SGM3111
3.3V Buck/Boost Charge Pump DC/DC Converter

GENERAL DESCRIPTION

The SGM3111 is a Buck/Boost charge pump DC/DC converter that can deliver a fixed output voltage of 3.3V from an input supply voltage range of 1.8V to 5.5V.

When the input voltage drops to 100mV lower than the output voltage, the chip will smoothly switch to Boost mode. In Boost mode, the SGM3111 is used as a constant frequency of 1.2MHz double charge pump. When the input voltage rises above the regulated output voltage, the chip enters a Buck mode, which can be used for low dropout linear regulators to step down.

The soft-start circuit of SGM3111 can limit the inrush current during startup. A current-limiting circuit and thermal shutdown allow the device to accept a sustained short-circuit of the output to ground. Low operating current (60μA, TYP) during no-load operation and ultra-low shutdown operating current (< 0.6μA) make the device more power efficient.

The application of SGM3111 only needs three ceramic capacitors with small package size. The SGM3111 is available in a Green TDFN-2×2-6FL package.

FEATURES

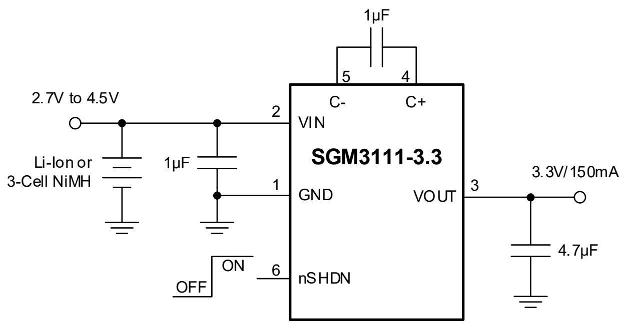
- **Input Supply Voltage Range: 1.8V to 5.5V**
- **Fixed 3.3V Output**
- **Up to 150mA Output Current**
- **Mode Automatic Switching**
- **1.2MHz Switching Frequency in Boost Mode**
- **Operation in Low Dropout Linear Regulator in Buck Mode**
- **No-Load Quiescent Current: 60μA (TYP)**
- **Less than 0.6μA Ultra-Low Shutdown Current**
- **Soft-Start Circuit Limits Inrush Current**
- **Input Disconnected from Load during Shutdown**
- **Short-Circuit Protection**
- **Thermal Shutdown**
- **Available in a Green TDFN-2×2-6FL Package**

APPLICATIONS

2-3AA/Li-Ion to 3.3V

Low Power Device for I/O Supplies, Cameras, Audio, Misc. PC Cards, Logic, etc., in Different Kinds of Handheld Products

TYPICAL APPLICATION



Li-Ion to 3.3V at Up to 150mA

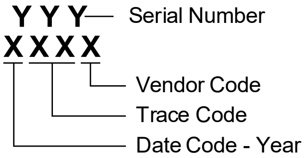
Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM3111-3.3	TDFN-2×2-6FL	-40℃ to +85℃	SGM3111-3.3YTGL6G/TR	08R XXXX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXX = Date Code, Trace Code and Vendor Code.



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	-0.3V to 6V
VOUT to GND	-0.3V to 5.5V
nSHDN to GND	-0.3V to (V_{IN} + 0.3V)
VOUT Short-Circuit Duration	Indefinite
Package Thermal Resistance	
TDFN-2×2-6FL, θ_{JA}	106℃/W
Junction Temperature	+150℃
Storage Temperature Range	-65℃ to +150℃
Lead Temperature (Soldering, 10s)	+260℃
ESD Susceptibility	
HBM	4000V
CDM	1000V

RECOMMENDED OPERATING CONDITIONS

Operating Ambient Temperature Range	-40℃ to +85℃
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.

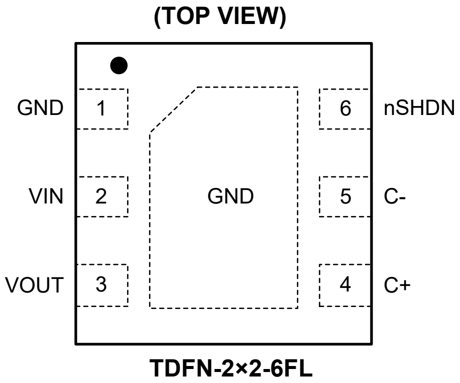
ESD SENSITIVITY CAUTION

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
1	GND	Ground. This pin needs to be connected to the GND layer of the PCB board.
2	VIN	Input Supply Pin. Connect a small package ceramic capacitor at least 1μF close to this pin.
3	VOUT	Regulated Output Voltage Pin. Place a small package ceramic capacitor at least 4.7μF next to this pin for decoupling.
4	C+	Positive Terminal of Flying Capacitor.
5	C-	Negative Terminal of Flying Capacitor.
6	nSHDN	Active Low Shutdown Input Pin. Connecting the nSHDN pin to GND shuts down the SGM3111. It is CMOS high-impedance input and must be driven by a valid level. Don’t leave it floating.
Exposed Pad	GND	Ground. The exposed pad needs to be connected to the PCB ground to form a ground return and transfer the heat of the chip to the copper of the PCB.

ELECTRICAL CHARACTERISTICS

(nSHDN = V_{IN}, C_{FLY} = 1μF, C_{IN} = 1μF, C_{OUT} = 4.7μF, T_A = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise noted.)

