control has inherent over-current protection. When a short circuit occurs, the high-side FET's current limit is reached, the device stops switching to prevent the device from damage.

DETAILED DESCRIPTION (continued)

Digital Interface (SWIRE Pin)

The negative output voltage V_{OUT} can be programmed through the SWIRE digital interface with 0.1V steps.

Figure 4 shows an example for SGM660 programming V_{OUT}. The SWIRE pin can be used as a standard enable pin if programming is not required. The device starts with default values (green marked values in Table 1) if enabled.

Inverting Buck-Boost Converter (VOUT Pin)

The inverting Buck-Boost converter operates with a peak-current-mode topology and 1.6MHz (TYP) frequency. The output voltage can be programmed between -5.2V to -0.8V (default -2.5V) with 0.1V steps (see Table 1).

Device Reset

Power resetting resets the device to default settings. If 63 pulses are applied to the SWIRE pin, all digital settings will be reset to default values.

Table 1. Programming Table

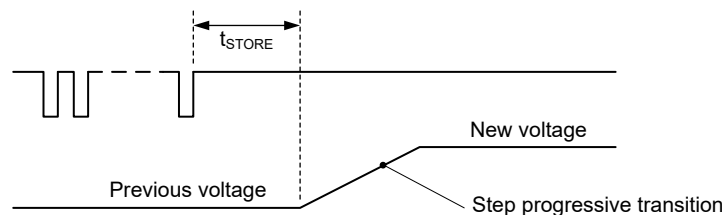| Rising Edges	V_{OUT}	Rising Edges	V_{OUT}	Rising Edges	Switching Frequency	Rising Edges	Current Limit	Rising Edges	Forced PWM Mode at Light Load
0/no pulse	-2.5V			0/no pulse	1.6MHz	0/no pulse	0.81A	0/no pulse	ON
1	Reserved	26	-3.1V	50	1.8MHz	53	0.81A	56	OFF
2	Reserved	27	-3.0V	51	1.4MHz	54	0.62A	57	ON
3	Reserved	28	-2.9V	52	1.6MHz	55	0.435A		
4	Reserved	29	-2.8V						
5	-5.2V	30	-2.7V						
6	-5.1V	31	-2.6V						
7	-5.0V	32	-2.5V						
8	-4.9V	33	-2.4V						
9	-4.8V	34	-2.3V						
10	-4.7V	35	-2.2V						
11	-4.6V	36	-2.1V						
12	-4.5V	37	-2.0V						
13	-4.4V	38	-1.9V						
14	-4.3V	39	-1.8V						
15	-4.2V	40	-1.7V						
16	-4.1V	41	-1.6V						
17	-4.0V	42	-1.5V						
18	-3.9V	43	-1.4V						
19	-3.8V	44	-1.3V						
20	-3.7V	45	-1.2V						
21	-3.6V	46	-1.1V						
22	-3.5V	47	-1.0V						
23	-3.4V	48	-0.9V						
24	-3.3V	49	-0.8V						
25	-3.2V								

Figure 4. Programming V_{OUT}

APPLICATION INFORMATION

Inductor Selection (L)

The important factors for inductor selection are inductance (L), saturation current (I_{SAT}), RMS rating (I_{RMS}), DC resistance (DCR) and dimensions. Use Equation 1 and 2 to calculate the inductor peak current (I_{L_MAX}) and peak-to-peak ripple current (ΔI_L) in static conditions:

$$I_{L\_MAX} = \frac{I_{O\_MAX}}{1\text{-}D} + \frac{\Delta I_L}{2} \qquad (1)$$

$$\Delta I_L = V_{OUT} \times \frac{1-D}{L \times f_{SW}} \qquad (2)$$

I_{O_MAX} is the maximum load current, D represents duty cycle and f_{SW} is the switching frequency.

I_{SAT} should be higher than I_{L_MAX}, and sufficient margin should be reserved. Typically, the saturation current above high-side current limit is enough, and a 10% to 30% ripple current is selected to calculate the inductance. Larger inductance values reduce the ripple current but lead to slower transient response.

Capacitor Selection

The SGM660 requires just a single ceramic capacitor at the input and output side for proper operation. Due to the nature of DC derating of ceramic capacitor, care should be taken to verify enough capacitance at the operating conditions.

A minimal of 3.5μF effective capacitance with 6.3V or higher rating ceramic capacitor is recommended for the input.

The recommended effective output capacitance ranges from 3.5μF to 24μF with minimal of 6.3V voltage rating.
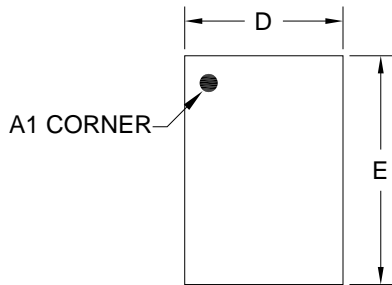
REVISION HISTORY

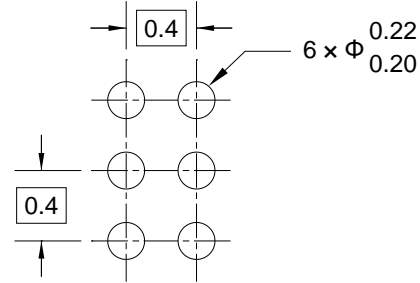NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

PACKAGE OUTLINE DIMENSIONS

WLCSP-0.9×1.3-6B

TOP VIEW

RECOMMENDED LAND PATTERN (Unit: mm)
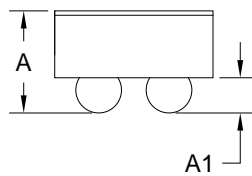
SIDE VIEW
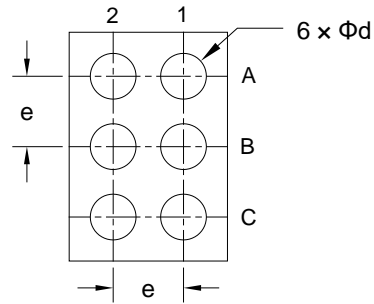
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	**MOD**	**MAX**
A	0.535	0.580	0.625
A1	0.180	0.200	0.220
D	0.870	0.900	0.930
E	1.270	1.300	1.330
d	0.240	0.260	0.280
e	0.400 BSC		

NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS
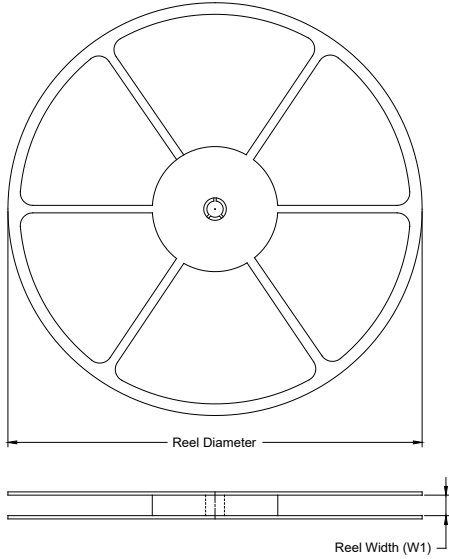
TAPE DIMENSIONS

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

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
WLCSP-0.9×1.3-6B	7″	9.5	1.05	1.45	0.70	4.0	4.0	2.0	8.0	Q1

DD0001

CARTON BOX DIMENSIONS

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

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002