SGM3112
5V Charge Pump Boost Converter

GENERAL DESCRIPTION

The SGM3112 is a switched capacitor converter with low noise output voltage. The SGM3112 is capable of delivering 200mA output current at 5V output from 3.1V to 5.5V input voltage range. The available output current is 125mA when the input voltage reaches 2.7V. In the case of small output current, SGM3112 operates in PFM mode to reduce power loss. The PFM mode can be configured by pulling MODE pin to logic high. In addition, by pulling the OUTDIS pin to logic high, the device will discharge the output voltage when the device is disabled.

The SGM3112 is available in a Green TDFN-2×2-8AL package. It offers excellent thermal performance which prevents the device from overheating under rated operating conditions.

FEATURES

- **Input Voltage Range: 2.7V to 5.5V**
- **5V Fixed Output Voltage**
- **200mA Output Current Capability**
- **Inductorless: Only 3 External Components**
- **Input Disconnected from Load during Shutdown**
- **Thermal Shutdown/Short-Circuit Protection**
- **2.2MHz Switching Frequency in Step-up Mode**
- **Operating in Pulse Frequency Modulation (PFM) Mode at Light Load**
- **Available in a Green TDFN-2×2-8AL Package**

APPLICATIONS

Multi-Cell AA Battery Applications
5V Bias
I/O Bias Power

TYPICAL APPLICATION

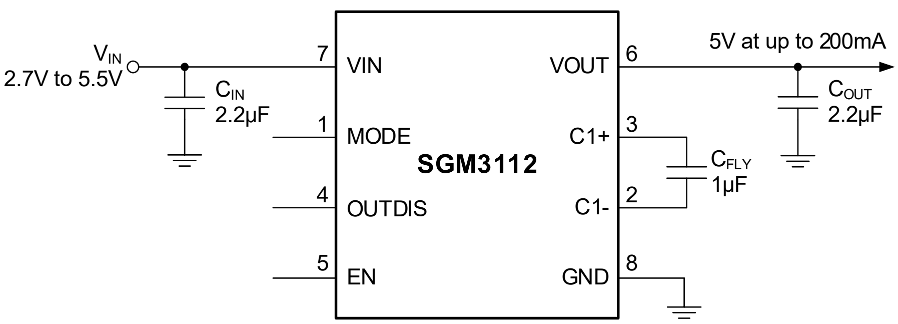


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM3112	TDFN-2×2-8AL	-40℃ to +85℃	SGM3112YTDE8G/TR	3112 XXXX	Tape and Reel, 3000

MARKING INFORMATION

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

X X X X
- Vendor Code
- Trace Code
- Date Code - Year

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, VOUT .... -0.3V to 6V
EN, OUTDIS, MODE .... -0.3V to V_{IN} + 0.3V with 6V Max
Package Thermal Resistance
TDFN-2×2-8AL, θ_{JA}.. 58℃/W
Junction Temperature...+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s)............................+260℃
ESD Susceptibility
HBM...4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

V_{IN}..2.7V to 5.5V
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.

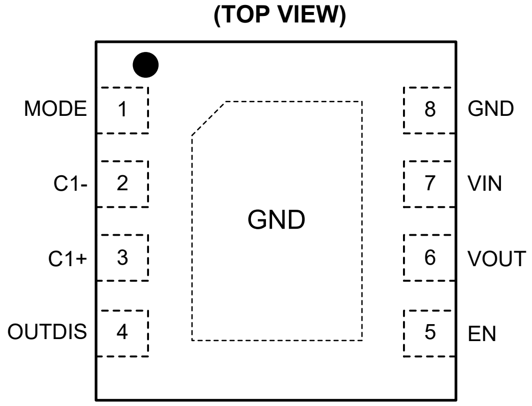
ESD SENSITIVITY CAUTION

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



TDFN-2×2-8AL

PIN DESCRIPTION

PIN	NAME	I/O	FUNCTION
1	MODE	I	PFM Mode Enable Input. This pin enables or disables PFM operation. 1 = PFM enabled. 0 = PFM disabled (PWM enabled).
2	C1-	P	Negative Connection for the Charge Pump Flying Capacitor.
3	C1+	P	Positive Connection for the Charge Pump Flying Capacitor.
4	OUTDIS	I	Logic high enables output discharge when EN is disabled, and logic low for high impedance output without output discharge when disabled.
5	EN	I	Active High Enable Input. Logic high enables the chip and logic low disables the chip.
6	VOUT	O	Output of the Charge Pump Converter.
7	VIN	P	Power Supply Input.
8	GND	G	Ground.
Exposed Pad	GND	—	Exposed Pad. It should be connected to the ground.