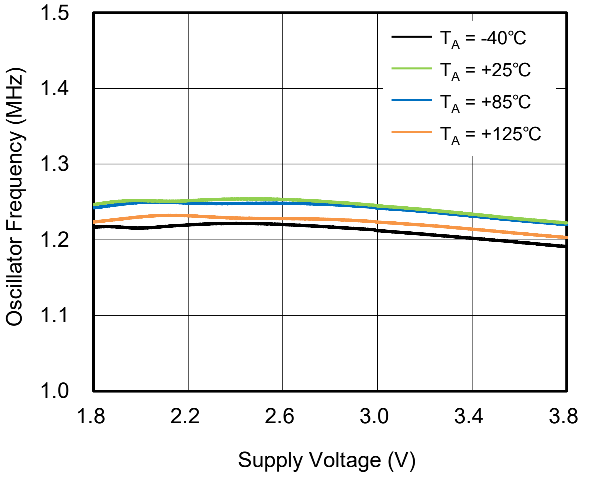
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		1.8		5.5	V
Output Voltage Range	V_{OUT}	1.8V ≤ V_{IN} ≤ 2.5V, in burst mode	3.168	3.300	3.432	V
		2.5V ≤ V_{IN} ≤ 5.5V, I_{OUT} < 150mA	3.168	3.300	3.432	
No Load Input Current	I_{IN}	V_{OUT} = 3.6V, 1.8V ≤ V_{IN} ≤ 3.65V, T_A = +25℃		45	70	μA
		V_{OUT} = 3.6V, 1.8V ≤ V_{IN} ≤ 3.65V			80	
		I_{OUT} = 0, 3.45V ≤ V_{IN} ≤ 5.5V, T_A = +25℃		60	90	
		I_{OUT} = 0, 3.45V ≤ V_{IN} ≤ 5.5V			100	
Shutdown Current	I_{nSHDN}	I_{nSHDN} = 0V, V_{OUT} = 0V, T_A = +25℃		0.0	0.6	μA
		I_{nSHDN} = 0V, V_{OUT} = 0V			1.0	
Efficiency	η	V_{IN} = 2.5V, I_{OUT} = 100mA		65		%
		V_{IN} = 3.7V, I_{OUT} = 100mA		89		
nSHDN Input High Voltage	V_{IH}	1.8V ≤ V_{IN} ≤ 5.5V	1.2			V
nSHDN Input Low Voltage	V_{IL}	1.8V ≤ V_{IN} ≤ 5.5V			0.4	V
nSHDN Input Current	I_{IH}	V_{nSHDN} = V_{IN} = 5.5V	-1		1	μA
nSHDN Input Current	I_{IL}	V_{nSHDN} = 0V	-1		1	μA
Output Current Limit	I_{LIM}	V_{IN} = 3.7V, V_{OUT} = 0V, Buck mode		340		mA
		V_{IN} = 2.4V, V_{OUT} = 0V, Buck mode		300		
V_{OUT} Turn-On Time	t_{ON}	From the rising edge of nSHDN to 90% of V_{OUT} V_{IN} = 2.5V, R_{LOAD} = 66Ω		0.5		ms
		V_{IN} = 3.7V, R_{LOAD} = 66Ω		0.6		
Step-Up Mode						
Burst Mode Threshold	I_{BURST}	V_{IN} = 2.4V		12		mA
Output Ripple	V_{RIPPLE}	I_{OUT} = 100mA, V_{OUT} = 2.5V or 3.3V		23		mV_{P-P}
Switching Frequency	f_{OSC}	V_{IN} = 2.4V	0.8	1.2	1.6	MHz
Burst Mode Output Ripple	$V_{RIPPLE(BURST)}$	V_{IN} = 2.4V		20		mV_{P-P}
Effective Open-Loop Output Resistance (1)	R_{OL}	Doubler Mode V_{IN} = 1.8V, V_{OUT} = 3V		7.2		Ω

NOTE: $R_{OL} = (2V_{IN} - V_{OUT})/I_{OUT}$.

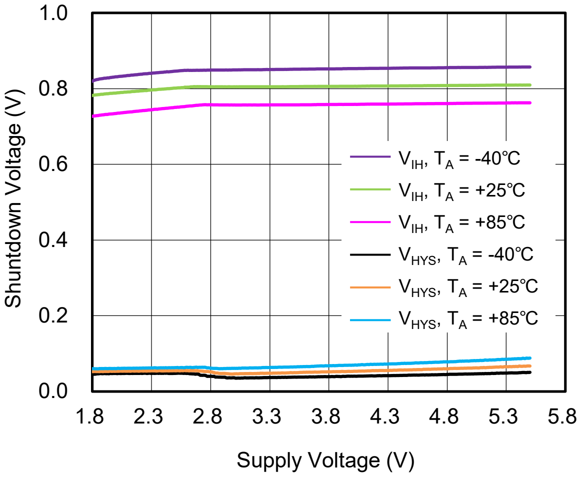
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, C_{OUT} = 4.7μF, C_{FLY} = C_{IN} = 1μF, unless otherwise noted.

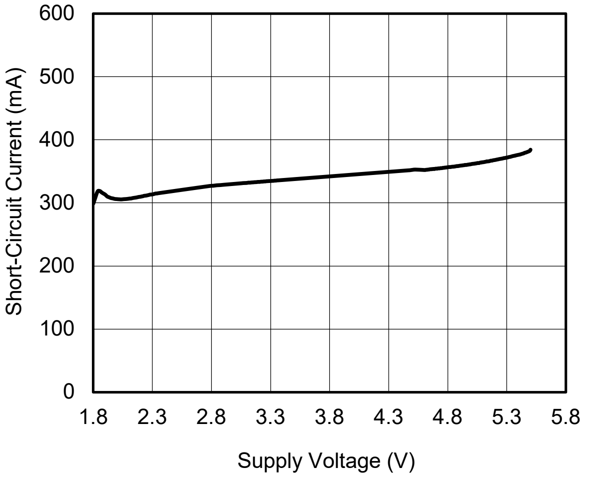
Oscillator Frequency vs. Supply Voltage (Doubler Mode)



