SGM6611
12.6V, 7A Fully-Integrated Synchronous Boost Converter

GENERAL DESCRIPTION

The SGM6611 family includes the SGM6611A and the SGM6611B. The SGM6611 is a fully-integrated synchronous boost converter with a 16mΩ main power switch and a 27mΩ rectifier switch. The device provides a high efficiency and small size power solution for portable equipment. The SGM6611 features wide input voltage range from 2.7V to 12V to support applications powered with single-cell or two-cell Li-Ion/Polymer batteries. The SGM6611 has 7A continuous switch current capability and is capable of providing an output voltage up to 12.6V.

The SGM6611 uses peak current control topology to regulate the output voltage. In moderate to heavy load condition, the SGM6611 works in the Pulse Width Modulation (PWM) mode. In light load condition, the SGM6611A works in the Pulse Frequency Modulation (PFM) mode to improve the efficiency, while the SGM6611B still works in the PWM mode to avoid application problems caused by low switching frequency. The switching frequency in the PWM mode is adjustable from 200kHz to 2.2MHz. The SGM6611 also implements a built-in 4ms soft-start function and an adjustable peak switch current limit function. In addition, the device provides 13.2V output over-voltage protection, cycle-by-cycle over-current protection, and thermal shutdown protection.

The SGM6611A and SGM6611B are both available in the Green TQFN-2×2.5-11L package.

FEATURES

- **Input Voltage Range: 2.7V to 12V**
- **Output Voltage Range: 4.5V to 12.6V**
- **Up to 90% Efficiency at V_{IN} = 3.3V, V_{OUT} = 9V, and I_{OUT} = 2A**
- **Resistor-Programmable Peak Current Limit Up to 9.5A for High Pulse Current**
- **Adjustable Switching Frequency: 200kHz to 2.2MHz**
- **4ms Built-In Soft-Start Time**
- **PFM Operation Mode at Light Load (SGM6611A)**
- **Forced PWM Operation Mode at Light Load (SGM6611B)**
- **Internal Output Over-Voltage Protection at 13.2V**
- **Cycle-by-Cycle Over-Current Protection**
- **Thermal Shutdown**
- **Available in Green TQFN-2×2.5-11L Package**

APPLICATIONS

Bluetooth Speaker
Quick Charge Power Bank
Portable POS Terminal
E-Cigarette

TYPICAL APPLICATION

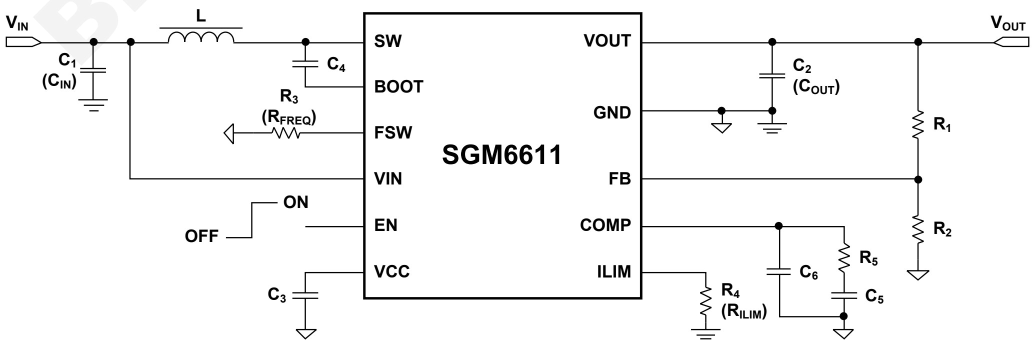


Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM6611A	TQFN-2×2.5-11L	-40℃ to +85℃	SGM6611AYTQV11G/TR	6611A XXXXX	Tape and Reel, 3000
SGM6611B	TQFN-2×2.5-11L	-40℃ to +85℃	SGM6611BYTQV11G/TR	6611B XXXXX	Tape and Reel, 3000

NOTE: XXXXX = Date 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

BOOT Voltage .... -0.3V to V_{SW} + 6V
VIN, SW, FSW, VOUT Voltages .... -0.3V to 14.5V
EN, VCC, COMP, ILIM, FB Voltages .... -0.3V to 6V
Junction Temperature ....+150℃
Storage Temperature Range........................-65℃ to +150℃
Lead Temperature (Soldering, 10s) ....+260℃

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range ....2.7V to 12V
Output Voltage Range ....4.5V to 12.6V
Inductance, Effective Value, L....................... 0.47μH to 10μH
Input Capacitance, Effective Value, C_{IN} .... 10μF (MIN)
Output Capacitance, Effective Value, C_{OUT} ... 10μF to 1000μF
Operating Junction Temperature Range ...... -40℃ to +125℃
Operating Ambient Temperature Range......... -40℃ to +85℃

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

ESD SENSITIVITY CAUTION

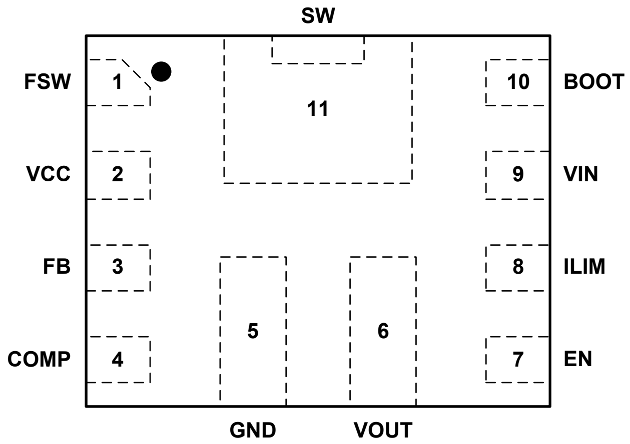
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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, specification or other related things if necessary without notice at any time.

PIN CONFIGURATION

SGM6611A/SGM6611B (TOP VIEW)



TQFN-2×2.5-11L

PIN DESCRIPTION

PIN	NAME	I/O	FUNCTION
1	FSW	I	The switching frequency is programmed by a resister between this pin and the GND pin.
2	VCC	O	Output of the Internal Regulator. A ceramic capacitor of more than 1.0μF is required between this pin and ground.
3	FB	I	Output Voltage Feedback.
4	COMP	O	Output of the Internal Error Amplifier. The loop compensation network should be connected between this pin and the GND pin.
5	GND	-	Ground.
6	VOUT	O	Boost Converter Output.
7	EN	I	Enable Logic Input. Logic high level enables the device. Logic low level disables the device and turns it into shutdown mode.
8	ILIM	O	Adjustable Switching Peak Current Limit. An external resister should be connected between this pin and the GND pin.
9	VIN	I	IC Power Supply Input.
10	BOOT	O	Power Supply for High-side MOSFET Gate Driver. A capacitor must be connected between this pin and the SW pin.
11	SW	I	The Switching Node Pin of the Converter. It is connected to the drain of the internal low-side power MOSFET and the source of the internal high-side power MOSFET.