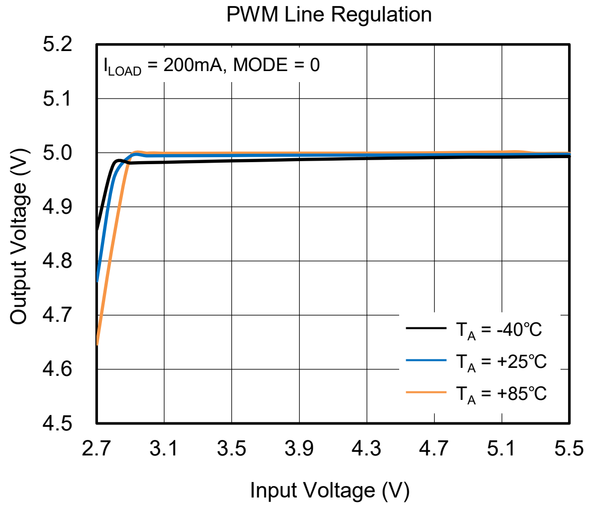
ELECTRICAL CHARACTERISTICS

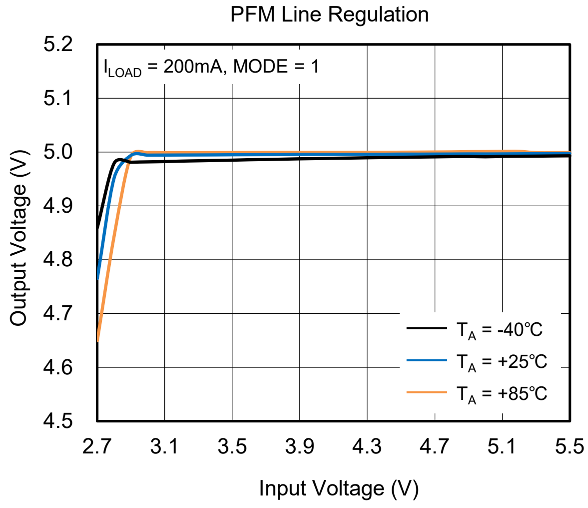
(V_{IN} = 3.6V, C_{IN} = C_{OUT} = 2.2μF, C_{FLY} = 1μF, T_A = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise noted.)

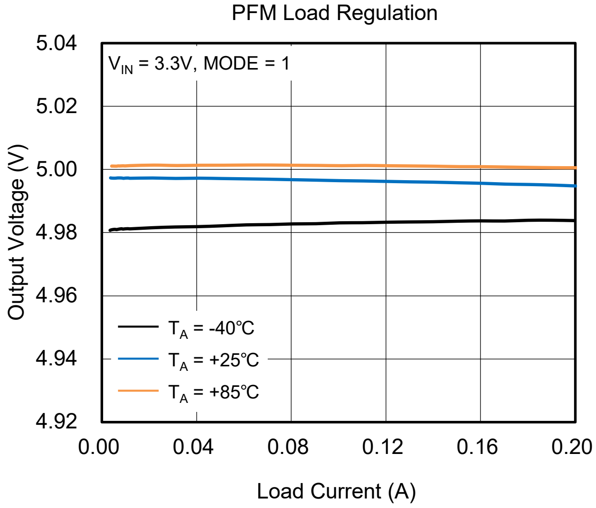
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage Regulation	V_{OUT}	I_{OUT} = 180mA	4.85	5	5.15	V
Quiescent Current	I_Q	I_{OUT} = 0mA, MODE = 1		60	100	μA
		I_{OUT} = 0mA, MODE = 0		5.5		mA
Shutdown Current	I_{SD}	EN = 0		0	1	μA
Output Discharge Current	I_{OUTDIS}	OUTDIS = 1		540		μA
Input Current Limit	I_{CL}			630		mA
Input Logic Low: EN, OUTDIS, MODE	V_{IL}		0		0.4	V
Input Logic High: EN, OUTDIS, MODE	V_{IH}		1.2		V_{IN}	V
Under-Voltage Lockout Threshold	UVLO	V_{IN} rising		2.61	2.70	V
		V_{IN} falling		2.40	2.53	
Switching Frequency	f_{SW}		1.8	2.2	2.7	MHz
Over-Temperature Protection				+150		℃
Over-Temperature Hysteresis				20		℃

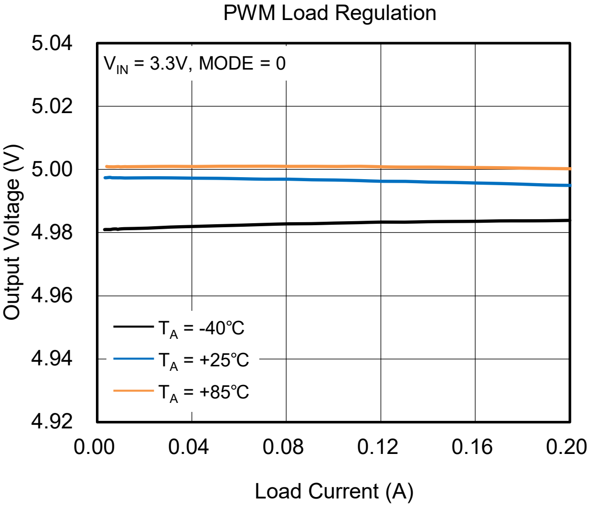
TYPICAL PERFORMANCE CHARACTERISTICS

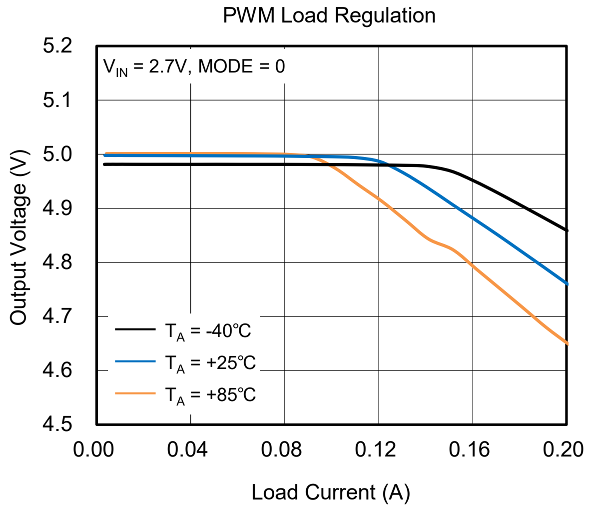
T_A = +25℃, V_{IN} = 3.6V, C_{IN} = C_{OUT} = 10μF (10V, 0603 case), C_{FLY} = 1μF (10V, 0402 case), V_{EN} = V_{IN}, unless otherwise noted.

