SGM660
Buck-Boost Converter for Negative Output Voltage

GENERAL DESCRIPTION

The SGM660 is an inverting buck-boost converter with adjustable negative output voltage in a tiny 6-ball thin WLCSP package. Its unique control method is designed to provide fast transient response, low output noise and high efficiency. The SGM660 has built-in soft-start, peak current limit, and under-voltage lockout functions with no external compensation required. For ease of use, the digital interface control (SWIRE) pin allows programming of the negative output voltage in digital steps.

FEATURES

- **2.8V to 5.5V Input Voltage Range**
- **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
- **No External Compensation**
- **Internal Soft-Start Function**
- **Shutdown Current: 1μA (MAX)**
- **Available in a Green WLCSP-0.9×1.3-6B Package**

APPLICATIONS

General Purpose Negative Voltage Supply
Negative Rail/Bias Supply for OPA and Data Converters
LCD Biasing
Sensor and Modulator Bias

TYPICAL APPLICATION

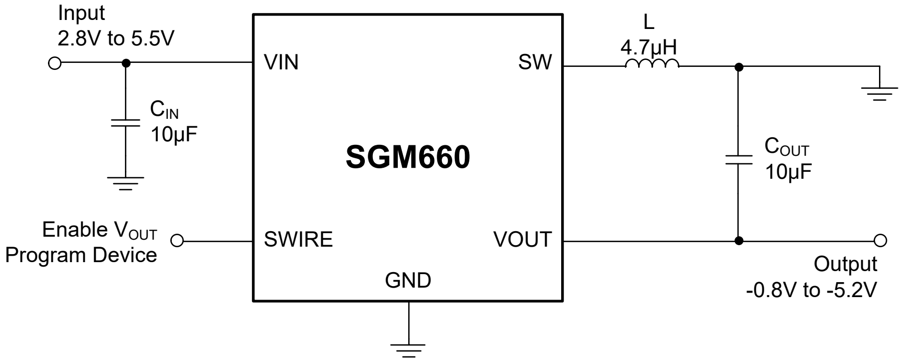


Figure 1. Typical Application Circuit

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.

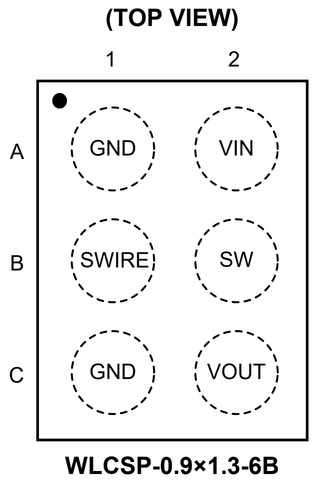
ESD SENSITIVITY CAUTION

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



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

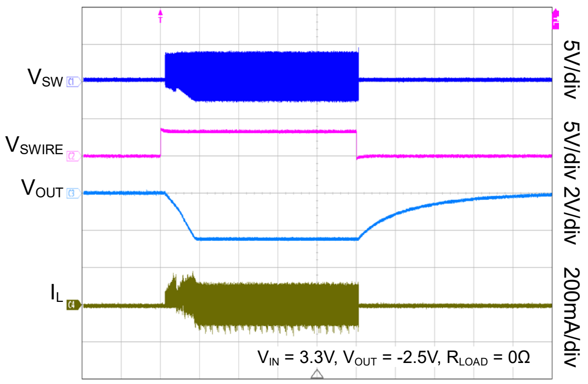
(V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, T_J = -40℃ to +125℃, typical values are at T_J = +25℃, unless otherwise noted.)

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

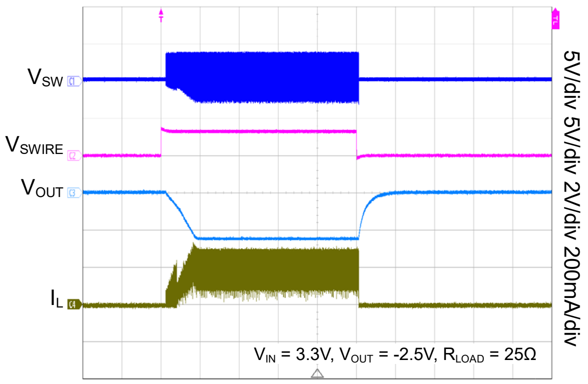
T_J = +25℃, V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, C_{IN} = 10μF, C_{OUT} = 10μF, L = 4.7μH, unless otherwise noted.