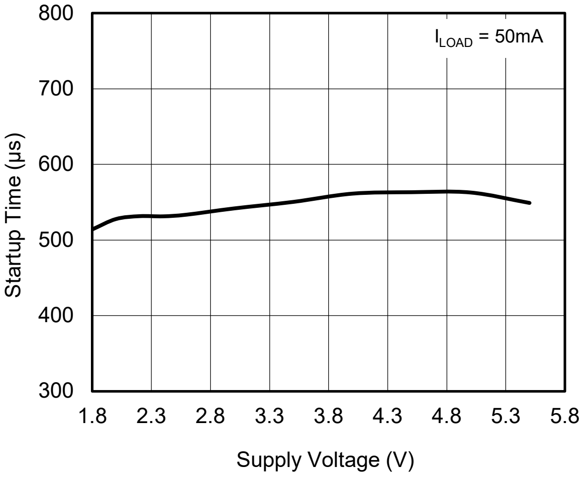
nSHDN Threshold Voltage vs. Supply Voltage



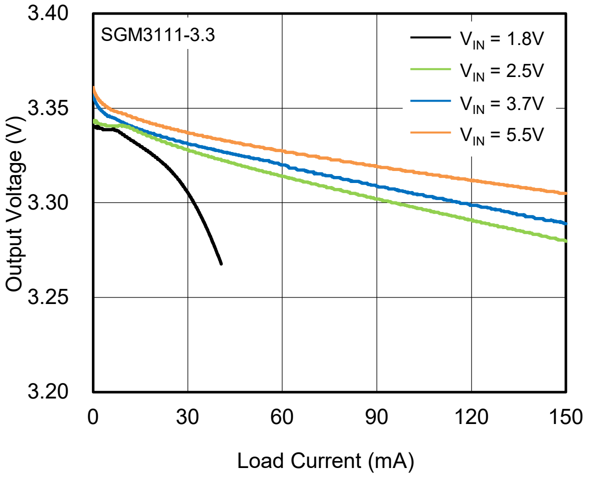
Short-Circuit Current vs. Supply Voltage



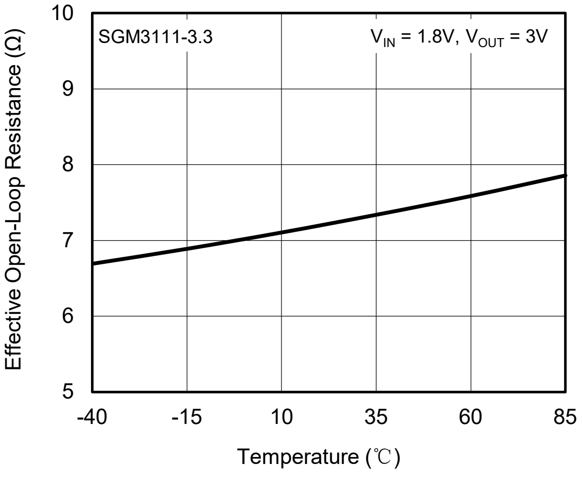
Startup Time vs. Supply Voltage



Load Regulation



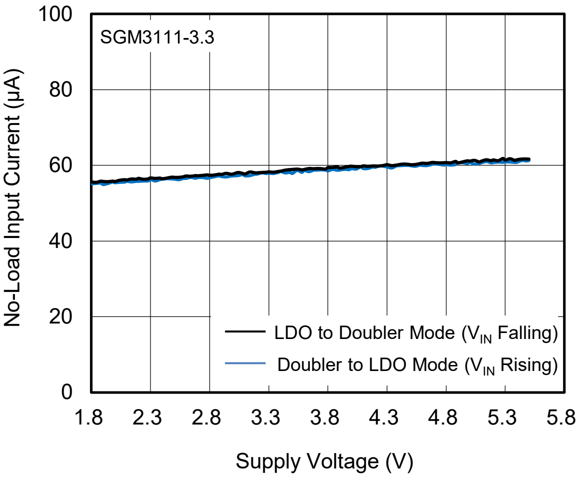
Effective Open-Loop Resistance vs. Temperature



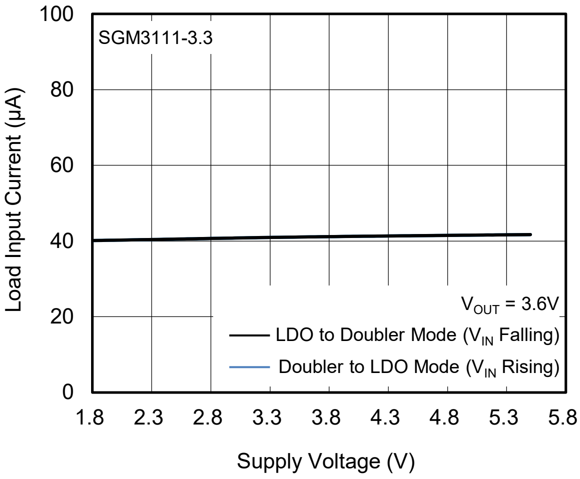
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, C_{OUT} = 4.7μF, C_{FLY} = C_{IN} = 1μF, unless otherwise noted.