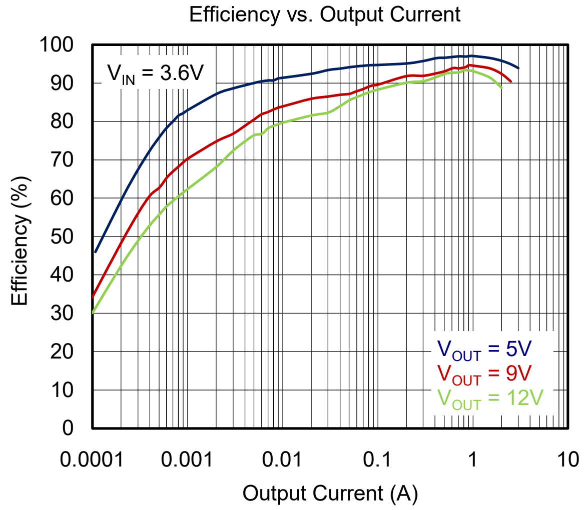
ELECTRICAL CHARACTERISTICS

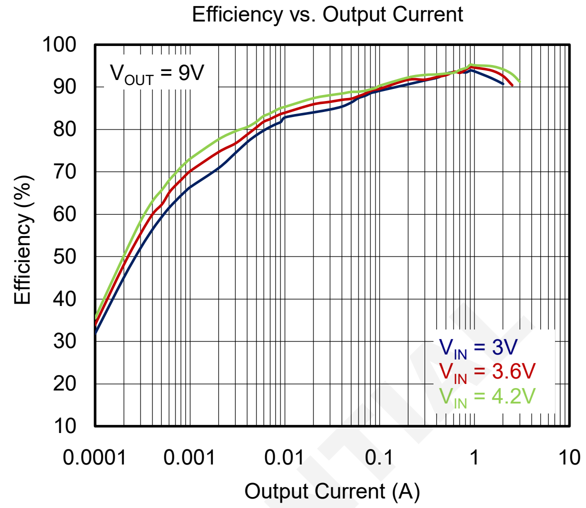
(V_{IN} = 2.7V to 5.5V, V_{OUT} = 9V, Full = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise noted.)

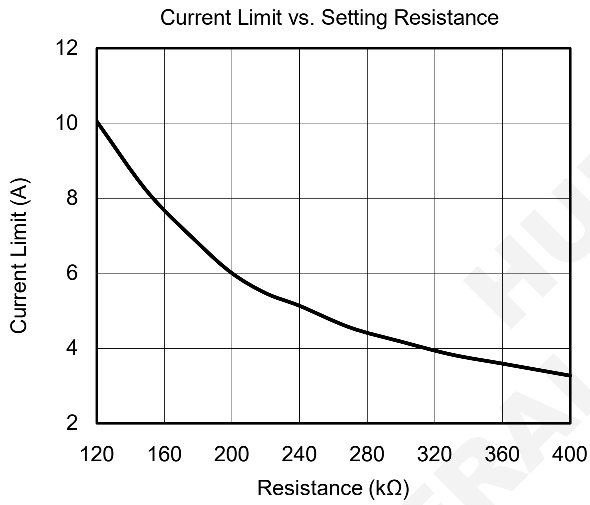
PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
POWER SUPPLY							
Input Voltage Range	V_{IN}		Full	2.7		12	V
VIN Under-Voltage Lockout Threshold	V_{IN_UVLO}	V_{IN} rising	+25℃		2.5		V
		V_{IN} falling			2.4		
VIN Under-Voltage Lockout Hysteresis	V_{IN_HYS}		+25℃		100		mV
VCC Regulation	V_{CC}	I_{CC} = 2mA, V_{IN} = 8V	+25℃		5		V
VCC Under-Voltage Lockout Threshold	V_{CC_UVLO}	V_{CC} falling	+25℃		2.1		V
Operating Quiescent Current — VIN Pin	I_Q	IC enabled, no load, V_{FB} = 1.3V, V_{OUT} = 12V	+25℃		0.2		μA
Operating Quiescent Current — VOUT Pin					100		
Shutdown Current into the VIN Pin	I_{SHDN}	IC disabled	+25℃		0.6		μA
OUTPUT							
Output Voltage Range	V_{OUT}		Full	4.5		12.6	V
Reference Voltage at the FB Pin	V_{REF}	PWM mode	+25℃		1.205		V
		PFM mode	+25℃		1.207		
Leakage Current into the FB Pin	I_{FB_LKG}	V_{FB} = 1.2V	+25℃		10		nA
Output Over-Voltage Protection Threshold	V_{OVP}	V_{OUT} rising	+25℃		13.2		V
Output Over-Voltage Protection Hysteresis	V_{OVP_HYS}	V_{OUT} falling below V_{OVP}	+25℃		0.15		V
Soft Startup Time	t_{SS}	C_{OUT} (effective) = 47μF, I_{OUT} = 0A	+25℃		4		ms
ERROR AMPLIFIER							
COMP Pin Sink Current	I_{SINK}	V_{FB} = V_{REF} + 100mV, V_{COMP} = 1.2V	+25℃		120		μA
COMP Pin Source Current	I_{SOURCE}	V_{FB} = V_{REF} - 100mV, V_{COMP} = 1.2V	+25℃		15		μA
High Clamp Voltage at the COMP Pin	V_{CCLPH}	V_{FB} = 1.1V, R_{ILIM} = 127kΩ	+25℃		2.0		V
Low Clamp Voltage at the COMP Pin	V_{CCLPL}	V_{FB} = 1.3V, R_{ILIM} = 127kΩ	+25℃		0.4		V
Error Amplifier Transconductance	G_{EA}	V_{COMP} = 1.2V	+25℃		150		μS
POWER SWITCH							
High-side MOSFET On-Resistance	$R_{DS(ON)}$	V_{CC} = 5V	+25℃		27		mΩ
Low-side MOSFET On-Resistance		V_{CC} = 5V	+25℃		16		mΩ
SWITCHING FREQUENCY							
Switching Frequency	f_{SW}	R_{FSW} = 301kΩ	+25℃		470		kHz
		R_{FSW} = 46.4kΩ	+25℃		2200		kHz
Minimum On-Time	t_{ON_MIN}	V_{CC} = 5V	+25℃		120		ns
CURRENT LIMIT							
Peak Switch Current Limit (SGM6611A)	I_{LIM}	R_{ILIM} = 127kΩ	+25℃		9.5		A
Reference Voltage at the ILIM Pin	V_{ILIM}		+25℃		1.205		V
EN LOGIC INPUT							
EN Logic High Threshold	V_{ENH}		Full	1.3			V
EN Logic Low Threshold	V_{ENL}		Full			0.3	V
EN Pull-Down Resistor	R_{EN}		+25℃		800		kΩ
THERMAL SHUTDOWN							
Thermal Shutdown Threshold	T_{SD}	T_A rising			160		℃
Thermal Shutdown Hysteresis	T_{SD_HYS}	T_A falling below T_{SD}			20		℃

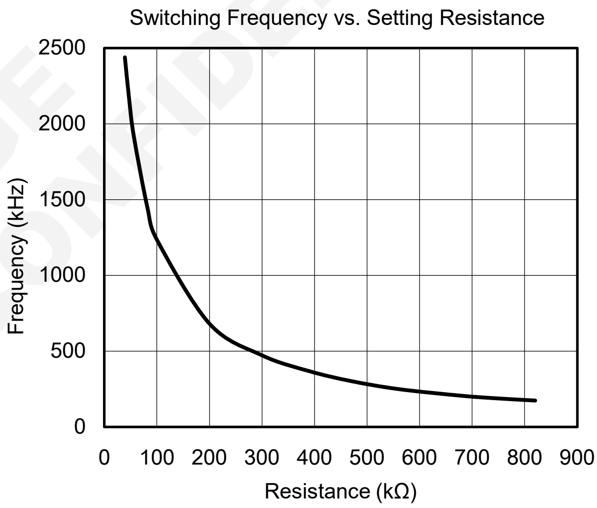
TYPICAL PERFORMANCE CHARACTERISTICS

At T_A = +25℃, V_{IN} = 3.6V, V_{OUT} = 9V, unless otherwise noted.



