SGM61032
Low Voltage 3A High Efficiency
Synchronous Step-Down Converter

GENERAL DESCRIPTION

The SGM61032 is an efficient high frequency synchronous step-down converter with integrated switches and 3A output current capability which is optimized for compact solutions. It operates in PWM mode at 1.5MHz (TYP) in the medium to heavy load range and automatically enters or exits the power-save mode (PSM) at light loads to maintain its high efficiency. During shutdown, the quiescent current is 0.1µA (TYP).

Thanks to the internal compensation the number of required external components is minimal that along with the device high switching frequency, provides a perfect solution for compact power supply designs.

Other features include an enable (EN) input and a power good (PG) output. It also employs an internal soft-start circuit for limiting the startup inrush currents. Short-circuit and thermal protections, and an internal output discharge circuit are also provided.

The SGM61032 is available in a Green SOT-563-6 package and can operate in the -40℃ to +125℃ ambient temperature range.

FEATURES

- **2.5V to 5.5V Input Voltage Range**
- **0.6V to V_{IN} Adjustable Output Voltage Range**
- **Up to 3A Output Current**
- **95% Peak Efficiency**
- **1.5MHz (TYP) Switching Frequency**
- **Low R_{DSON} Internal Switches: 58.5mΩ/26.5mΩ**
- **Improved Light Load Efficiency with PSM**
- **Low Dropout with 100% Duty Cycle**
- **Reduce the I_Q to 32µA (TYP) when Low Dropout**
- **42µA Operating Quiescent Current**
- **0.1µA (TYP) Shutdown Quiescent Current**
- **PG Output (Except for the SGM61032A)**
- **Internal Soft-Start with Pre-biased Startup**
- **Output Discharge at Shutdown**
- **Hiccup Mode OCP/Short-Circuit Protection**
- **Thermal Shutdown Protection**
- **Available in a Green SOT-563-6 Package**

APPLICATIONS

General Purpose Point-of-Load Power Supplies
Battery-Powered Applications
Wireless Routers, Solid State Drives
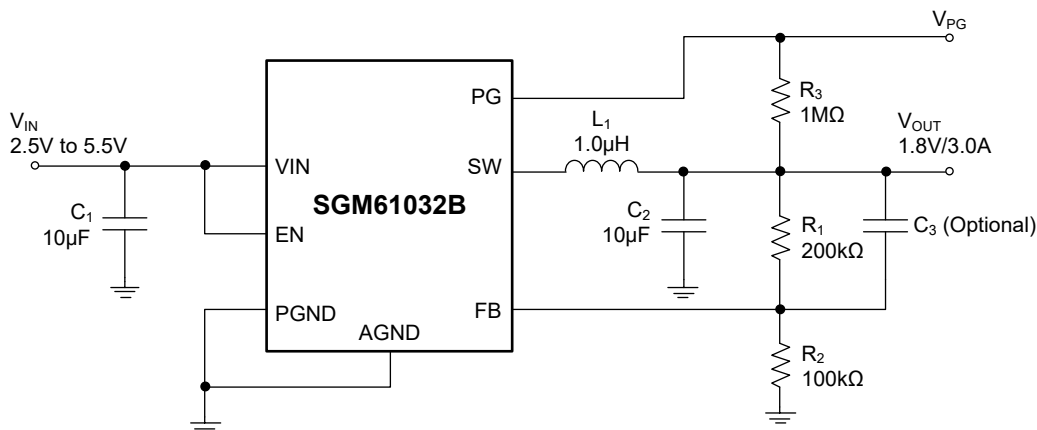Set-Top Boxes, Multi-Function Printers
Motor Control

## TYPICAL APPLICATION

Figure 1. Typical Application Circuit

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM61032A	SOT-563-6	-40℃ to +125℃	SGM61032AXKB6G/TR	1SXX	Tape and Reel, 5000
SGM61032B	SOT-563-6	-40℃ to +125℃	SGM61032BXKB6G/TR	1TXX	Tape and Reel, 5000

MARKING INFORMATION

NOTE: XX = Date Code.