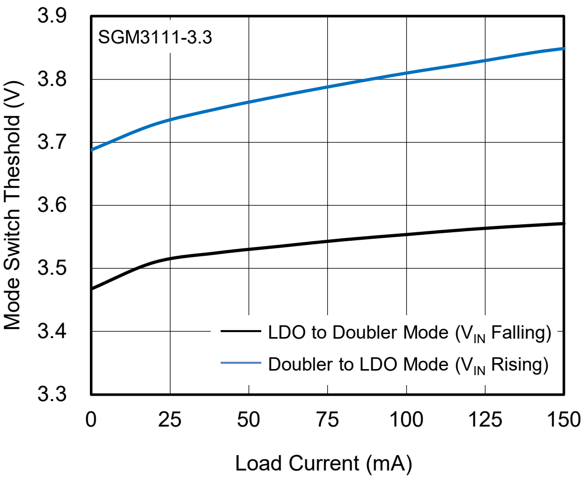
No-Load Input Current vs. Supply Voltage



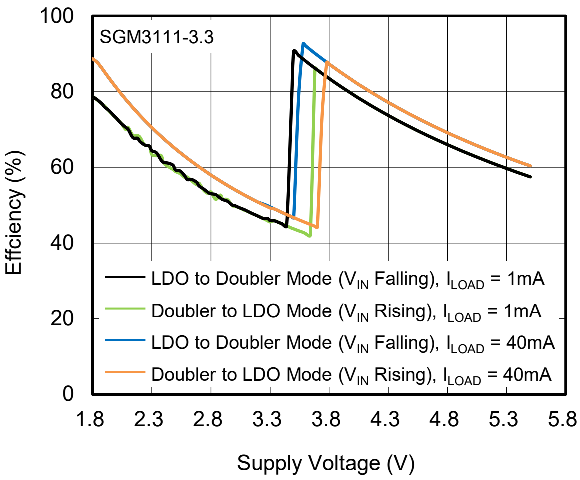
Load Input Current vs. Supply Voltage



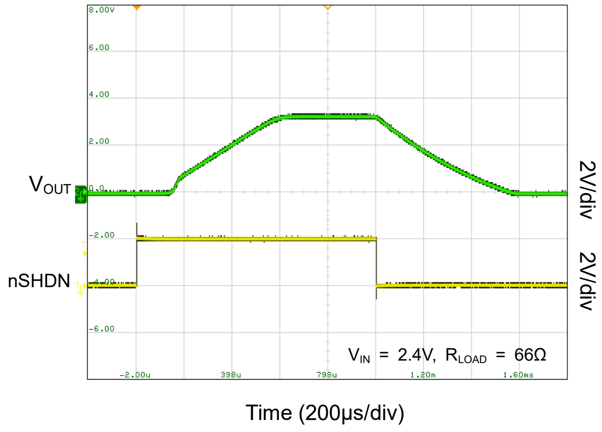
Mode Switch Threshold vs. Load Current



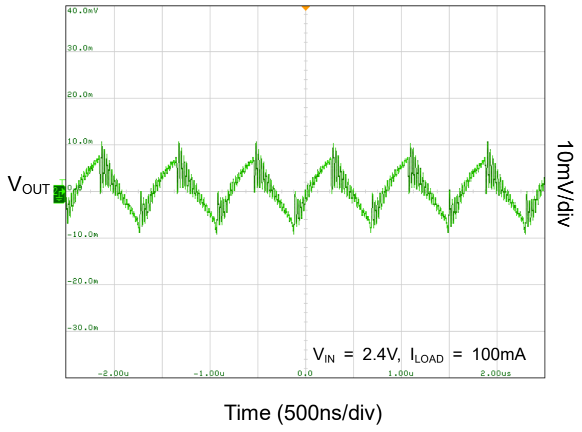
Efficiency vs. Supply Voltage



V_{OUT} Soft-Start

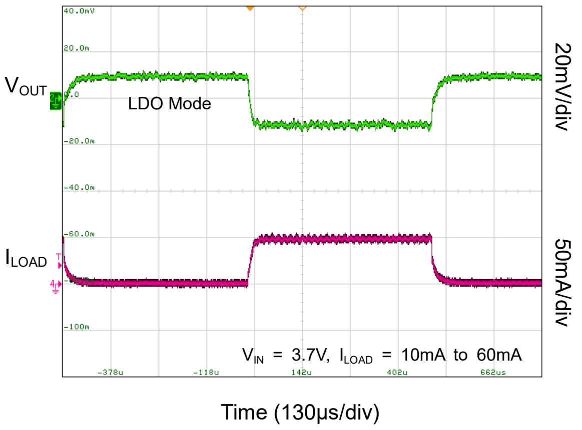


Output Noise/Ripple

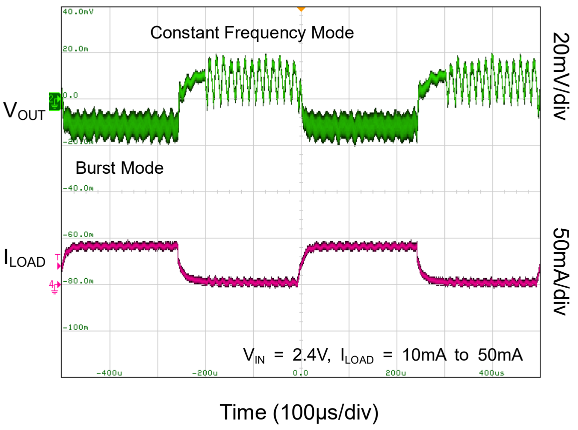


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, C_{OUT} = 4.7μF, C_{FLY} = C_{IN} = 1μF, unless otherwise noted.