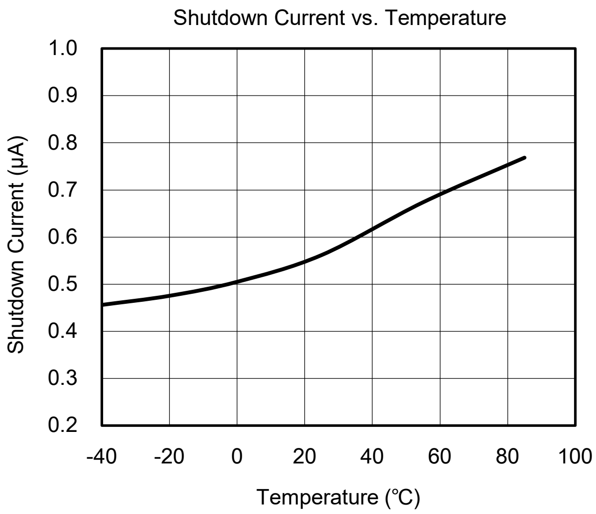


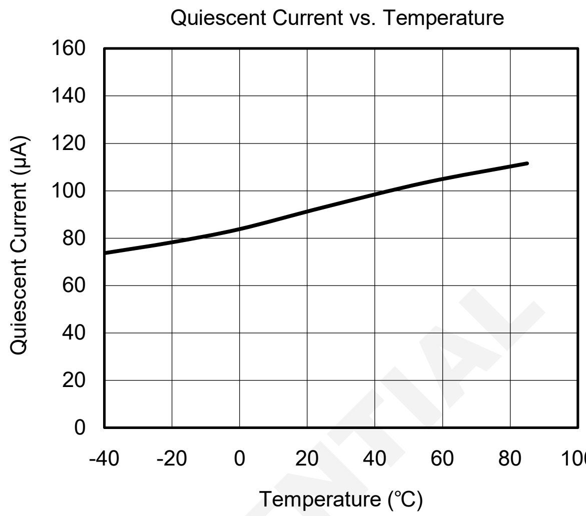


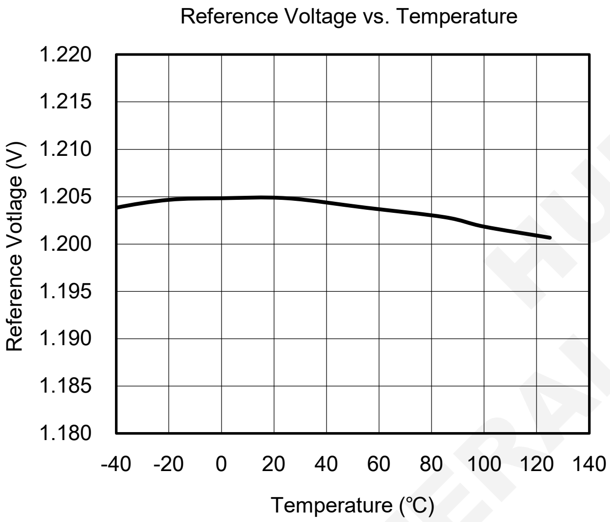


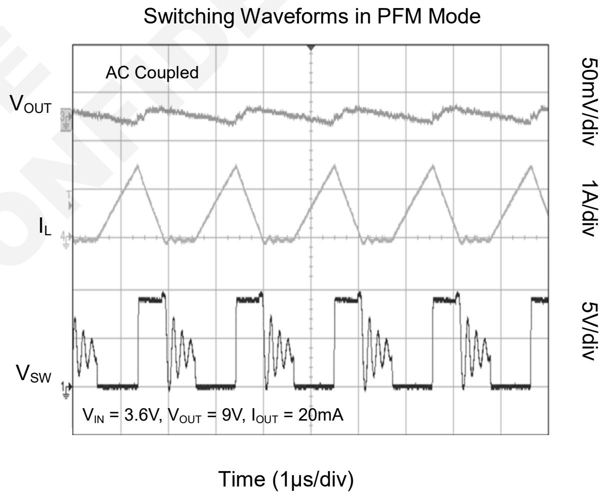
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{IN} = 3.6V, V_{OUT} = 9V, unless otherwise noted.





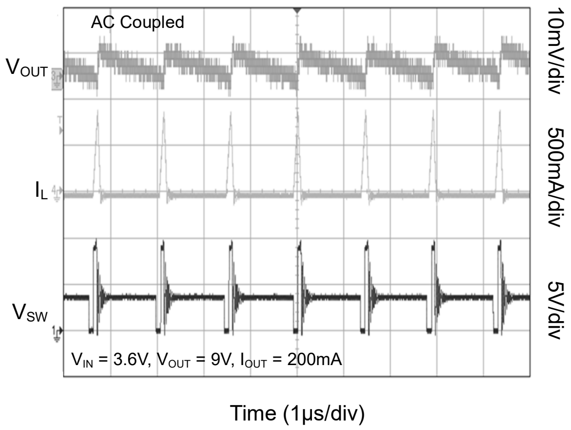




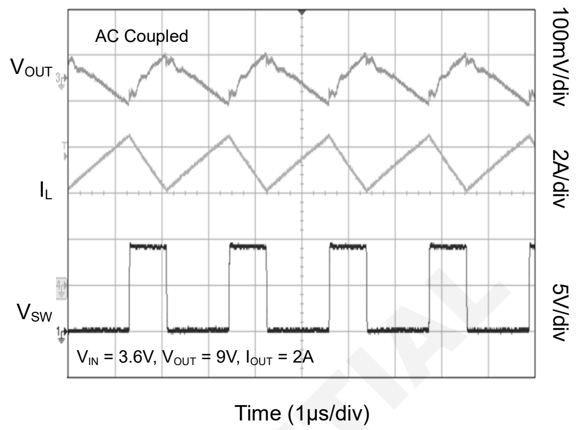
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At T_A = +25℃, V_{IN} = 3.6V, V_{OUT} = 9V, unless otherwise noted.