Soft-Start and Soft-Off Waveform



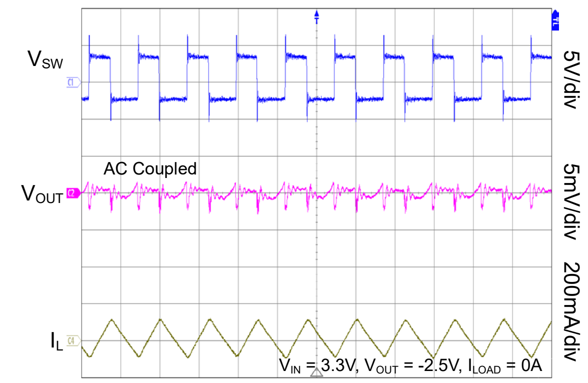
Time (1ms/div)

Soft-Start and Soft-Off Waveform



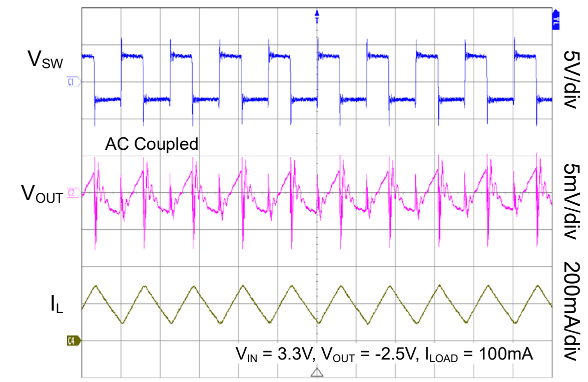
Time (1ms/div)

Typical Switching Waveform



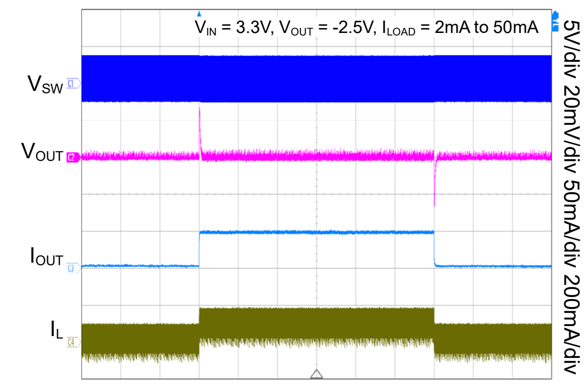
Time (500ns/div)

Typical Switching Waveform



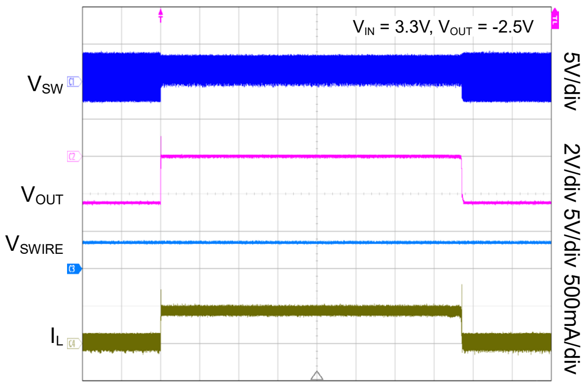
Time (500ns/div)

Load Transient



Time (2ms/div)