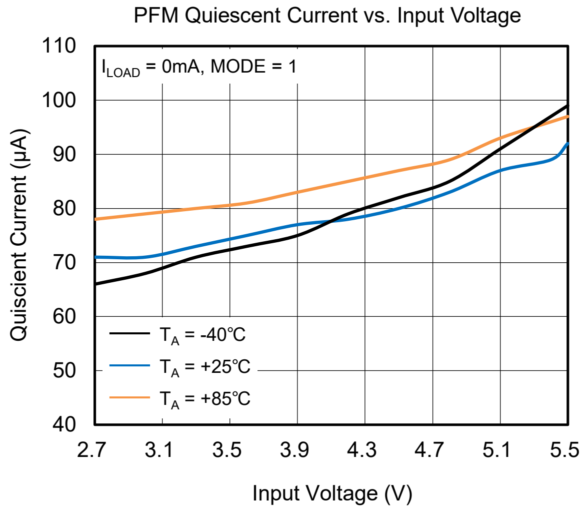








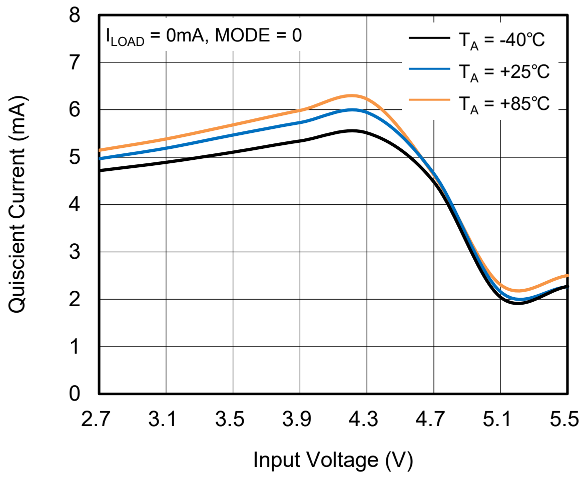




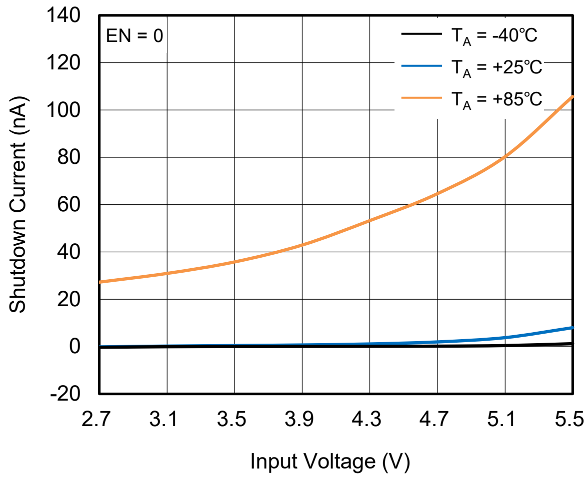
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_{IN} = 3.6V, C_{IN} = C_{OUT} = 10μF (10V, 0603 case), C_{FLY} = 1μF (10V, 0402 case), V_{EN} = V_{IN}, unless otherwise noted.

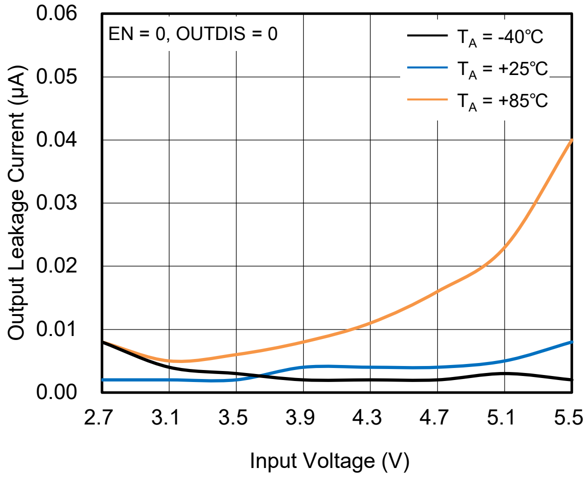
PWM Quiescent Current vs. Input Voltage



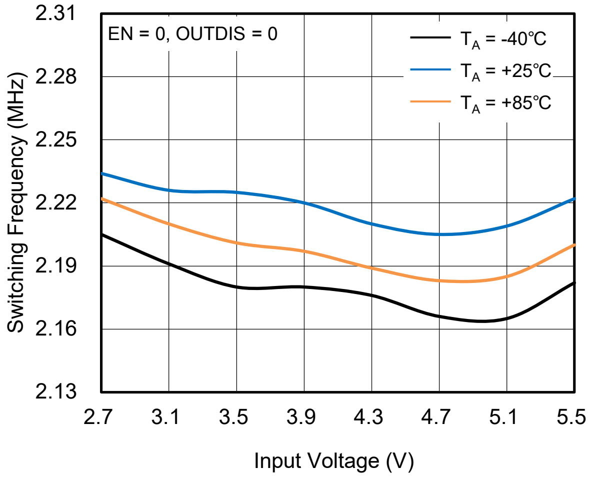
Shutdown Current vs. Input Voltage



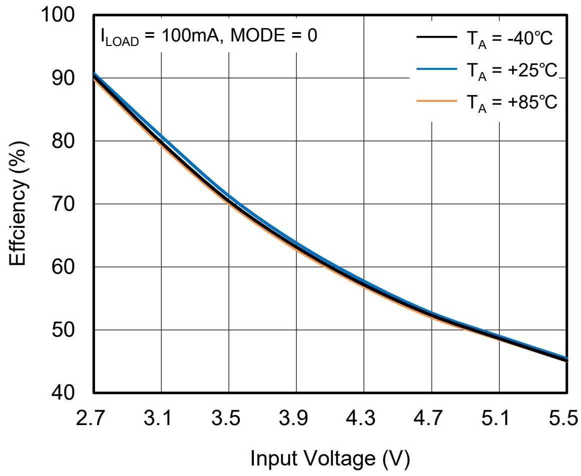
Output Leakage Current vs. Input Voltage