Load Transient Response



Load Transient Response

FUNCTIONAL BLOCK DIAGRAM

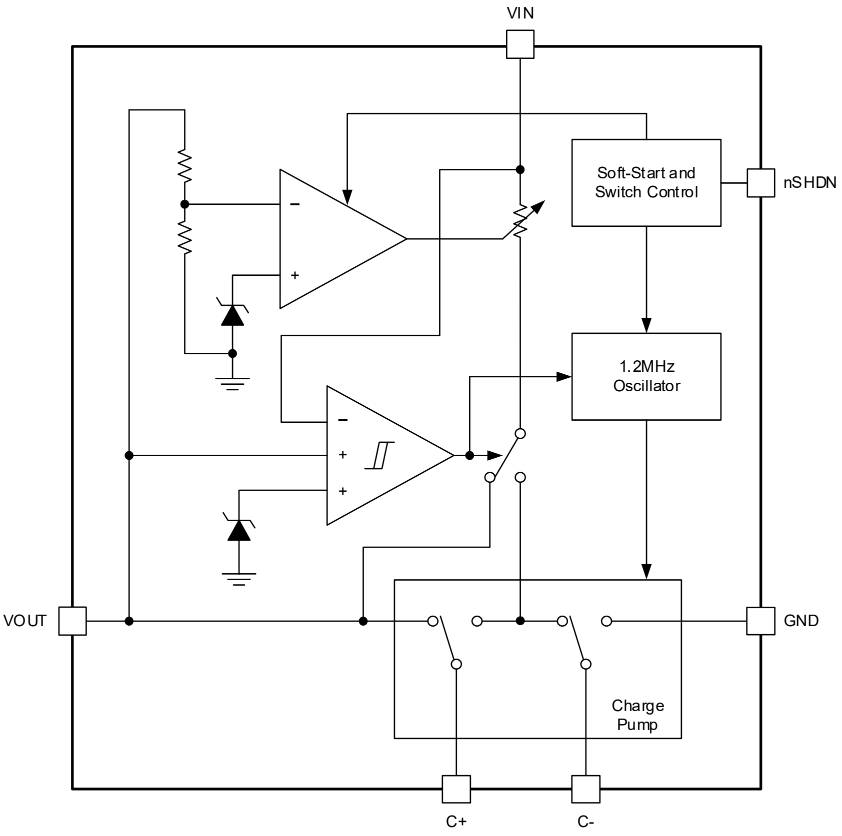


Figure 2. Functional Block Diagram

DETAILED DESCRIPTION

The SGM3111 is a Buck/Boost DC/DC charge pump converter. When the input voltage is about 100mV greater than the output voltage, it works in LDO state. Once the input voltage falls to less than 100mV above the output voltage, the device automatically switches to charge pump mode to boost the output voltage to the desired level. Voltage regulation is achieved by the inside dividing resistor, and the output current of the charge pump is adjusted according to the error signal of error amplifier.

In charge pump mode, a non-overlapping two-phase clock will enable the charge pump switch. In the first phase of the clock, the flying capacitor is charged from the input voltage. In the second phase of the clock, it is in series with VIN and connected to the output capacitor. The charging and discharging sequence of the flying capacitor will continue to operate at a switching frequency of 1.2MHz (TYP).

Shutdown Mode

In enable shutdown mode, all circuits stop working and the chip only consumes leakage current from the VIN pin. Also, the input and output voltages are completely disconnected. nSHDN, a CMOS input, has a turn-on voltage of about 0.8V. When the nSHDN pin is tied to a low logic level, the SGM3111 circuit is completely shut down. nSHDN is a CMOS high-impedance input pin and must be driven by a valid level and cannot be left floating.

Burst Mode Operation

When the chip works in charge pump mode and light load, it can enter automatic burst mode operation, thereby improving converter efficiency. Burst mode is automatically entered when the load current is lower than the internally set threshold. Once the chip enters burst mode, it will enter sleep state and the internal clock is turned off to reduce switching losses. The device only consumes 60μA from VIN in this low consumption state. When V_{OUT} drops below the threshold set by the comparator, the IC will re-run at the normal operating frequency and continue to supply energy to the output capacitor. If the output current remains below the burst mode setting, the IC will restart sleep mode. As VIN, VOUT, and the output capacitance change, the burst-mode threshold will also change.

Soft-Start

The SGM3111 adopts soft-start mode when starting, which can reduce inrush current. The soft-start circuit is implemented by an internal setting, and the circuit realizes that the load capacity of the output capacitor is raised from 0mA to 300mA in about 0.5ms. The circuit resets on thermal shutdown or power-down.

Short-Circuit Protection/Thermal Shutdown

The SGM3111 integrates the functions of over-temperature protection and short-circuit current limiting. When shorted, the output current is automatically limited to around 300mA by the device. Once the junction temperature (T_J) is above approximately +160℃, the thermal shutdown circuit prevents current from flowing to VOUT pin. When T_J falls below approximately +150℃, the device resumes operation. When an over-temperature condition occurs, the device will cycle in and out of thermal shutdown without damage or latch-up. When VOUT is no longer shorted, the thermal shutdown mechanism is exited. Prolonged thermal stress (i.e. working in an environment higher than +125℃) is still avoided in use, as it will reduce the operating time of the device and cause performance degradation.

APPLICATION INFORMATION

Power Efficiency

When working in LDO state, the efficiency (η) of SGM3111 is calculated by the following Equation:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times I_{OUT}} = \frac{V_{OUT}}{V_{IN}} \qquad (1)$$

At moderate to high output currents, the quiescent current of the IC can be approximately ignored. Use Equation 1 to caculate the efficiency. If V_{IN} is 3.7V, I_{OUT} is 100mA and V_{OUT} is 3.3V, then the calculated efficiency (η) will be about 89% which is close to the measured value of 89%.