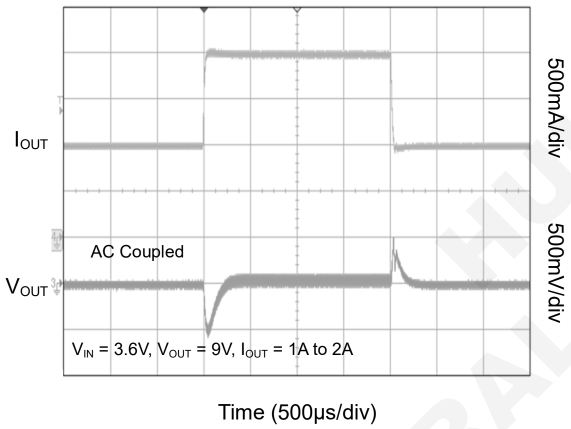
Switching Waveforms in DCM



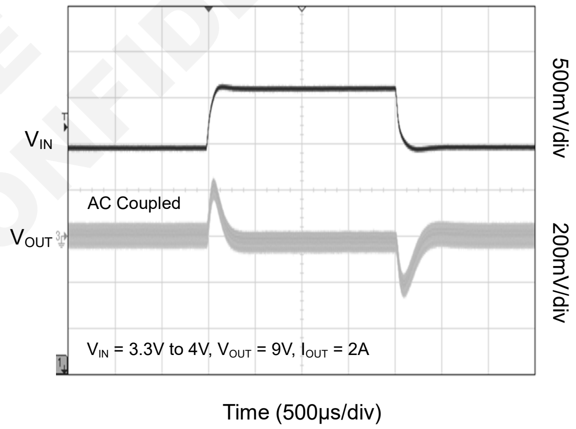
Switching Waveforms in CCM



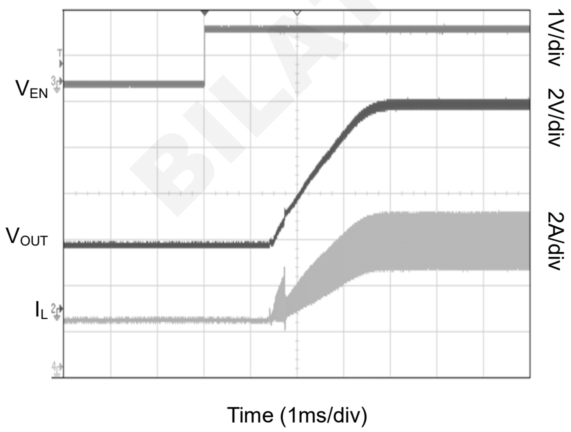
Load Transient Response



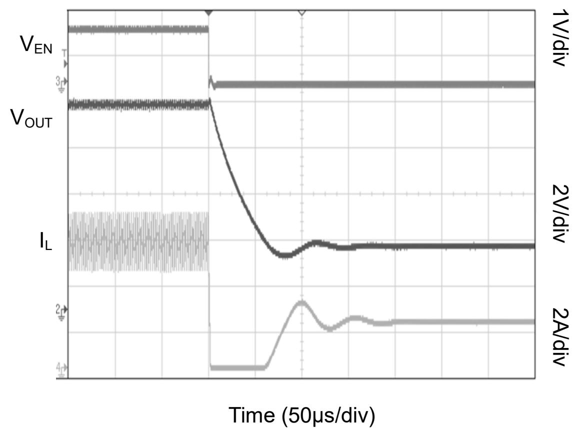
Line Transient Response



Startup Waveforms



Shutdown Waveforms



FUNCTIONAL BLOCK DIAGRAM

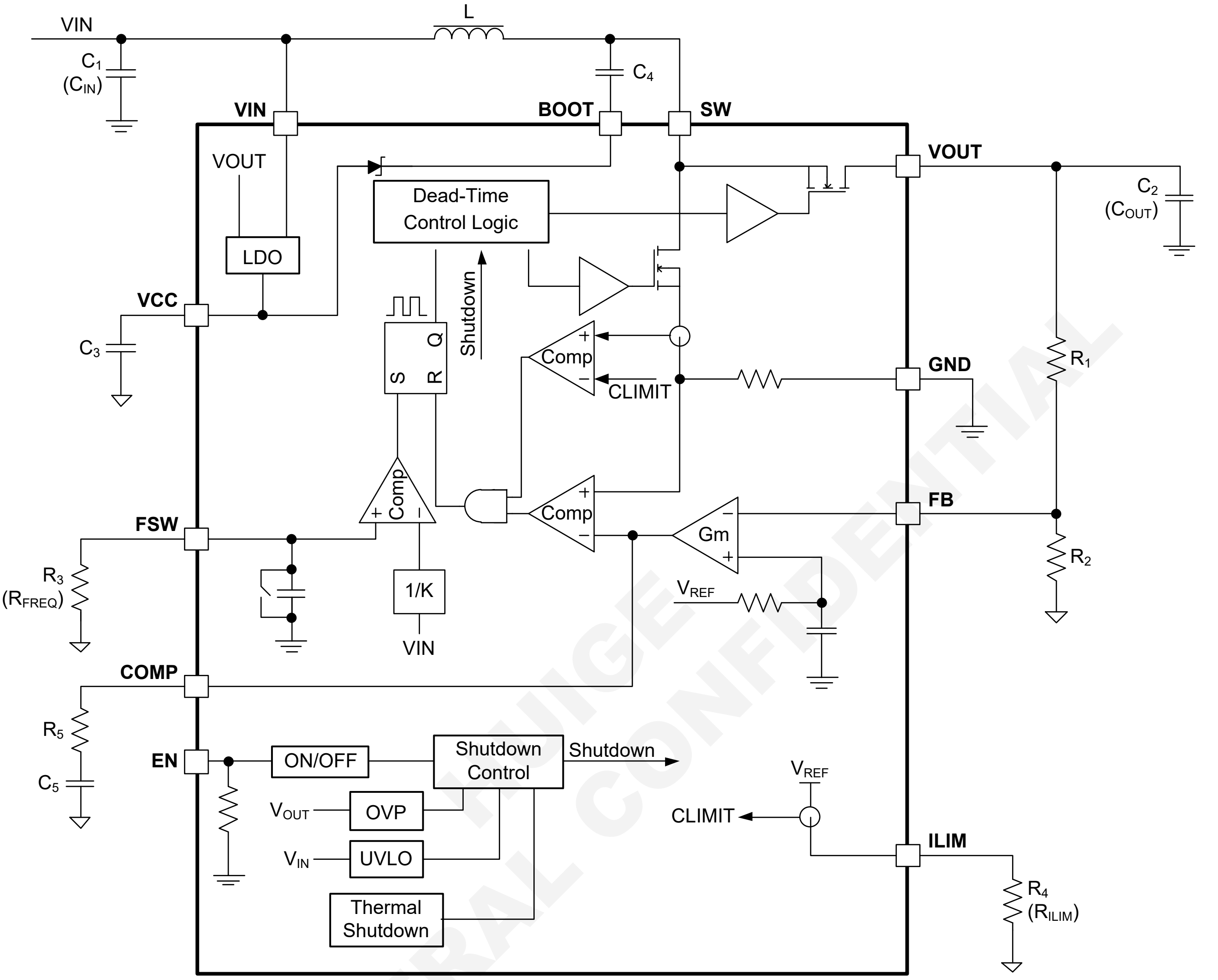


Figure 2. Block Diagram

DETAILED DESCRIPTION

The SGM6611 is a synchronous boost converter integrating a 16mΩ main power switch and a 27mΩ rectifier switch with adjustable switch current up to 9.5A. It is capable to output continuous power of more than 18W from input of a single-cell Li-Ion battery or two-cell Li-Ion batteries in series. The SGM6611 operates at a constant frequency Pulse Width Modulation (PWM) at moderate to heavy load currents. At light load current, the SGM6611A operates in Pulse Frequency Modulation (PFM) mode and the SGM6611B operates in forced PWM (FPWM) mode. The PFM mode brings high efficiency over the entire load range, and the FPWM mode can avoid the acoustic noise and switching frequency interference at light load. The converter uses the peak current mode control scheme, which provides excellent line and load transient responses with minimal output capacitance. The external loop compensation brings flexibility to use different inductors and output capacitors. The SGM6611 supports adjustable switching frequency ranging from 200kHz to 2.2MHz. The device implements cycle-by-cycle current limit to protect the device from overload conditions during boost switching. The current limit is set by an external resistor.

Under-Voltage Lockout (UVLO)

An under-voltage lockout (UVLO) circuit prevents the device from malfunctioning at low input voltage and the battery from excessive discharge. The SGM6611 has both VIN UVLO function and VCC UVLO function. It disables the device from switching when the falling voltage at the VIN pin trips the UVLO threshold V_{IN_UVLO}, which is typically 2.4V. A hysteresis of 100mV is added so that the device cannot be enabled again until the input voltage goes up to 2.5V. It also disables the device when the falling voltage at the VCC pin trips the UVLO threshold V_{CC_UVLO}, which is typically 2.1V.

Enable and Disable

When the input voltage is above maximum UVLO rising threshold of 2.5V and the EN pin is pulled above the high threshold, the SGM6611 is enabled. When the EN pin is pulled below the low threshold, the SGM6611 goes into shutdown mode. The device stops switching in the shutdown mode and consumes less than 1μA current. VIN and VOUT are connected through the body diode of the high-side rectifier FET in the shutdown mode.

Soft-Start

The SGM6611 implements the soft-start function to reduce the inrush current during startup. The SGM6611 begins soft-start when the EN pin is pulled to logic high voltage. The soft-start time is typically 4ms.

Adjustable Switching Frequency

The SGM6611 features a wide adjustable switching frequency range from 200kHz to 2.2MHz. The switching frequency is set by a resistor connected between the FSW pin and the GND pin of the SGM6611. Do not leave the FSW pin open. Use Equation 1 to calculate the resistor value required for a desired frequency.

$$R_{FREQ} = \frac{1}{C_{FREQ} \times f_{SW} - 0.2 \times 10^{-6}} \quad (1)$$

where R_{FREQ} is the resistance connected between the FSW pin and the GND pin, C_{FREQ} = 6.3pF, and f_{SW} is the desired switching frequency.

Adjustable Peak Current Limit

To avoid an accidental large peak current, an internal cycle-by-cycle current limit is adopted. The low-side switch turns off immediately as long as the peak switch current touches the limit. The peak inductor current can be set by selecting the correct external resistor value correlating with the required current limit. Use Equation 2 to calculate the correct resistor value for the SGM6611A.

$$I_{LIM} = \frac{1.2 \times 10^{6}}{R_{ILIM}} \quad (2)$$

where R_{ILIM} is the resistance connected between the ILIM pin and ground, and I_{LIM} is the switch peak current limit.