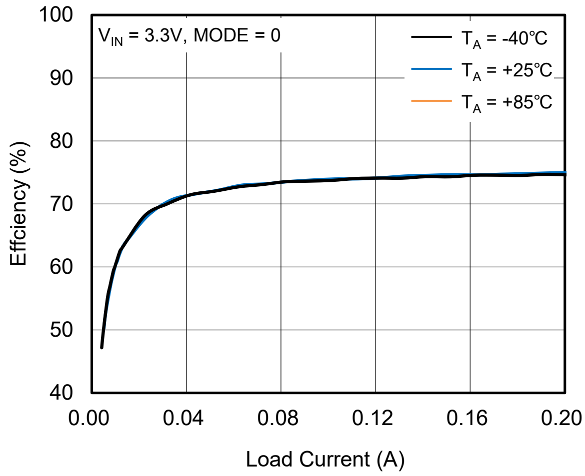
Switching Frequency vs. Input Voltage



PWM Effciency vs. Input Voltage



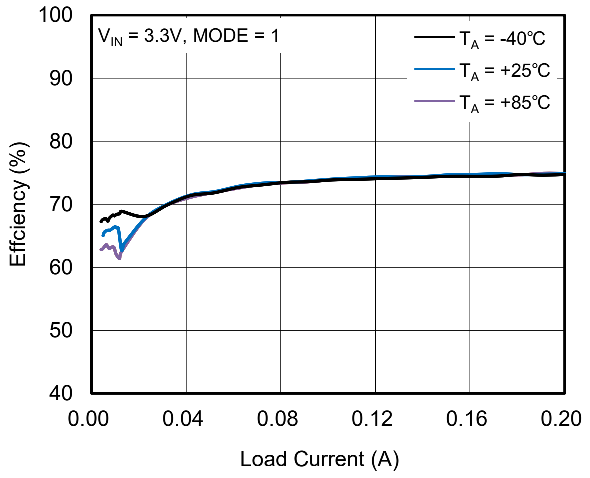
PWM Effciency vs. Load Current



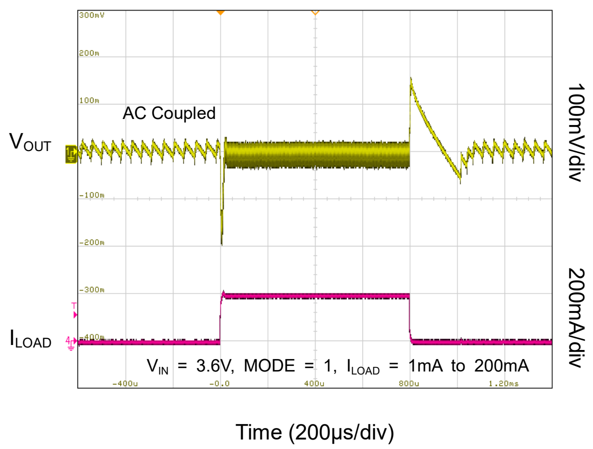
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_{IN} = 3.6V, C_{IN} = C_{OUT} = 10μF (10V, 0603 case), C_{FLY} = 1μF (10V, 0402 case), V_{EN} = V_{IN}, unless otherwise noted.