When operating in a charge pump state, the efficiency (η) of the SGM3111 is similar to that of an LDO with an effective input voltage equal to twice the actual input voltage. This is because the output current of the voltage doubler charge pump is approximately one-half the input current. In an ideal voltage doubler charge pump, the efficiency calculation is given by:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 2I_{OUT}} = \frac{V_{OUT}}{2V_{IN}} \qquad (2)$$

At moderate to high output currents, the IC's quiescent current and switching losses can be ignored. Use Equation 2 to caculate the efficiency. If V_{IN} is 2.5V, V_{OUT} is 3.3V, and I_{OUT} is 100mA, then the calculated efficiency (η) will be 66% which is close to the measured value of 65%.

Effective Open-Loop Output Resistance (R_{OL})

Another important determinant of charge pump strength is the effective open-loop output resistance (R_{OL}). The value of this resistor is affected by many factors, such as the flying capacitor (C_{FLY}), the oscillator frequency (f_{OSC}), and the ESR of the external capacitor and internal switch resistance (R_S), non-overlapping time, etc. A first-order approximation of R_{OL} is calculated as:

$$R_{OL} \cong 2 \sum_{S=1T04} R_S + \frac{1}{f_{OSC} \times C_{FLY}} \qquad (3)$$

If the IC works in a charge pump state, use Equation 4 to caculate the maximum output voltage and the available current as shown in Figure 3.

$$I_{OUT} = \frac{2V_{IN} - V_{OUT}}{R_{OL}} \qquad (4)$$

where:

$2V_{IN}$ is the effective output voltage.

R_{OL} is the effective open-loop output resistance.

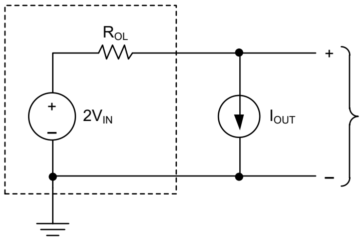


Figure 3. Equivalent Open-Loop Circuit

Input and Output Capacitor Selection

The size and type of capacitors selected for the SGM3111 determines several key parameters such as output ripple, loop stability, start-up time, and charge pump strength.

It is recommended to connect low ESR (< 0.1Ω) ceramic capacitors on C_{IN} and C_{OUT} to increase ripple and noise immunty. The actual capacitance of C_{IN} should be at least 1μF, and the actual capacitance value of C_{OUT} should be at least 4.7μF. It is not recommended to use Aluminum or Tantalum capacitors due to their higher ESR.

In the charge pump state, the size of C_{OUT} directly determines the ripple size of the corresponding output current. Larger C_{OUT} will reduce output ripple, however, it also increase the minimum start-up time.

Use Equation 5 to caculate the peak-to-peak output ripple approximately.

$$V_{RIPPLE(P-P)} = \frac{I_{OUT}}{2f_{OSC} \times C_{OUT}} \qquad (5)$$

where:

C_{OUT} is the actual output capacitor value.

f_{OSC} is the oscillator operating frequency (1.2MHz, TYP).

APPLICATION INFORMATION (continued)

In addition, the package and value of the output capacitor will have a great impact on the stability of the SGM3111. As shown in Figure 2, a linear loop control is designed to adjust the strength of the charge pump in order to the match the desired output current. The error signal of this control loop acts directly on the output capacitor through a linear loop. And the dominant pole of the control loop is formed by the output capacitor. To avoid instability or oscillation of the SGM3111, it is necessary to keep the output capacitor larger than 2μF under any conditions.

The larger ESR of the output capacitor will also affect the chip loop stability. The designed SGM3111 closed-loop output impedance is 0.5Ω. When the load current changes by 100mA, the output voltage will fluctuate by about 50mV. When using a 0.5Ω or larger ESR output capacitor, the closed-loop frequency response will no longer drop through a simple single-pole, which may result in poor load transient response or loop instability. The characteristics of low ESR of ceramic capacitors, combined with a reasonable circuit board layout, will produce superior transient response and good stability.

In charge pump mode, just as the output capacitor affects the output ripple, the input capacitor also affects the input voltage ripple. The chip maintains a relatively constant input current during both the input charging and output charging phases, and is zero during non-overlapping times. Although the chip has a short non-overlapping time (typically ~25ns), this state still produces a small perturbation on the input power line. Ceramic capacitors with low ESR will produce less input noise than capacitors with higher ESR such as tantalum capacitors. Therefore, it is necessary to choose capacitors with good ESR performance, and ceramic capacitors are still recommended here.

Inserting a smaller inductor at the input of the chip can attenuate the input noise, as shown in Figure 4. A 10nH inductor will attenuate the input current ripple so that the current load on the input remains nearly constant. Considering economic factors, a 10nH inductor can be made from a PCB board, and the trace length is about 1cm (0.4").

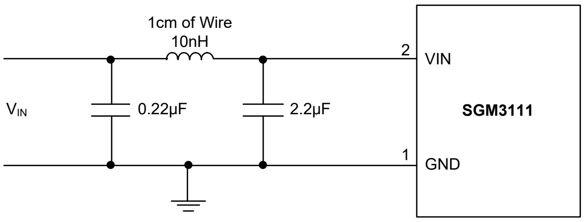


Figure 4. 10nH Inductor Used for Additional Input Noise Reduction

Flying Capacitor Selection

WARNING: Flying capacitors must not be used with polarized capacitors (such as aluminum or tantalum), as it will sustain reverse voltage when the chip starts up. It is appropriate to choose a low ESR ceramic capacitor as the flying capacitor.

The strength of the charge pump is controlled by the flying capacitor. It is recommended to use at least 1μF ceramic capacitors as flying capacitors. For V_{OUT} = 3.3V and 1.8V ≤ V_{IN} ≤ 2.5V, when a rated current of 40mA is required, a flying capacitor value greater than 0.5μF should be selected.