For a typical current limit of 9.5A, the resistor value is 127kΩ for the SGM6611A.

Over-Voltage Protection

If the output voltage at the VOUT pin is detected above over-voltage protection threshold of 13.2V (TYP), the SGM6611 stops switching immediately until the voltage at the VOUT pin drops the hysteresis voltage lower than the output over-voltage protection threshold. This function prevents over-voltage on the output and secures the circuits connected to the output from excessive over-voltage.

DETAILED DESCRIPTION (continued)

Thermal Shutdown

A thermal shutdown is implemented to prevent damage due to excessive heat and power dissipation. Typically, the thermal shutdown happens at the junction temperature of +160℃. When the thermal shutdown is triggered, the device stops switching until the junction temperature falls below typically +140℃, then the device starts switching again.

Device Functional Modes

Operation

The synchronous boost converter SGM6611 operates at a constant frequency Pulse Width Modulation (PWM) in moderate to heavy load condition. At the beginning of each switching cycle, the low-side N-MOSFET switch, shown in Functional Block Diagram, is turned on, and the inductor current ramps up to a peak current that is determined by the output of the internal error amplifier. After the peak current is reached, the current comparator trips, and it turns off the low-side N-MOSFET switch and the inductor current goes through the body diode of the high-side N-MOSFET in a dead-time duration. After the dead-time duration, the high-side N-MOSFET switch is turned on. Because the output voltage is higher than the input voltage, the inductor current decreases. After a short dead-time duration, the low-side switch is turned on again and the switching cycle is repeated.

In light load condition, the SGM6611A implements PFM mode for applications requiring high efficiency at light load. And the SGM6611B implements forced PWM mode for applications requiring fixed switching frequency to avoid unexpected switching noise interference.

Forced PWM Mode

In the forced PWM mode, the SGM6611B keeps the switching frequency unchanged in light load condition. When the load current decreases, the output of the internal error amplifier decreases as well to keep the inductor peak current down, delivering less power from input to output. When the output current further reduces, the current through the inductor will decrease to zero during the off-time. The high-side N-MOSFET is not turned off even if the current through the MOSFET is zero. Thus, the inductor current changes its direction after it runs to zero. The power flow is from output side to input side. The efficiency will be low in this mode. But with the fixed switching frequency, there is no audible noise and other problems which might be caused by low switching frequency in light load condition.

PFM Mode

The SGM6611A improves the efficiency at light load with the PFM mode. When the converter operates in light load condition, the output of the internal error amplifier decreases to make the inductor peak current down, delivering less power to the load. When the output current further reduces, the current through the inductor will decrease to zero during the off-time. Once the current through the high-side N-MOSFET is zero, the high-side MOSFET is turned off until the beginning of the next switching cycle. When the output of the error amplifier continuously goes down and reaches a threshold with respect to the peak current of $I_{LIM}/10$, the output of the error amplifier is clamped at this value and does not decrease any more. If the load current is smaller than what the SGM6611A delivers, the output voltage increases above the nominal setting output voltage. The SGM6611A extends its off time of the switching period to deliver less energy to the output and regulate the output voltage to 0.2% higher than the nominal setting voltage. With the PFM operation mode, the SGM6611A keeps the efficiency above 70% even when the load current decreases to 1mA. At light load, the output voltage ripple is much smaller due to low peak inductor current. Refer to Figure 3.