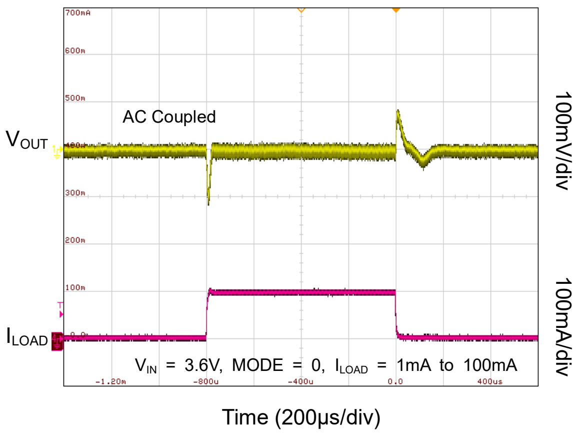
PFM Effciency vs. Load Current



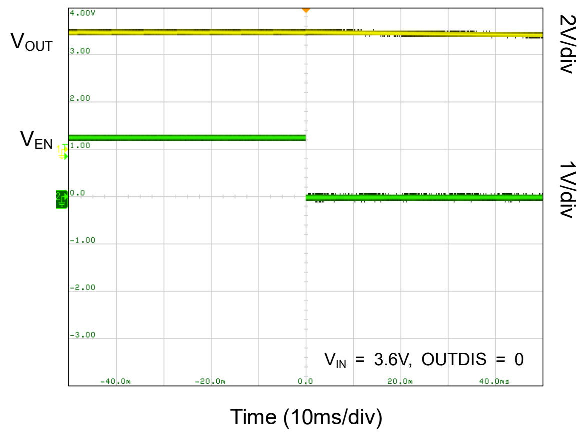
PFM Load Step



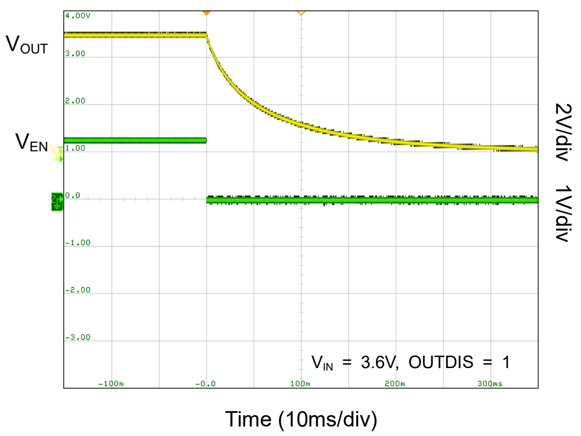
PWM Load Step



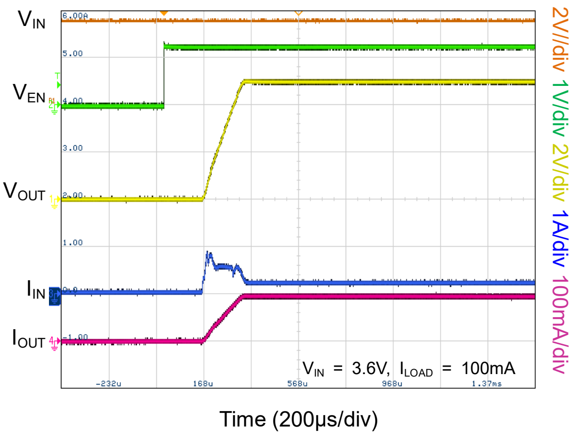
Output Discharge Disabled



Output Discharge Enabled



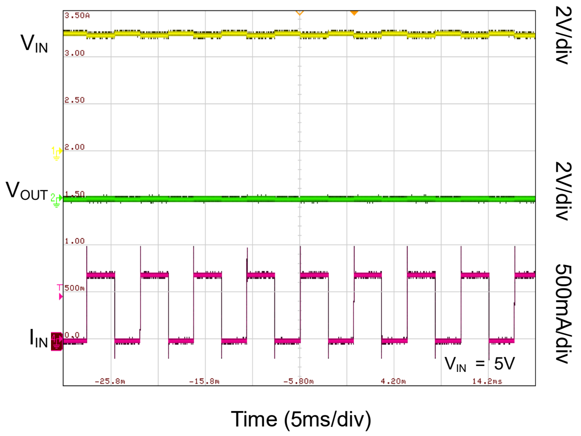
Start-up into a Load



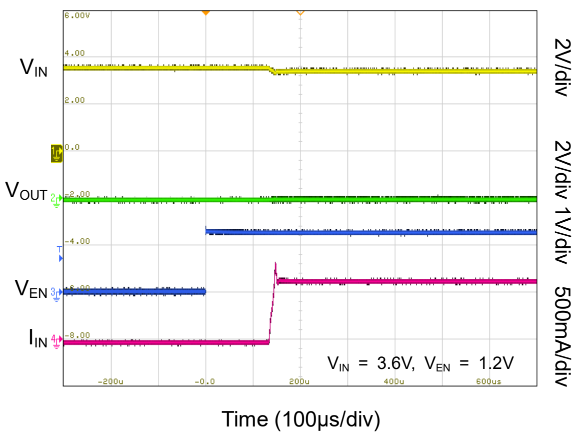
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_{IN} = 3.6V, C_{IN} = C_{OUT} = 10μF (10V, 0603 case), C_{FLY} = 1μF (10V, 0402 case), V_{EN} = V_{IN}, unless otherwise noted.

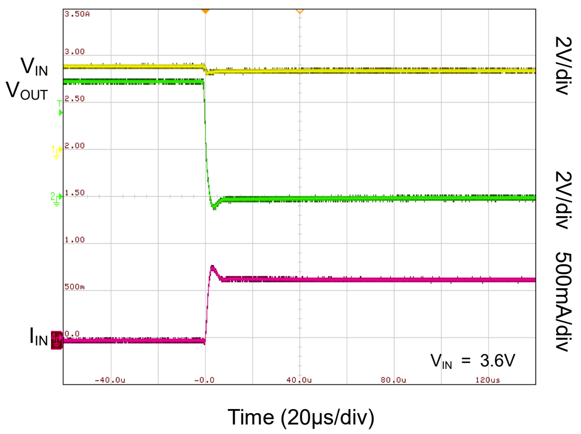
OUT Pin Short-Circuit During Steady State