When the chip works in a very light load condition, the flying capacitor value can be reduced to compress space and reduce costs. The paragraph "Effective open-loop output resistance" gives a first-order approximation of R_{OL}, and the theoretical minimum output impedance of the charge pump can be calculated by:

$$R_{OL(MIN)} = \frac{2V_{IN} - V_{OUT}}{I_{OUT}} \cong \frac{1}{f_{OSC} \times C_{FLY}} \qquad (6)$$

where f_{OSC} is the switching frequency (1.2MHz) and C_{FLY} is the value of the flying capacitor. Due to the on-resistance of MOS, the actual strength of the charge pump will be smaller than the theoretical calculation. However, when the load is relatively light, the startup capacitor value can be obtained from the above expression.

APPLICATION INFORMATION (continued)

Ceramic Capacitors

Ceramic capacitors with different materials have different capacitance derating at higher voltage or temperature. For example, in the range of -40℃ to +85℃, the capacitance of X5R or X7R material will not decrease much, but the capacitance of Z5U or Y5V type capacitor will decrease significantly. Z5U and Y5V capacitors have low voltage coefficients and their capacitances decrease by 60% or more when rated voltage is applied. Therefore, when comparing different capacitors, it is usually more reasonable to compare the actual capacitance value under the same package, rather than the nominal capacitance value. For example, the capacitance of a 4.7μF 10V Y5V ceramic capacitor of 0805 package is only 25% of its rated capacitance over the full temperature range and at 3.3V, but the actual capacitance of a 4.7μF 10V X5R ceramic capacitor under the same conditions can reach 80% of the rated capacitance. The user should check the capacitor manufacturer's manual to ensure that the desired capacitance is obtained over the entire voltage and temperature range.

Optional ceramic capacitor manufacturers are AVX, Kemet, Murata, Taiyo Yuden, Vishay, TDK, etc.

Thermal Management

When the SGM3111 is used in the conditions of larger output current and higher input voltage, the chip may consume more power. When the junction temperature of the chip exceeds about +160℃, the thermal shutdown circuit will stop the chip output current. For better heat dissipation, it is recommended that the chip is in good contact with the copper layer of the board. Connecting the exposed pad of the TDFN package and GND (pin 1) together to the ground plane under the board can effectively reduce the thermal resistance between the PCB board and the package.

Derating Power at High Temperatures

In order to avoid overheating of the chip during high current output, it is necessary to obtain the maximum power consumption at different ambient temperatures according to Figure 5.

The loss of the SGM3111 needs to be always less than the power value corresponding to a given ambient temperature. Chip losses in charge pump mode are calculated by:

$$P_D = (2V_{IN} - V_{OUT}) \times I_{OUT} \tag{7}$$

The power dissipation in Buck mode is given by:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \tag{8}$$

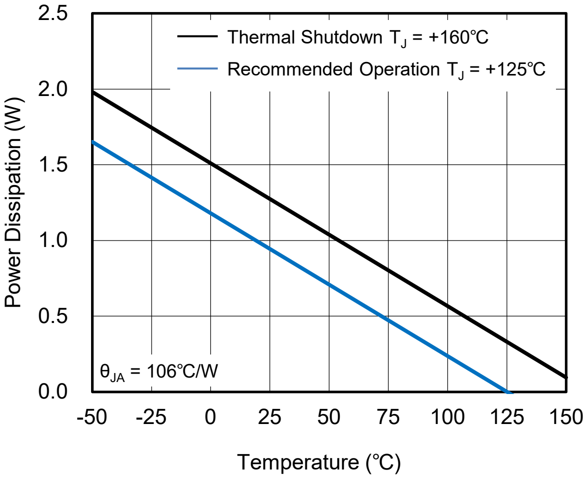


Figure 5. Maximum Power Dissipation vs. Ambient Temperature

This derating curve is obtained assuming that the maximum thermal resistance θ_{JA} of the TDFN-2×2-6FL package is 106℃/W. This curve can be achieved by a good connection between the ground plane of the PCB and the exposed pad of the TDFN and the ground pin of the chip.

It is recommended that the chip work continuously in the region where $T_J \leq$ +125℃ , as shown in Figure 5. In the range of +125℃ ≤ $T_J \leq$ +160℃ , the chip can work for a short time, but it should be forbidden to work in this area for a long time, because it may cause the performance or life cycle of the device to decrease. In the region of $T_J \geq$ +160℃, the chip remains in thermal shutdown state.

APPLICATION INFORMATION (continued)

Layout Guidelines

Due to the high transient current and switching frequency of this chip, a reasonable board layout is required to achieve superior performance. Set up a true ground plane and route all capacitor grounds to GND as short as possible to optimize performance and correct voltage regulation. Figure 6 shows a layout example of the SGM3111.

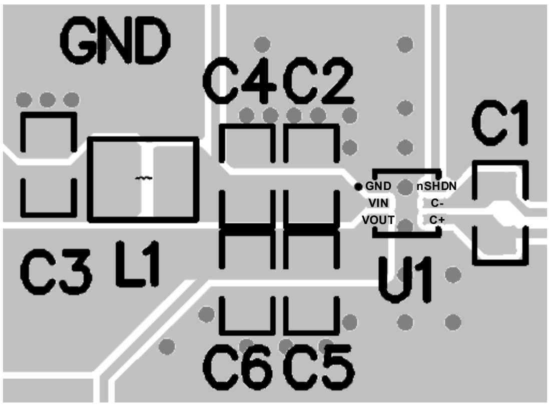


Figure 6. PCB Layout Reference

REVISION HISTORY

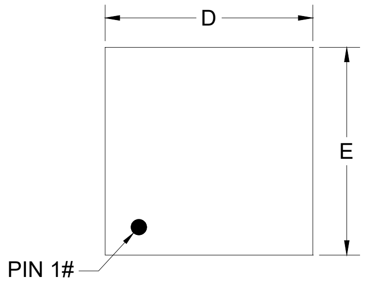
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (JULY 2023) to REV.A