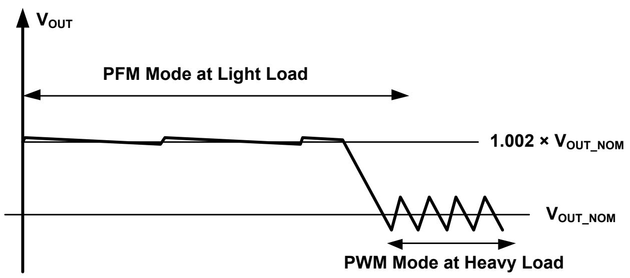


Figure 3. Output Voltage in PWM Mode and PFM Mode

APPLICATION INFORMATION

The SGM6611 is designed for outputting voltage up to 12.6V with 7A continuous switch current capability to deliver more than 18W power. The SGM6611 operates at a constant frequency Pulse Width Modulation (PWM) in moderate to heavy load condition. In light load condition, the SGM6611A operates in the PFM mode and the SGM6611B operates in the forced PWM mode. The PFM mode brings high efficiency over entire load range, while the PWM mode can avoid the acoustic noise as the switching frequency is fixed. In PWM mode, the SGM6611 converter uses the peak current control scheme, which provides excellent transient line and load responses with minimal output capacitance. The SGM6611 can work with different inductor and output capacitor combination by external loop compensation. It also supports adjustable switching frequency ranging from 200kHz to 2.2MHz.

Table 1. Design Parameters

DESIGN PARAMETERS	EXAMPLE VALUES
Input Voltage Range	3.0V to 4.35V
Output Voltage	9V
Output Voltage Ripple	100mV peak-to-peak
Output Current Rating	2A
Operating Frequency	500kHz
Operation Mode at Light Load	PFM

Setting Switching Frequency

The switching frequency is set by a resistor connected between the FSW pin and the GND pin of the SGM6611. The resistor value required for a desired frequency can be calculated using Equation 3.

$$R_{FREQ} = \frac{1}{C_{FREQ} \times f_{SW} - 0.2 \times 10^{-6}} \tag{3}$$

where R_{FREQ} is the resistance connected between the FSW pin and the GND pin, C_{FREQ} = 6.3pF, and f_{SW} is the desired switching frequency.

Setting Peak Current Limit

The peak input current is set by selecting the correct external resistor value correlating to the required current limit. Use Equation 4 to calculate the correct resistor value:

$$I_{LIM} = \frac{1.2 \times 10^{6}}{R_{ILIM}} \tag{4}$$

where R_{ILIM} is the resistance connected between the ILIM pin and ground, and I_{LIM} is the switching peak current limit.

For a typical current limit of 8A, the resistor value is 127kΩ. Considering the device variation and the tolerance over temperature, the minimum current limit at the worst case can be 2A lower than the value calculated by Equation 4. The minimum current limit must be higher than the required peak switch current at the lowest input voltage and the highest output power to make sure the SGM6611 does not hit the current limit and still can regulate the output voltage in these conditions.

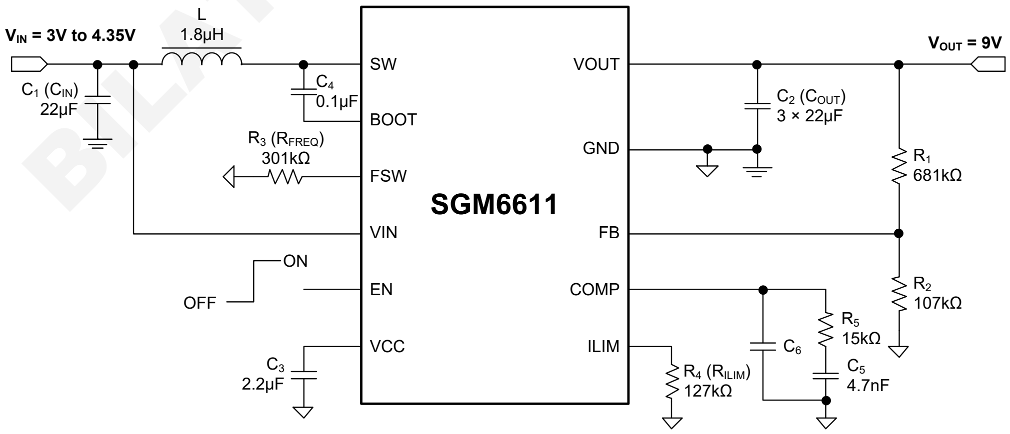


Figure 4. SGM6611 Single-Cell Li-Ion Battery to 9V/2A Output Converter

APPLICATION INFORMATION (continued)

Setting Output Voltage

The output voltage is set by an external resistor divider (R_1, R_2 in Figure 4). Typically, a minimum current of 10μA flowing through the feedback divider gives good accuracy and noise covering. A resistor of less than 120kΩ is typically selected for low-side resistor R_2.

When the output voltage is regulated, the typical voltage at the FB pin is V_{REF}. Thus the value of R_1 is calculated as:

$$R_1 = \frac{(V_{OUT} - V_{REF}) \times R_2}{V_{REF}} \quad (5)$$

Inductor Selection

Because the selection of the inductor affects the power supply's steady state operation, transient behavior, loop stability, and boost converter efficiency, the inductor is the most important component in switching power regulator design. Three most important specifications to the performance of the inductor are the inductor value, DC resistance, and saturation current.

The SGM6611 is designed to work with inductor values between 0.47μH and 10μH. A 0.47μH inductor is typically available in a smaller or lower-profile package, while a 10μH inductor produces lower inductor current ripple. If the boost output current is limited by the peak current protection of the IC, using a 10μH inductor can maximize the controller's output current capability.

Inductor values can have ±20% or even ±30% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the value at 0A current depending on how the inductor vendor defines saturation. When selecting an inductor, make sure its rated current, especially the saturation current, is larger than its peak current during the operation.

Follow Equation 6 to Equation 8 to calculate the peak current of the inductor. To calculate the current in the worst case, use the minimum input voltage, maximum output voltage, and maximum load current of the application. To leave enough design margin, SGMICRO recommends using the minimum switching frequency, the inductor value with -30% tolerance, and a low-power conversion efficiency for the calculation.

In a boost regulator, calculate the inductor DC current as in Equation 6.

$$I_{DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \quad (6)$$

where V_{OUT} is the output voltage of the boost regulator, I_{OUT} is the output current of the boost regulator, V_{IN} is the input voltage of the boost regulator, and η is the power conversion efficiency.

Calculate the inductor current peak-to-peak ripple as in Equation 7.

$$I_{PP} = \frac{1}{L \times \left(\frac{1}{V_{OUT} - V_{IN}} + \frac{1}{V_{IN}}\right) \times f_{SW}} \quad (7)$$

where I_{PP} is the inductor peak-to-peak ripple, L is the inductor value, f_{SW} is the switching frequency, V_{OUT} is the output voltage, and V_{IN} is the input voltage.

Therefore, the peak current, I_{LPEAK}, seen by the inductor is calculated with Equation 8.

$$I_{LPEAK} = I_{DC} + \frac{I_{PP}}{2} \quad (8)$$

Set the current limit of the SGM6611 higher than the peak current I_{LPEAK}. Then select the inductor with saturation current higher than the setting current limit.