YY X X

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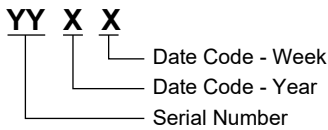
Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

VIN, EN, PG Voltages [1] .... -0.3V to 6V
FB Voltage [1] .... -0.3V to 3V
SW Voltage
  DC [1] ....-0.3V to V_{IN} + 0.3V
  While Switching, Less than 100ns [1] .... -3.0V to 9V
Package Thermal Resistance
SOT-563-6, θ_{JA} .... 169℃/W
Junction Temperature..+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s)............................+260℃

NOTES:
1. All voltages are referred to the ground terminal.

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range, V_{IN} ....2.5V to 5.5V
Output Voltage Range, V_{OUT}................................ 0.6V to V_{IN}
Sink Current at PG Pin, I_{SINK_PG} 1mA
Output Current ....0A to 3A
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.
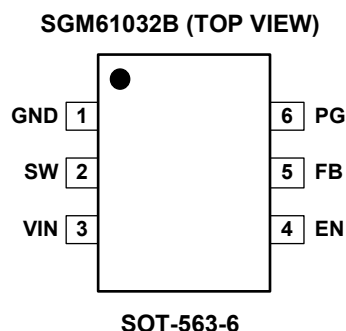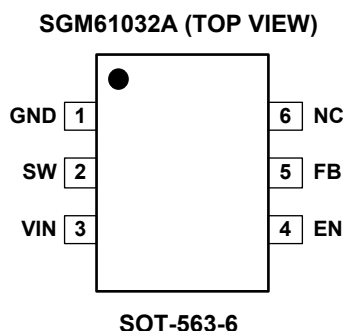
ESD SENSITIVITY CAUTION

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 CONFIGURATIONS

SGM61032A (TOP VIEW)

```
     GND  1        6  NC
     SW   2        5  FB
     VIN  3        4  EN
```

SOT-563-6

SGM61032B (TOP VIEW)

```
     GND  1        6  PG
     SW   2        5  FB
     VIN  3        4  EN
```

SOT-563-6

PIN DESCRIPTION

PIN		NAME	I/O	DESCRIPTION
SGM61032A	SGM61032B			
1	1	GND	G	Ground Pin.
2	2	SW	P	Converter Switching Node Output Pin. Connect to the switching terminal of the output inductor.
3	3	VIN	P	Power Supply Input Pin.
4	4	EN	I	Logic Active-High Enable Input. A Logic low disables the device and puts it into shutdown. Do not leave this pin floating.
5	5	FB	I	Feedback Input Pin for the Control Loop. Connect this pin to the output feedback resistor divider.
6	—	NC	—	No Connection Pin. Leave these pins open or connect them to the output or AGND.
—	6	PG	O	Power Good Open-Drain Output Pin. Pull this pin up with a resistor to a voltage below 5.5V. If not used, leave it open or connect to AGND.

NOTE: I = input, O = output, P = power, G = ground.

ELECTRICAL CHARACTERISTICS

(The values are given for V_{IN} = 5V and T_J = +25℃, unless otherwise noted.)

| PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply						
Input Voltage Range	V_{IN}		2.5		5.5	V
Quiescent Current into VIN	I_Q	No load, device not switching		42		µA
Shutdown Current into VIN	I_{SD}	EN = low		0.1		µA
Under-Voltage Lockout Threshold	V_{UVLO}	V_{IN} falling		2.2		V
Under-Voltage Lockout Hysteresis				210		mV
Thermal Shutdown Threshold	T_{JSD}	T_J rising		150		℃
Thermal Shutdown Hysteresis				25		℃
EN Logic Levels						
High-Level Input Voltage	V_{IH}	V_{IN} = 2.5V to 5.5V	1.2			V
Low-Level Input Voltage	V_{IL}	V_{IN} = 2.5V to 5.5V			0.4	V
Soft-Start and Power Good						
Soft-Start Time	t_{SS}	Time from EN high until V_{OUT} reaches 95% nominal		900		µs
Power Good Threshold	V_{PG}	V_{OUT} rising, (% of nominal V_{OUT})		95		%
		V_{OUT} falling, (% of nominal V_{OUT})		90		
Low-Level Output Voltage	V_{PG_OL}	I_{SINK} = 1mA			0.4	V
Input Leakage Current into PG Pin	I_{PG_LKG}	V_{PG} = 5.0V		0.01		µA
Power Good Delay	t_{PG_DLY}	V_{FB} falling		45		µs
Output						
Feedback Regulation Voltage	V_{FB}	PWM mode, 2.5V ≤ V_{IN} ≤ 5.5V		600		mV
Feedback Input Leakage Current	I_{FB_LKG}	V_{FB} = 0.6V		0.01		µA
Output Discharge FET On-Resistance	R_{DIS}	EN = low, V_{OUT} = 1.8V		15		Ω
Power Switch						
High-side FET On-Resistance	R_{DSON}			58.5		mΩ
Low-side FET On-Resistance				26.5		mΩ
High-side FET Switch Current Limit	I_{LIM}			4.6		A
PWM Switching Frequency	f_{SW}	V_{OUT} = 1.8V, I_{OUT} = 1A		1.5		MHz

FUNCTIONAL BLOCK DIAGRAM
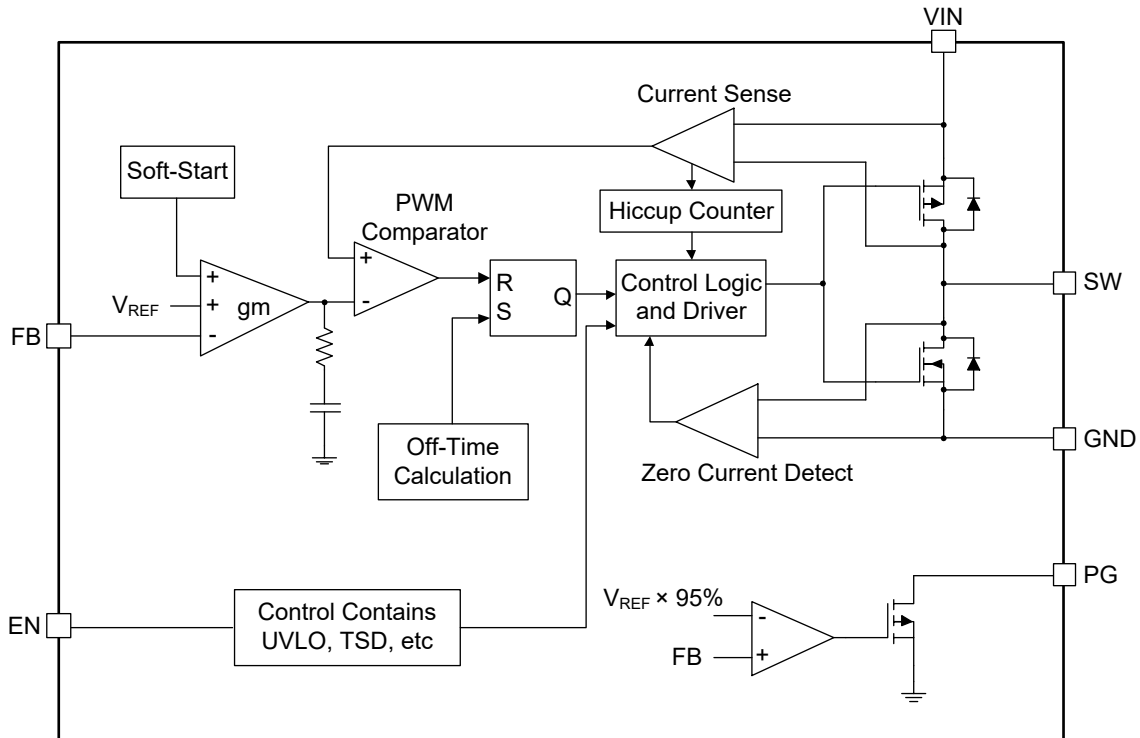
Figure 2. SGM61032B Functional Block Diagram