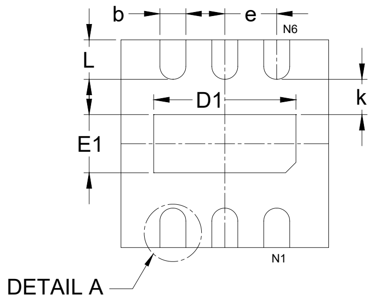
Changed from product preview to production data .... All

PACKAGE OUTLINE DIMENSIONS

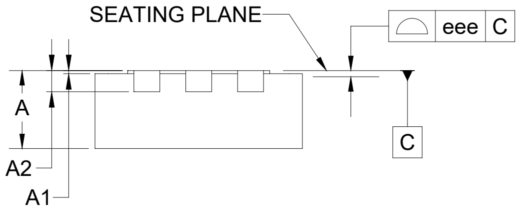
TDFN-2×2-6FL



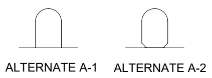
TOP VIEW



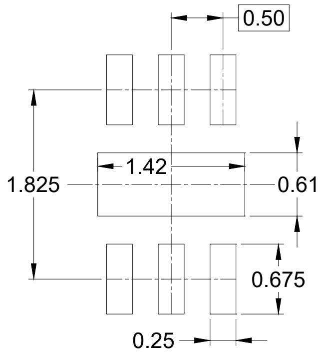
BOTTOM VIEW



SIDE VIEW



DETAIL A
ALTERNATE TERMINAL
CONSTRUCTION



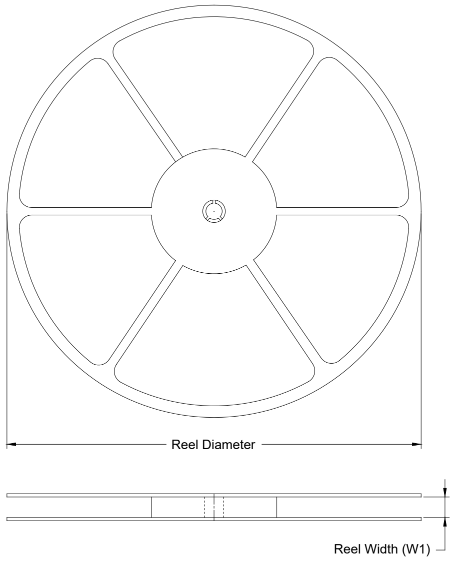
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.700	-	0.800
A1	0.000	-	0.050
A2	0.203 REF		
b	0.200	-	0.300
D	1.900	-	2.100
D1	1.270	-	1.470
E	1.900	-	2.100
E1	0.460	-	0.660
k	0.200	-	-
e	0.500 BSC		
L	0.280	-	0.480
eee	0.080		

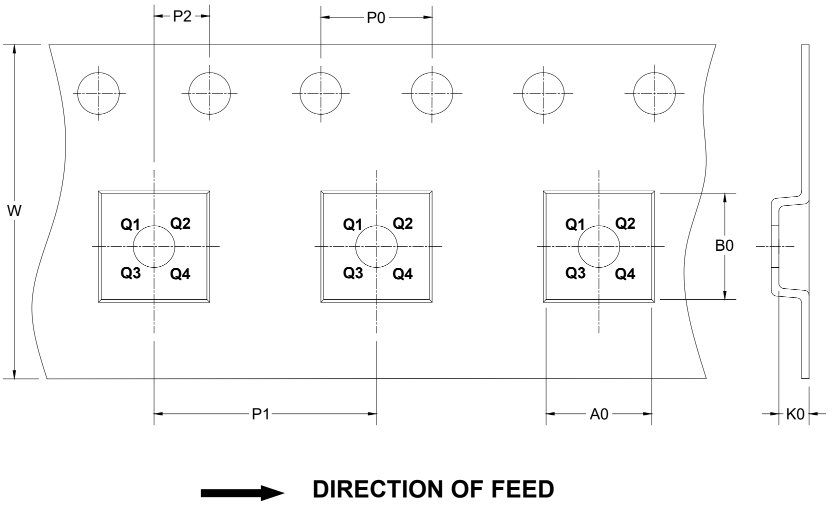
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



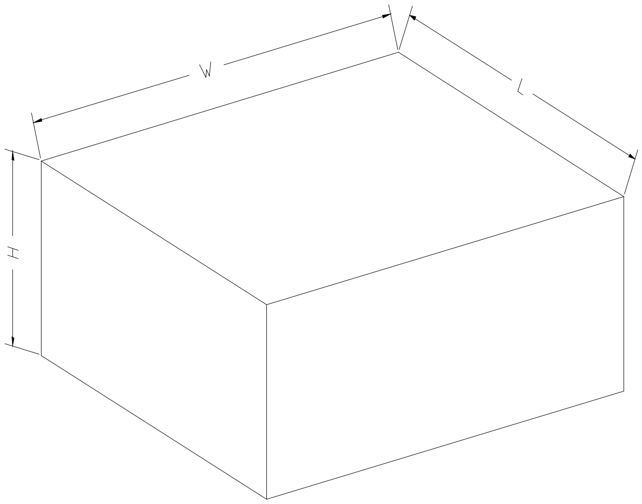
NOTE: The picture is only for reference. Please make the object as the standard.

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
TDFN-2×2-6FL	7"	9.5	2.25	2.25	0.95	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