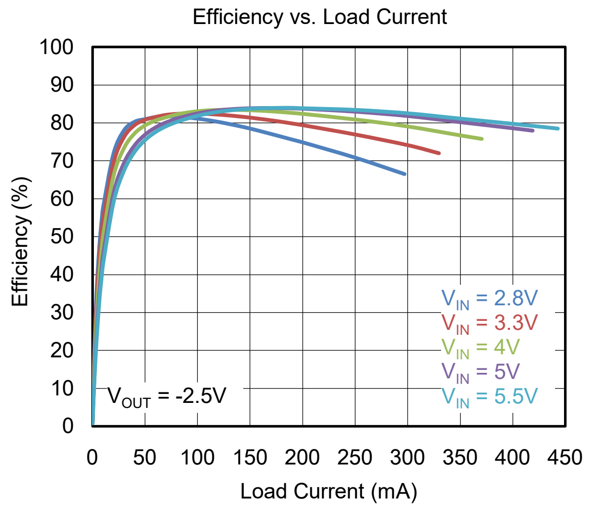
Short Circuit Waveform

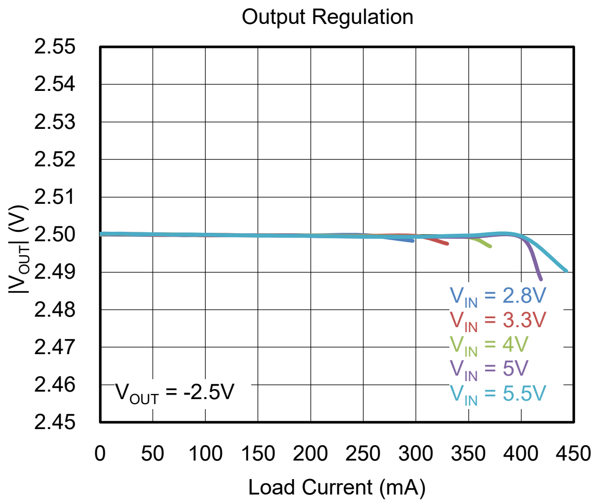


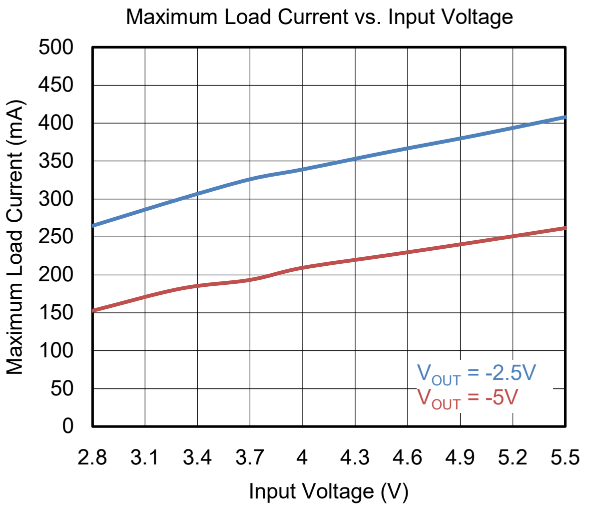
Time (10ms/div)

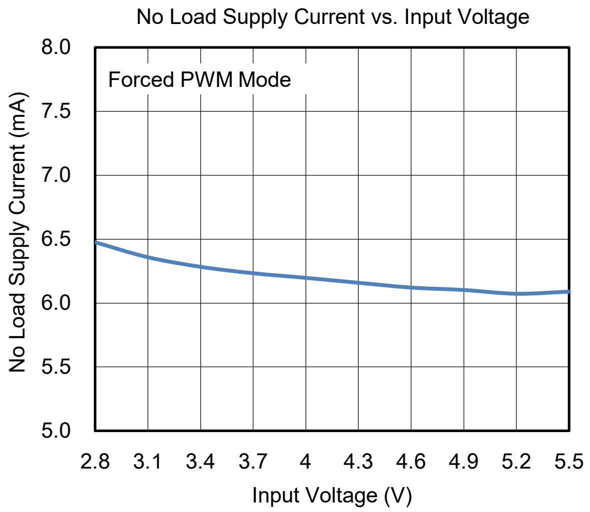
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

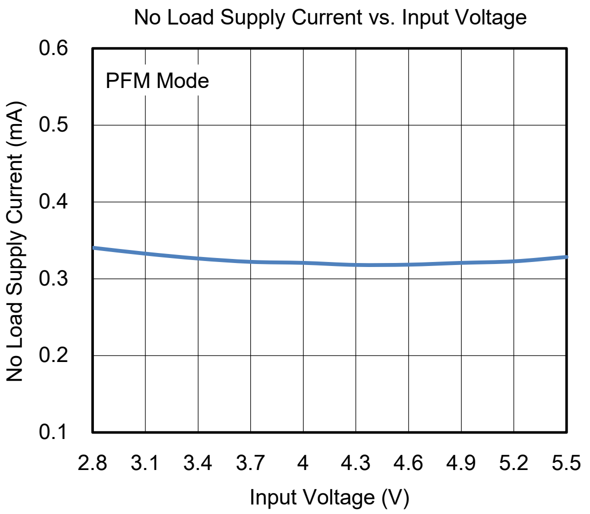
T_J = +25℃, V_{IN} = 3.3V, V_{SWIRE} = V_{IN}, V_{OUT} = -2.5V, C_{IN} = 10μF, C_{OUT} = 10μF, L = 4.7μH, unless otherwise noted.