APPLICATION INFORMATION (continued)

Boost converter efficiency is dependent on the resistance of its current path, the switching loss associated with the switching MOSFETs, and the inductor's core loss. The SGM6611 has optimized the internal switch resistance. However, the overall efficiency is affected significantly by the inductor's DC resistance (DCR), equivalent series resistance (ESR) at the switching frequency, and the core loss. Core loss is related to the core material and different inductors have different core loss. For a certain inductor, larger current ripple generates higher DCR and ESR conduction losses and higher core loss. Usually, a data sheet of an inductor does not provide the ESR and core loss information. If needed, consult the inductor vendor for detailed information. Generally, SGMICRO would recommend an inductor with lower DCR and ESR. However, there is a tradeoff among the inductor's inductance, DCR and ESR resistance, and its footprint. Furthermore, shielded inductors typically have higher DCR than unshielded inductors. Table 2 lists recommended inductors for the SGM6611. Verify whether the recommended inductor can support the user's target application with the previous calculations and bench evaluation. In this application, the Wurth-Elektronik's inductor 744325180 is selected for its low DCR.

Table 2. Recommended Inductors

PART NUMBER	L (μH)	DCR MAX (mΩ)	SATURATION CURRENT/ HEAT RATING CURRENT (A)	SIZE MAX (L × W × H mm)	VENDOR
CDMC8D28NP-1R8MC	1.8	12.6	9.4/9.3	9.5 × 8.7 × 3.0	Sumida
744325180	1.8	3.5	18/14	10.5 × 10.2 × 4.7	Wurth-Elektronik
744311150	1.5	7.2	14.0/11.0	7.3 × 7.2 × 4.0	Wurth-Elektronik
744311220	2.2	12.5	13.0/9.0	7.3 × 7.2 × 4.0	Wurth-Elektronik
PIMB103T-2R2MS	2.2	9.0	16/13	11.2 × 10.3 × 3.0	Cyntec
PIMB065T-2R2MS	2.2	12.5	12/10.5	7.4 × 6.8 × 5.0	Cyntec

Input Capacitor Selection

For good input voltage filtering, SGMICRO recommends low-ESR ceramic capacitors. The VIN pin is the power supply for the SGM6611. A 0.1μF ceramic bypass capacitor is recommended as close as possible to the VIN pin of the SGM6611. The VCC pin is the output of the internal LDO. A ceramic capacitor of more than 1.0μF is required at the VCC pin to get a stable operation of the LDO.

For the power stage, because of the inductor current ripple, the input voltage changes if there is parasitic inductance and resistance between the power supply and the inductor. It is recommended to have enough input capacitance to make the input voltage ripple less than 100mV. Generally, 10μF input capacitance is sufficient for most applications.

Output Capacitor Selection

For small output voltage ripple, SGMICRO recommends a low-ESR output capacitor like a ceramic capacitor. Typically, three 22μF ceramic output capacitors work for most applications. Higher capacitor values can be used to improve the load transient response. Take care when evaluating a capacitor's derating under DC bias. The bias can significantly reduce capacitance. Ceramic capacitors can lose most of their capacitance at rated voltage. Therefore, leave margin on the voltage rating to ensure adequate effective capacitance. From the required output voltage ripple, use the following equations to calculate the minimum required effective capacitance C_{OUT}:

$$V_{RIPPLE\_DIS} = \frac{(V_{OUT} - V_{IN\_MIN}) \times I_{OUT}}{V_{OUT} \times f_{SW} \times C_{OUT}} \tag{9}$$

$$V_{RIPPLE\_ESR} = I_{LPEAK} \times R_{ESR} \tag{10}$$

where V_{RIPPLE_DIS} is output voltage ripple caused by charging and discharging of the output capacitor, V_{RIPPLE_ESR} is output voltage ripple caused by ESR of the output capacitor, V_{IN_MIN} is the minimum input voltage of boost converter, V_{OUT} is the output voltage, I_{OUT} is the output current, I_{LPEAK} is the peak current of the inductor, f_{SW} is the converter's switching frequency, and R_{ESR} is the ESR of the output capacitors.

APPLICATION INFORMATION (continued)

Loop Stability

The SGM6611 requires external compensation, which allows the loop response to be optimized for each application. The COMP pin is the output of the internal error amplifier. An external compensation network comprised of resister R_5, ceramic capacitors C_5 and C_6 is connected to the COMP pin.

The power stage small signal loop response of peak current control can be modeled by Equation 11.

$$G_{PS}(S)=\frac{R_O\times(1-D)}{2\times R_{SENSE}}\times\frac{(1+\frac{S}{2\times\pi\times f_{ESRZ}})(1-\frac{S}{2\times\pi\times f_{RHPZ}})}{1+\frac{S}{2\times\pi\times f_P}} \quad (11)$$

where D is the switching duty cycle, R_O is the output load resistance, R_{SENSE} is the equivalent internal current sense resistor, which is 0.08Ω, f_P is the pole's frequency, f_{ESRZ} is the zero's frequency, and f_{RHPZ} is the right-half-plane-zero's frequency.

The D, f_P, f_{ESRZ} and f_{RHPZ} can be calculated by following equations.

$$D=1-\frac{V_{IN}\times\eta}{V_{OUT}} \quad (12)$$

where η is the power conversion efficiency.

$$f_P=\frac{2}{2\pi\times R_O\times C_{OUT}} \quad (13)$$

where C_{OUT} is effective capacitance of the output capacitor.

$$f_{ESRZ}=\frac{1}{2\pi\times R_{ESR}\times C_{OUT}} \quad (14)$$

where R_{ESR} is the equivalent series resistance of the output capacitor.

$$f_{RHPZ}=\frac{R_O\times(1-D)^2}{2\pi\times L} \quad (15)$$

The COMP pin is the output of the internal transconductance amplifier. Equation 16 shows the small signal transfer function of compensation network.

$$G_C(S)=\frac{G_{EA}\times R_{EA}\times V_{REF}}{V_{OUT}}\times\frac{(1+\frac{S}{2\times\pi\times f_{COMZ}})}{(1+\frac{S}{2\times\pi\times f_{COMP1}})(1+\frac{S}{2\times\pi\times f_{COMP2}})} \quad (16)$$

where G_{EA} is the amplifier's transconductance, R_{EA} is the amplifier's output resistance, V_{REF} is the reference voltage at the FB pin, V_{OUT} is the output voltage, f_{COMP1}, f_{COMP2} are the poles' frequency of the compensation network, and f_{COMZ} is the zero's frequency of the compensation network.

The next step is to choose the loop crossover frequency, f_C. The higher in frequency that the loop gain stays above zero before crossing over, the faster the loop response is. It is generally accepted that the loop gain cross over no higher than the lower of either 1/10 of the switching frequency, f_{SW}, or 1/5 of the RHPZ frequency, f_{RHPZ}.

At the crossover frequency, the loop gain is 1. Thus the value of R_5 can be calculated by Equation 17. Then set the values of C_5 and C_6 (in Figure 4) by Equation 18 and Equation 19.

$$R_5=\frac{2\pi\times V_{OUT}\times R_{SENSE}\times f_C\times C_{OUT}}{(1-D)\times V_{REF}\times G_{EA}} \quad (17)$$

where f_C is the selected crossover frequency.