OUT Pin Short-Circuit During Steady State



Power-up with OUT Pin Short-Circuit to GND



FUNCTIONAL BLOCK DIAGRAM

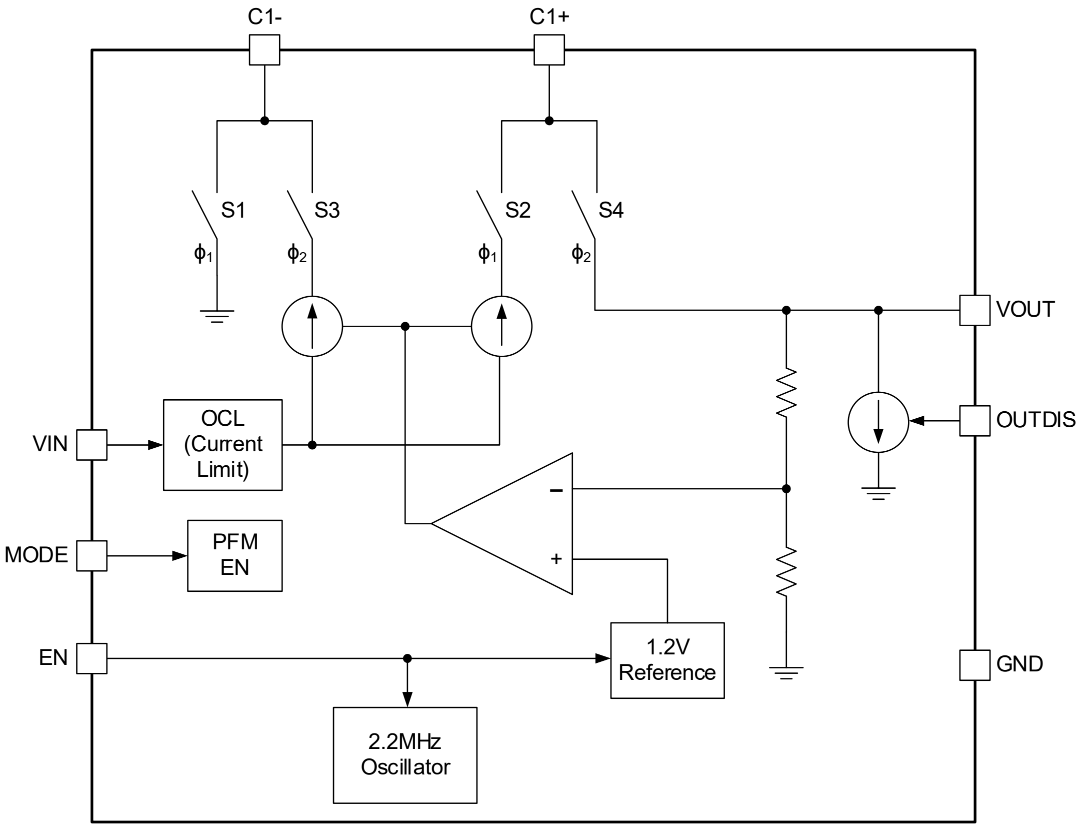


Figure 2. Functional Block Diagram

DETAILED DESCRIPTION

Overview

The SGM3112 is a fully integrated switched-cap Boost converter which is capable of providing a stable output voltage from various input sources such as single-cell Li-Ion battery or 2-cell or 3-cell alkaline battery. The output voltage is regulated via a two-phase non-overlapping clock which controls the output of the converter. When the device is enabled, during phase 1 (ϕ1), the flying capacitor is charged to the input voltage through internal switches S1 and S2, and during phase 2 (ϕ2), the flying capacitor is connected between the input and output via internal switches S3 and S4. The charge of the flying capacitor boosts the output voltage on top of the input voltage to supply the load demand of the output.

The 50% duty operation of the internal switch-cap boosts the input voltage to twice the input voltage. Output voltage regulation is achieved by modulating the current of the S2 and S3 in each phase connected to the VIN pin.

Input Feed-Forward

The internal architecture of the SGM3112 consists of four switches and an external flying capacitor. Output voltage regulation is achieved by controlling the current through the two switches connected to the VIN pin, one switch in each phase which results in that the output regulation is achieved before the voltage doubling, thus achieving VIN feed-forward. This control method effectively removes the undesirable input current ripple that is common on many switched capacitor devices.

Input Current Limit

The SGM3112 implements internal current limit to protect the device against over current or output short to ground scenarios. In the case of output short to ground, the input current is limited to 630mA (TYP). During output short condition, higher power dissipation is expected which will cause the device to enter over-temperature cycle.

Pulse Frequency Modulation (PFM) Mode

By pulling the MODE pin to logic high, PFM mode is enabled. In PFM mode, power consumption is reduced by varying the switching frequency based on the load, where the switching is initiated when the output voltage drops below 5V. In no load condition, the switching frequency could drop below 1kHz to maintain output voltage regulation.

By pulling the MODE pin to logic low, fixed frequency is configured. Power consumption is increased in this setting. However, this setting offers various advantages such as fixed switching frequency and lower output ripple, which are beneficial for noise sensitive applications.

Output Discharge

When the device is disabled by pulling the EN pin to logic low, there are two ways to control the output voltage via the OUTDIS pin. Pulling the OUTDIS pin to logic high, the SGM3112 automatically pulls the output to GND for fast discharge, where the output pin sinks 540μA (TYP). Pulling the OUTDIS pin to logic low, the SGM3112 does not actively discharge the output, and the output voltage slowly reduces to zero when the EN pin is pulled to logic low, where the output pin consumes only 2.5μA (TYP).

Thermal Shutdown

The thermal shutdown circuit is integrated inside the SGM3112 to prevent the device from damaging due to overheating. When the junction temperature is greater than +150℃ (TYP), the chip performs thermal shutdown. The chip restarts when the junction temperature falls below +130℃ (TYP).

Under-Voltage Lockout

The SGM3112 implements under-voltage lockout on the VIN pin. The device is enabled when the input voltage is higher than 2.61V (TYP), and stops operation when the input voltage drops below 2.40V (TYP).

Shutdown

Pulling the EN pin to logic low or removing V_{IN} will shut down the SGM3112. In the shutdown state, the SGM3112 only consumes 1μA (MAX) shutdown current from the input.

Boost Mode

When the input voltage is above the 2.61V (TYP) UVLO rising threshold, and EN pin is logic high, the device operates in Boost mode to regulate the output voltage. According to the configuration of the MODE pin, the SGM3112 works in either PFM mode or fixed frequency mode.

APPLICATION INFORMATION

The SGM3112 is designed to deliver 200mA load current at 5V output. The 2.2MHz switching frequency enables the use of small value external components.

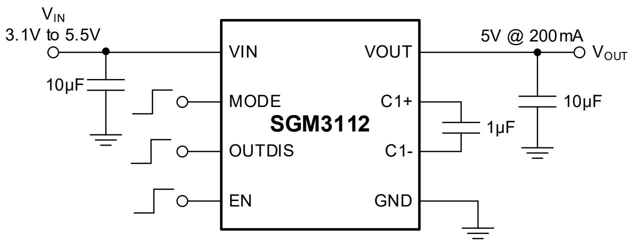


Figure 3. SGM3112 Typical Configuration

Design Requirements

Design Parameter	Example Value
Input Voltage Range	2.7V to 5.5V
Output Current Range	0mA to 200mA

Detailed Design Procedure

Output Current Capability

The SGM3112 is capable of delivering up to 200mA load current when the input voltage is higher than 3.1V. The maximum output current is 125mA when the input voltage operates from 2.7V to 3.1V.

Figure 4 is a simplified drawing of the voltage doubler architecture, which consists of a pre-regulation block, a voltage doubler block, and an equivalent output resistance which is used to estimate the output voltage drop in open loop operation.