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	

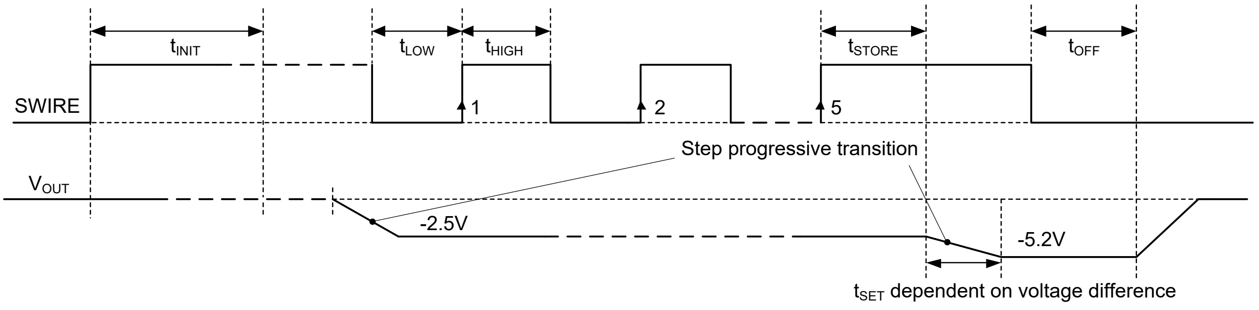


Figure 2. Timing Diagram

FUNCTIONAL BLOCK DIAGRAM

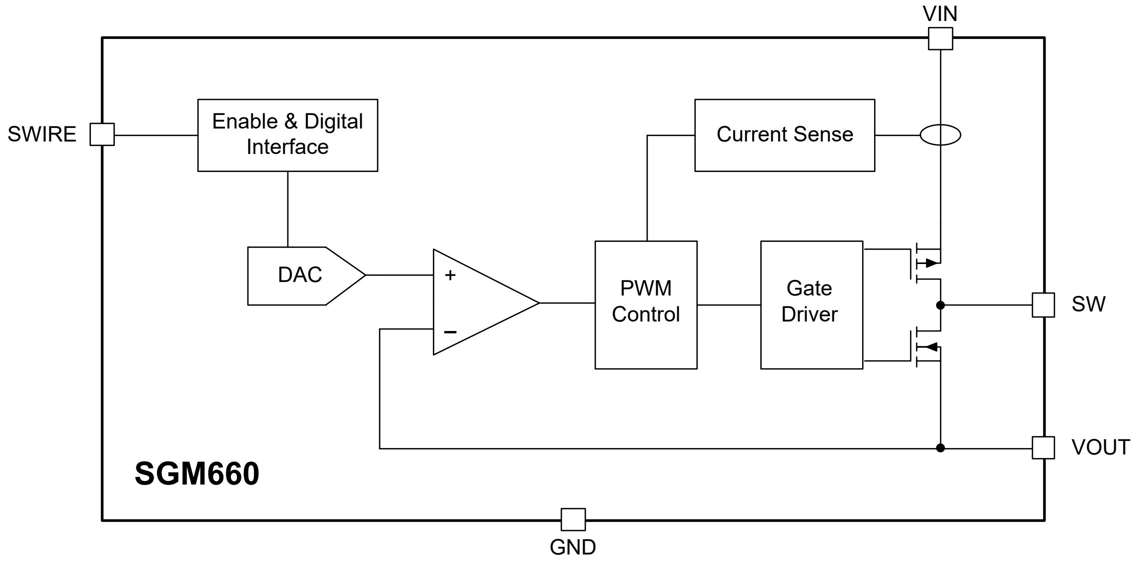


Figure 3. Block Diagram

DETAILED DESCRIPTION

The SGM660 is an inverting buck-boost converter with adjustable negative output voltage in a tiny 6-ball thin WLCSP package. Its unique control method is designed to provide fast transient response, low output noise and high efficiency. The SGM660 has built-in soft-start, peak current limit, and under-voltage lockout (UVLO) functions with no external compensation required. For ease of use, the digital interface control (SWIRE) pin allows programming of the negative output voltage in digital steps.

The device uses 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 device has a built-in under-voltage lockout function that disables the device when the input supply voltage is too low for normal operation.

Thermal Shutdown

A thermal shutdown is implemented to prevent damage caused by excessive heat and power dissipation. Once the temperature exceeds +160℃ (TYP), the device will shut down (the programming is not lost). When the temperature decreases to +140℃ (TYP), the device automatically restarts performing the start-up sequencing with the same voltages and programming as programmed before the thermal shutdown.