DETAILED DESCRIPTION

Overview

The SGM61032 is an adaptive off-time peak current mode control synchronous step-down converter optimized for high efficiency and compact size designs. It operates in PWM mode (1.5MHz TYP) in the medium to heavy load range. The low-side switch off-time is set internally based on the V_{IN}/V_{OUT} ratio. So, the switching frequency remains almost constant despite the variations of the input voltage, output voltage and the load current.

Power-Save Mode (PSM)

To keep high efficiency at light load, when the inductor current becomes discontinuous, the device automatically enters power-save mode. In this mode, the switching frequency is reduced to minimize the internal power consumption and also switching and gate losses. Usually in PSM, the output voltage goes slightly above the nominal value. To reduce this deviation, a larger output capacitance can be used or a feedforward capacitor can be added.

Low Dropout Operation with 100% Duty Cycle

The SGM61032 can operate at 100% duty cycle and keep the high-side switch continuously on for minimal input-to-output voltage difference. The low-side MOSFET is kept off. In this mode, the lowest input voltage for keeping the output regulated is determined by load current and the resistive drops from the input to the output as given in Equation 1:

$$V_{IN\_MIN} = V_{OUT} + I_{OUT\_MAX} \times (R_{DSON} + R_L) \qquad (1)$$

where:

V_{IN_MIN} is minimum input voltage to maintain output voltage in regulation.

I_{OUT_MAX} is maximum output current.

R_{DSON} is high-side MOSFET on-resistance.

R_L is inductor DC resistance (DCR).

DETAILED DESCRIPTION (continued)

Soft-Start and Pre-biased Startup

When the device is enabled the output voltage is ramped up towards its nominal value by an internal soft-start circuit with a rate determined by the startup time (t_{SS}). The soft-start is critical to prevent excessive inrush currents and to avoid triggering of the output over-current protection to provide a smooth output rise. It also prevents extreme input voltage drops due to large inrush current over the high impedance batteries and input sources that can interrupt the power-up.

Pre-biased startup is also supported and this device can start with pre-biased output capacitor. In this case, the output voltage ramp starts with the bias voltage and rises to its nominal value.

Switch Current Limits and Short-Circuit Protection (Hiccup)

The high-side switch current is limited to protect the device and the output against inductor over-current. This also prevents excessive loading on the input battery or voltage rail. Over-current may occur due to a heavy load, an output short, or inductor saturation or shorting. In each cycle, if the peak inductor current reaches the I_{LIM} threshold, the high-side switch is turned off and the low-side switch is turned on for a period (t_{OFF}) determined by the adaptive off-time controller to bring the inductor current down. If the switch limit threshold is reached for 32 successive cycles, the current limit will be first reduced for the next 32 cycles and then if the over-current continuous, the switching will stopped for protection. After 500µs (TYP), the device will automatically restart with a fresh startup sequence (hiccup). The hiccup process will repeat until the over-load or short-circuit fault condition is cleared. For the SGM61032, the hiccup mode protection is enabled during startup.

Under-Voltage Lockout (UVLO)

An insufficient supply voltage may cause malfunctions in the device circuitry. The UVLO keeps the device in shutdown mode until the input voltage is large enough for startup. The device will also enter shutdown mode if it is already operating and then the input voltage drops below the falling UVLO threshold. When the input voltage exceeds the rising UVLO threshold, the device restarts with a fresh startup sequence. The V_{UVLO} hysteresis is 210mV.

Reduced Quiescent Current in Low Dropout

When the device operates in low dropout state, the I_Q will be reduced to 32µA (TYP) (excluding the current flowing through the feedback resistor).