The equivalent output resistance is approximately 3.8Ω at V_{IN} = 2.7V, which is approximately twice the internal resistance of the four switches. Under normal operation, the device regulates the V' voltage to ensure the output voltage is 5V ± 3%. Increasing the load current causes the voltage drop on R_{OUT} increases, the SGM3112 adjusts the V' voltage to ensure the output voltage is within 5V regulation. When the voltage drop on R_{OUT} results in zero voltage drop on the regulator, V' voltage is equal to the input voltage. When this occurs, the SGM3112 is on the edge of out of regulation. As the load current increases further, the output voltage will decrease. Use Equation below to calculate the output voltage in out of regulation state.

$$V_{OUT} = 2 \times V_{IN} - I_{OUT} \times R_{OUT} \quad (1)$$

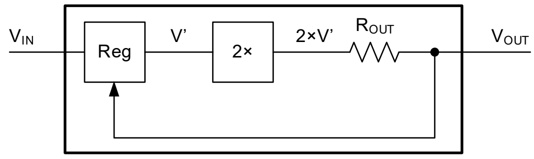


Figure 4. SGM3112 Output Resistance Model

Use Equation 2 to calculate the accurate output resistance.

$$R_{OUT} = 2 \times R_{SW} + \frac{1}{f_{SW} \times C_{FLY}} + 4 \times ESR_{CFLY} + ESR_{COUT} \quad (2)$$

R_{SW} resistance of 3Ω is the main contributor to the output resistance. The switching frequency and flying capacitor C_{FLY} only contribute 0.5Ω. Increasing the size of the flying capacitor improves the output current capability. However, careful design to balance the needed load current and flying capacitor size is necessary. If the selected output capacitor is ceramic capacitor, the ESR is not significant and can be neglected.

Efficiency

Use Equation 3 to calculate the charge pump efficiency.

$$I_{IN} = G \times I_{OUT}$$
$$E = (V_{OUT} \times I_{OUT}) \div (V_{IN} \times I_{IN}) = V_{OUT} \div (G \times V_{IN}) \quad (3)$$

where G is the charge pump gain, and G = 2 for SGM3112.

Use Equation 4 to estimate the efficiency with quiescent current taken into account.

$$E = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times (2 \times I_{OUT} + I_Q)} \quad (4)$$

Power Dissipation

Use Equation 5 to calculate the power loss of SGM3112.

$$P_D = P_{IN} - P_{OUT} = [V_{IN} \times (2 \times I_{OUT} + I_Q)] - [V_{OUT} \times I_{OUT}] \quad (5)$$

The highest power dissipation occurs at maximum V_{IN} and maximum load current, which is 5.5V/200mA, equivalent of 1.2W loss. Care should be taken when the operating condition is near the worst-case power dissipation where the device might enter thermal protection.

APPLICATION INFORMATION (continued)

Output Capacitor and Output Voltage Ripple

The output capacitor affects the output voltage ripple, while input voltage, load current, and flying capacitance also contribute to the output voltage ripple. Larger output capacitance results in lower output voltage ripple. In ϕ1 operation, the output capacitor supplies the current to the load. Use Equation below to estimate the output ripple, where the time of discharge is half the switching period.

$$V_{RIPPLE(PEAK\text{-}PEAK)} = \frac{I_{OUT}}{2 \times C_{OUT} \times f_{SW}} \quad (6)$$

The two operating phases' non-overlapping time and output capacitor ESR play significant role to the output voltage ripple. For proper operation, the two operating phases should not overlap. While the overlap occurs, all internal switches are turned off immediately. The SGM3112 has built-in mechanism on the internal clock to prevent the overlap from occurring. During the non-overlapping time, all switches are turned off, thus no energy is delivered to the output, and this period contributes to the output ripple. Use Equation below to calculate the overlap ripple, where the output capacitor discharge time is approximately 60% of the switching period.

$$V_{RIPPLE(PEAK\text{-}PEAK)} = \left(\frac{I_{OUT}}{C_{OUT}} \times \frac{0.6}{f_{SW}}\right) + \left(2 \times I_{OUT} \times ESR_{COUT}\right) \quad (7)$$

In general, a 10μF ceramic capacitor with 10V rating is recommended for the SGM3112. When PFM mode is enabled, and a small output capacitor is used, the output ripple increases during the transition between PFM mode and fixed frequency mode. DC bias derating should be evaluated when using ceramic capacitor.

Ceramic capacitors have small ESR in general. However, electrolytic capacitor or tantalum capacitor has larger ESR which will contribute to higher output ripple. A parallel combination of ceramic capacitor is recommended to reduce the effective ESR.

Input Capacitor and Input Voltage Ripple

The input capacitor serves various roles for SGM3112. During the charging phase, the input capacitor helps to speed up the charging of the flying capacitor. In addition, the input capacitor helps to avoid the input voltage drop when the flying capacitor is being charged. Lastly, the input capacitor serves as decoupling to filter out noise on the input line to reduce the input voltage ripple.

A 10μF, 10V or higher voltage rated X5R/X7R low ESR ceramic capacitor is recommended for SGM3112.

Flying Capacitor

A 1μF, 10V rated X5R/X7R low ESR ceramic capacitor is recommended for SGM3112. Tantalum or electrolytic capacitors must not be used for SGM3112. Since these types of capacitors have polarity requirement, these types of capacitors could become reverse-biased in normal operation.

Layout Guidelines

Layout is critical to ensure the proper operation and performance of the SGM3112. It is recommended to place the input, output and flying capacitors as close as possible to the device, and on the same side. Use short and wide traces to connect these capacitors to the IC is also critical to reduce trace parasitic.

Use multiple GND vias to connect the GND pin and the PCB ground plane to improve thermal dissipation performance.

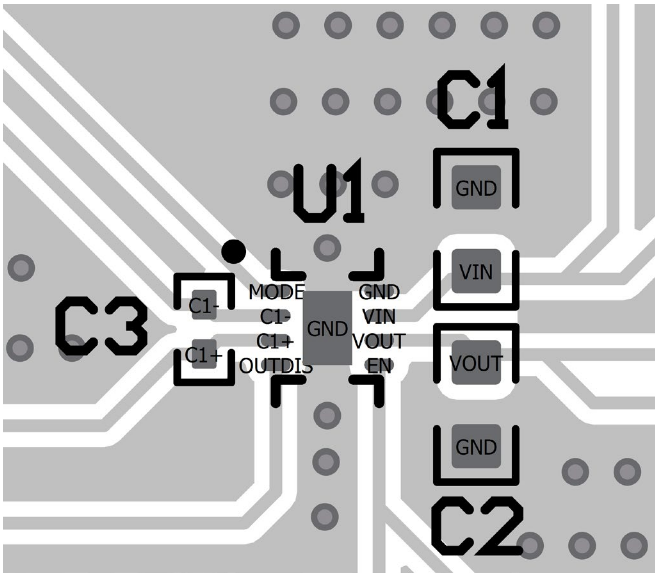


Figure 5. PCB Layout Reference

REVISION HISTORY

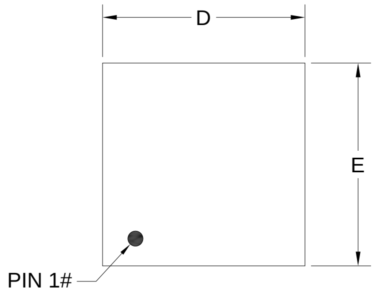
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (APRIL 2023) to REV.A