The value of C_5 can be set by Equation 18.

$$C_5=\frac{R_O\times C_{OUT}}{2R_5} \quad (18)$$

The value of C_6 can be set by Equation 19.

$$C_8=\frac{R_{ESR}\times C_{OUT}}{R_5} \quad (19)$$

If the calculated value of C_6 is less than 10pF, it can be left open.

Designing the loop for greater than 45° of phase margin and greater than 10dB gain margin eliminates output voltage ringing during the line and load transients.

APPLICATION INFORMATION (continued)

Layout Guidelines

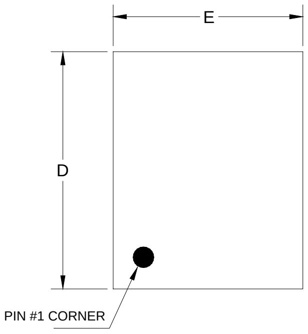
As for all switching power supplies, especially those running at high switching frequency and high currents, layout is an important design step. If layout is not carefully done, the regulator could suffer from instability and noise problems. To maximize efficiency, switching rise time and fall time are very fast. To prevent radiation of high-frequency noise (for example, EMI), proper layout of the high-frequency switching path is essential. Minimize the length and area of all traces connected to the SW pin, and always use a ground plane under the switching regulator to minimize interplane coupling. A ground shielding line needs to be added between SW and FSW paths to minimize the coupling.

The input capacitor should be close to the VIN pin and GND pin in order to reduce the input supply current ripple.

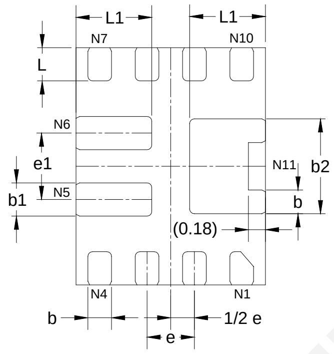
The most critical current path for all boost converters is from the switching FET, through the rectifier FET, then the output capacitors, and back to ground of the switching FET. This high current path contains rise and fall times in nanoseconds, and should be kept as short as possible. Therefore, the output capacitor should be close not only to the VOUT pin, but also to the GND pin to reduce the overshoot at the SW pin and VOUT pin.

PACKAGE OUTLINE DIMENSIONS

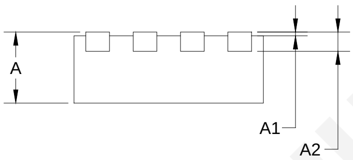
TQFN-2×2.5-11L



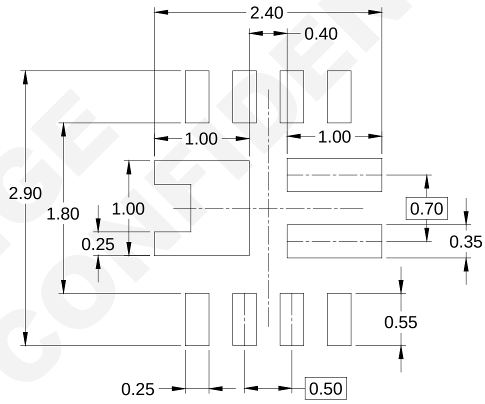
TOP VIEW



BOTTOM VIEW



SIDE VIEW

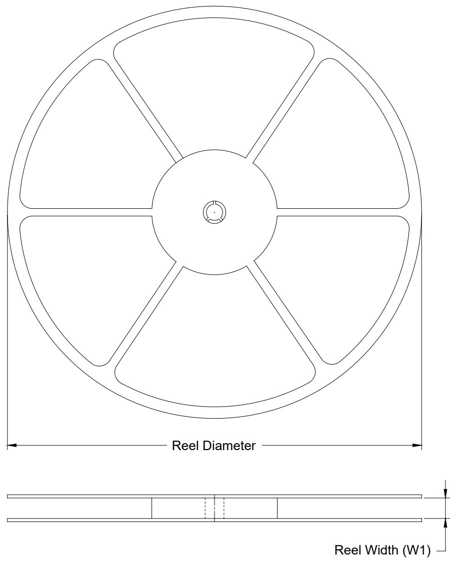


RECOMMENDED LAND PATTERN (mm)

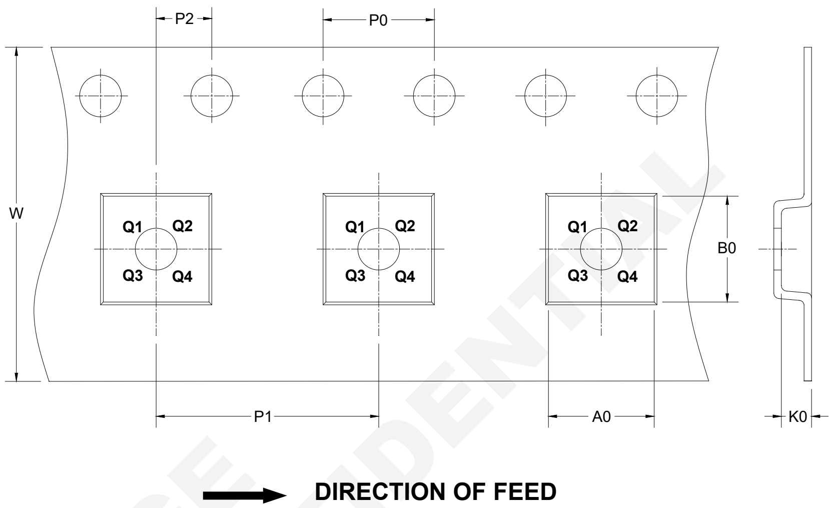
Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	0.7	0.75	0.8
A1	0	0.02	0.05
A2	0.203 REF		
D	2.5 BSC		
E	2 BSC		
e	0.5 BSC		
e1	0.7 BSC		
b	0.2	0.25	0.3
b1	0.3	0.35	0.4
b2	0.95	1	1.05
L	0.3	0.35	0.4
L1	0.75	0.8	0.85

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

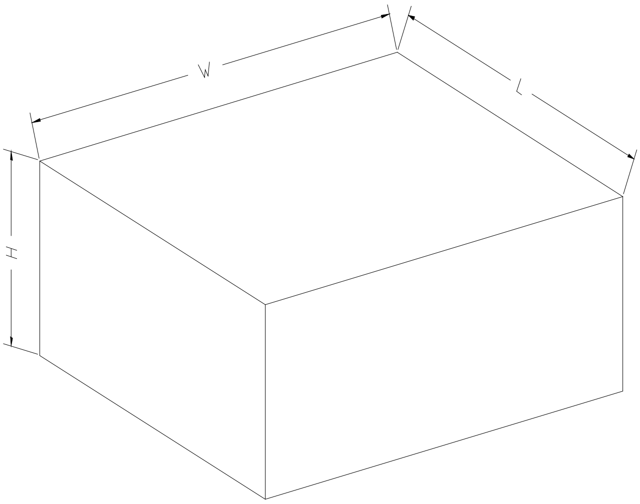


NOTE: The picture is only for reference. Please make the object as the standard.

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
TQFN-2×2.5-11L	7″	9.5	2.20	2.70	0.95	4.0	4.0	2.0	8.0	Q2

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