Thermal Protection and Shutdown

To protect the device from overheating damage, the die temperature (T_J) is monitored and if it exceeds the shutdown threshold (T_{JSD}) the switching will be stopped and the device shuts down. An automatic recovery with a fresh startup occurs when the die cools down for 25℃ below the T_{JSD} limit.

Device Enable and the Output Discharge FET

The SGM61032 is enabled by pulling the EN pin to logic high and disables (shut down) by pulling it low. The shutdown current is 0.1µA (TYP). In this mode, the converter and the entire control circuitry are turned off. During shutdown, an internal FET (15Ω typical on-resistance) is turned on and connects the SW pin to the GND for smooth discharge of the output.

Power Good (PG)

The PG is an open-drain indicator output to show that the output voltage is normal and in regulation range. This output will go high (with an external pull-up resistor) when the output voltage exceeds 95% of its nominal value. It is pulled low when the output falls below 90% of its nominal value. The PG pin output can sink up to 1mA. The pull-up voltage must be less than 5.5V. The PG can be used for sequencing of multiple voltage rails of the system by connecting the PG output of a preceding rail to the EN input of the next supply rail. Leave the PG pin open or short it to AGND when it is not used.

Table 1. PG Output Logic

Condition		PG State
Output Voltage Good ($V_{FB} \geq V_{PG}$)	EN = High	Hi-Z
Output Voltage Not Good ($V_{FB} \leq V_{PG}$)	EN = High	Low
Shutdown by EN	EN = Low	Low
Thermal Shutdown	EN = Low or High	Low
UVLO (1.4V < V_{IN} < 2.3V)	EN = Low or High	Low
Power Supply Removal ($V_{IN} \leq 1.4V$)	EN = Low or High	Hi-Z

APPLICATION INFORMATION

In this section, the design and selection of the external components for a complete power supply using SGM61032 is discussed. Typical applications are used as reference for other inputs and output voltage examples. The device is designed to operate from a 2.5V to 5.5V input supply with sufficient current rating.
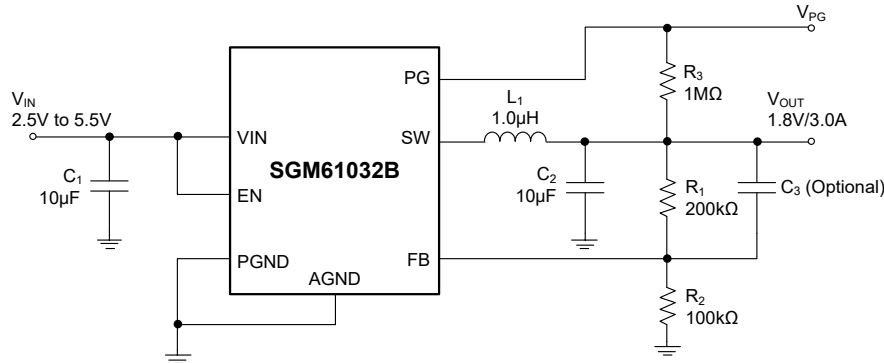

Figure 3. 1.8V Output Voltage Application

Design Requirements

For this example, the design requirement parameters are given in Table 2. The selected components are listed in Table 4.

Table 2. Design Parameters Example

Design Parameter	Example Value
Input Voltage	2.5V to 5.5V
Output Voltage	1.8V
Maximum Output Current	3A

Detailed Design Procedure

Output Voltage Adjustment

Use Equation 2 for selecting the feedback resistors (R_1 and R_2) in Figure 3 to set the desired output voltage (V_{OUT}):

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_1}{R_2}\right) = 0.6V \times \left(1 + \frac{R_1}{R_2}\right) \qquad (2)$$

First choose R_2 value below 100kΩ to avoid high noise sensitivity on the FB pin. Do not choose a very small value for R_2 otherwise the loss will be increased on this resistor that reduces the light load efficiency.