Soft-Start

The device has an implemented soft-start which limits the inrush current.

Input Power Supply

The input power supply voltage is recommended between 2.8V and 5.5V, and it should be stable and free of noise if the device's full performance is to be achieved. If the input supply is placed a few centimeters away from the device, additional bulk capacitance is required. The input capacitance shown in Figure 1 is sufficient for typical applications.

Short Circuit Protection

Peak current mode control has inherent short circuit protection. The protection level is the maximum inductor current limit level. It varies with VIN and temperature due to propagation delay.

DETAILED DESCRIPTION (continued)

Digital Interface (SWIRE Pin)

The digital interface allows programming of the negative output voltage V_{OUT} in digital steps. Once the device is enabled, the device starts with its default values (those values are in cells with blue background in Table 1). The interface counts the rising edges applied to the SWIRE pin and sets the new values as shown in Table 1. The settings are stored in a volatile memory. The reset behavior is described in the device reset section. The SWIRE pin can be used as a standard enable pin if programming is not required.

Inverting Buck-Boost Converter (VOUT Pin)

The inverting buck-boost converter uses a constant frequency peak current mode topology. The output voltage is adjustable between -5.2V and -0.8V with a default voltage of -2.5V (see Table 1).

Device Reset

A power cycle resets all settings to default values. 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								

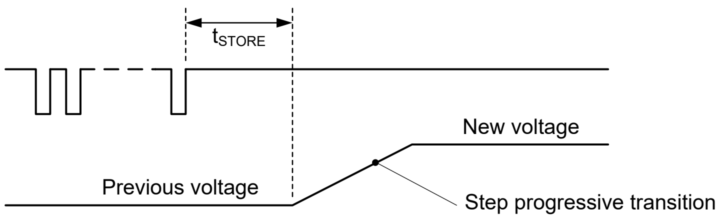


Figure 4. Programming V_{OUT}

APPLICATION INFORMATION

Input Inductor Selection

The main parameter for the inductor selection is the inductor saturation current, which must be higher than the peak switch current. Inductors with saturation current lower than the minimum switch current limit can be used when the maximum output current is not required; however, a minimum saturation current of 0.3A is required to ensure proper start-up. The minimum required saturation current is calculated by the peak inductor current formula.

The inductors DC resistance as well as its core losses affect the efficiency. Lower DC resistance results in higher high load efficiency. The core losses are especially important for light load efficiency. The core material as well as the inductor physical size has an influence on the core losses. The higher the quality factor Q of the inductor at the default switching frequency (1.6MHz), the lower the core losses.

- Minimum 0.8μH, maximum 6.8μH inductance.
- Minimum 0.8A saturation current, for full output current capability 0.3A.
- Minimum V_{IN} and maximum I_{OUT} must be taken to calculate the required saturation current.
- Duty Cycle:

$$D = \frac{V_{OUT}}{V_{OUT} - V_{IN} \times \eta} \tag{1}$$

where:
V_{IN} is the inverting buck-boost converter input supply voltage.
V_{OUT} is the inverting buck-boost converter output voltage.
η is the inverting buck-boost converter efficiency.

- Peak Inductor Current:

$$I_{SW} = \frac{I_{OUT}}{1 - D} + \frac{V_{IN} \times D}{2 \times f \times L} \tag{2}$$

where:
I_{OUT} is the inverting buck-boost converter output current.
f is the inverting buck-boost converter default switching frequency (1.6MHz).
L is the inverting buck-boost converter inductance (4.7μH).

Capacitor Selection

The main parameter for the capacitor selection is the capacitance at the operating voltage. The more voltage applies to the capacitor, the lower capacitance it produces (DC-bias effect). Temperature and AC-voltage also change the capacitance, but the DC-bias effect is dominant. For best voltage filtering (lowest voltage ripple), low ESR capacitors are recommended.

Input Capacitor:

- Minimum 3.5μF resulting capacitance.
- Minimum 6.3V voltage rating.

Output Capacitor:

- Minimum 3.5μF, maximum 24μF resulting capacitance.
- Minimum 10V voltage rating, when the maximum -5.2V is used, 6.3V rated capacitors can also be used.