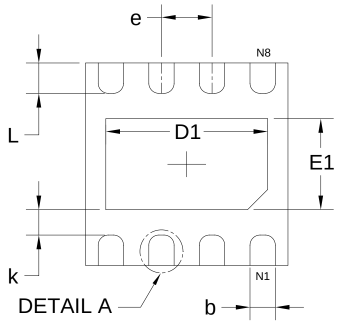
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

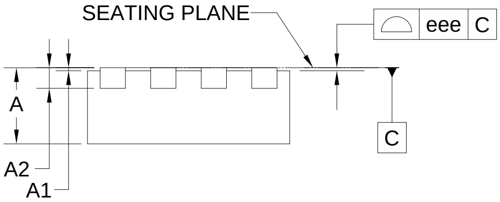
TDFN-2×2-8AL



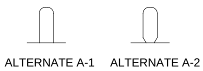
TOP VIEW



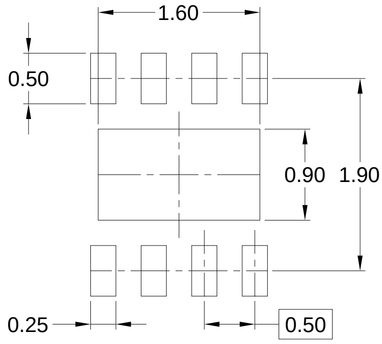
BOTTOM VIEW



SIDE VIEW



DETAIL A
ALTERNATE TERMINAL CONSTRUCTION



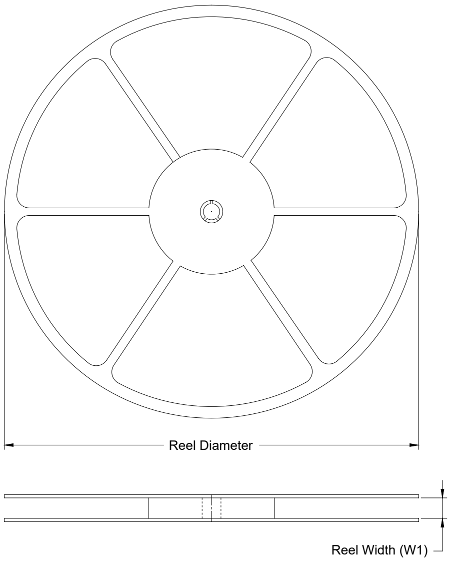
RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.700	0.750	0.800
A1	0.000	-	0.050
A2	0.203 REF		
b	0.200	0.250	0.300
D	1.900	2.000	2.100
D1	1.450	1.600	1.700
E	1.900	2.000	2.100
E1	0.750	0.900	1.000
k	0.150	0.250	0.350
e	0.450	0.500	0.550
L	0.200	0.300	0.400
eee	0.080		

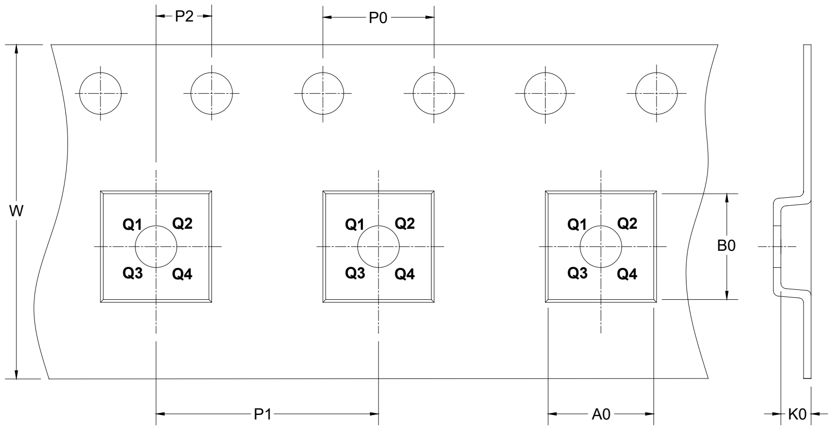
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

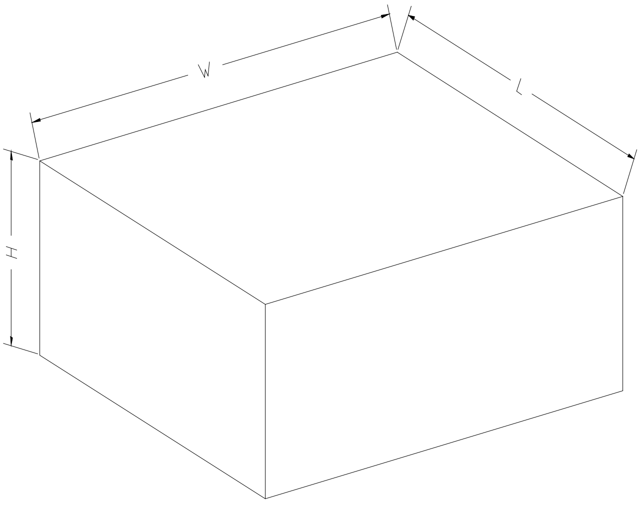
NOTE: The picture is only for reference. Please make the object as the standard.

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
TDFN-2×2-8AL	7"	9.5	2.30	2.30	1.10	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