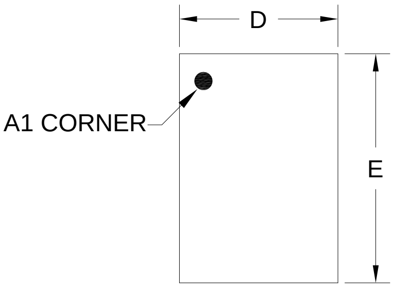
REVISION HISTORY

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

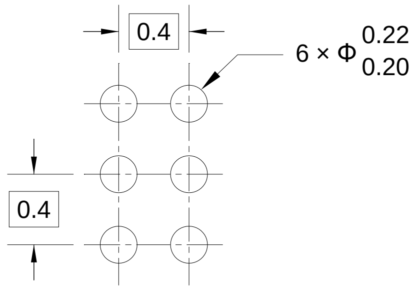
Changes from Original (AUGUST 2021) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

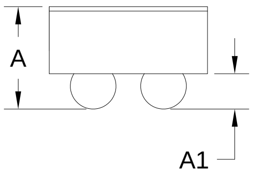
WLCSP-0.9×1.3-6B



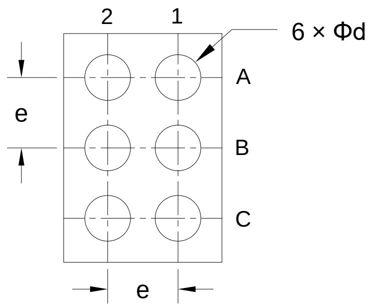
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



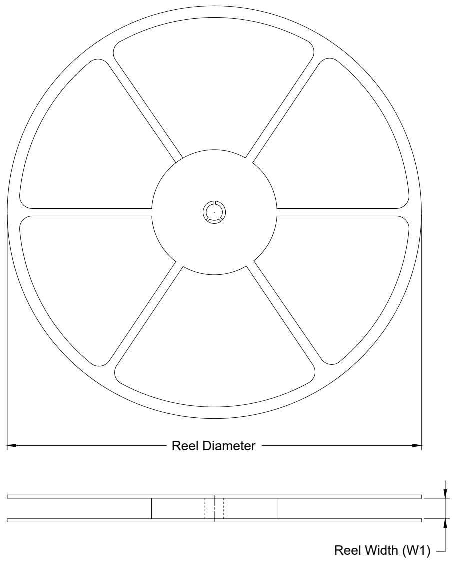
BOTTOM VIEW

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		

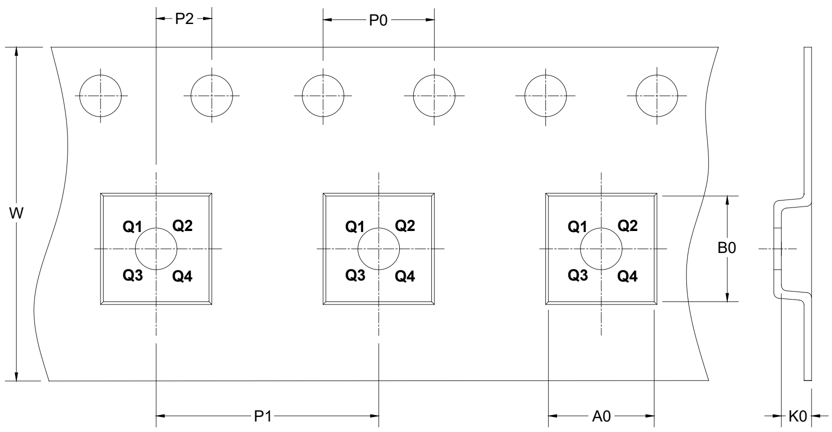
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

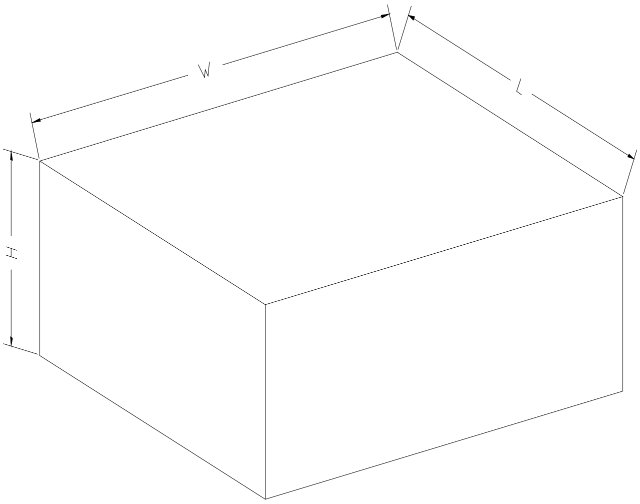
NOTE: The picture is only for reference. Please make the object as the standard.

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
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