LC Filter

The inductor (L) and the output capacitor (C) form a low-pass filter for removing switching AC components and passing the DC voltage to the output. Table 3 lists some suitable high frequency inductor and ceramic capacitor combinations that can be applied for most applications. Note that variations as high as +20% to -30% in the effective inductance due to tolerances and saturation/derating is expected. Similarly, for the C_{OUT}, due to tolerances and bias voltage derating the effective capacitance can vary by +20% to -50%. For lower ripple at small output voltages (< 1.8V), a larger output capacitance is needed (at least 22µF). If C_{OUT} > 47µF, a feed forward capacitor (C_3) should be used.

Table 3. Some Suitable Combinations L and C Values for the LC Filter

Nominal C_{OUT} / Nominal L	10µF	22µF	47µF	100µF
0.47µH				
1µH	Recommended	(Typical Configuration) Recommended	Recommended	
2.2µH				

Table 4. Selected Components for the Design Requirements Listed in Table 2

Reference	Description	Manufacturer
C_1	10µF, Ceramic Capacitor, 10V, X7R, size 0805, GRM21BR71A106ME51	Murata
C_2	22µF, Ceramic Capacitor, 6.3V, X7T, size 0805, GRM21BD70J226ME44	Murata
C_3	Optional	Std
L_1	1µH, Power Inductor, size 4mm × 4mm × 1.5mm, XFL4020-102ME	Coilcraft
R_1	Depending on the output voltage, 1%, size 0603	Std
R_2	100kΩ, Chip Resistor, 1/16W, 1%, size 0603	Std
R_3	1MΩ, Chip Resistor, 1/16W, 1%, size 0603	Std

APPLICATION INFORMATION (continued)

Inductor

The inductor current ripple is determined by the inductance value (L). A lower inductance, results in higher peak-to-peak current that increases the converter conduction losses. On the other hand, a large inductance results in slower transient response and larger size. Typically, the peak-to-peak inductor current is selected between 20% to 40% of the maximum output current. Equation 3 can be used to choose the inductance value based on ΔI_L.

$$I_{L\_MAX} = I_{OUT\_MAX} + \frac{\Delta I_L}{2}$$

$$\Delta I_L = V_{OUT} \times \frac{1 - \dfrac{V_{OUT}}{V_{IN}}}{L \times f_{SW}} \tag{3}$$

where:

I_{OUT_MAX} is the maximum output DC current.
ΔI_L is the inductor current ripple (peak-to-peak).
f_{SW} is switching frequency (MHz).
L is the inductance value (µH).

For a selected inductance value, the saturation current should have a reasonable margin relative to the expected steady state peak inductor current. It is recommended to choose an inductor that its saturation current is at least 20% to 30% higher than the calculated I_{L_MAX}. Selecting an inductor with low DCR provides better efficiency.

Input and Output Capacitor

Thanks to the advanced controller of the SGM61032, low ESR ceramic capacitors can be used in the output of the SGM61032. Especially the X5R or X7R or better grade ceramic capacitors are recommended to achieve low output voltage ripple and compact size with low thermal tolerance. The SGM61032 is designed to operate with 10µF to 47µF output capacitors. A 22µF, X7T capacitor is used in this example as given in Table 4 for C_2.

A low ESR ceramic capacitor is also recommended for the input to provide a low-impedance circulation path for the high frequency switching currents and keep them away from the input source and the input impedances for stable operation. For most applications, a 10µF ceramic capacitor is sufficient, however a larger value can be used to reduce the input ripples.

A feedforward capacitor improves transient response to the load steps and reduces the output ripple in PSM. It is recommended when the output voltage setting is below 1.8V or the output capacitance is above 47µF. A 22pF capacitor is recommended for the 1.8V output in the typical application.

Thermal Considerations

Especial care must be taken for power dissipation and thermal relief in high power density designs. The SGM61032 is a low-profile and fine-pitch surface-mount package that is typically use in a small area or volume. Thermal coupling, airflow and heat sinking must be considered in the system level and the space between heat generating elements must be managed properly.

To enhance the thermal performance, the PCB itself has a significant role and can help transferring the heat away by using large copper traces/planes that are connected to the device pins (and thermal pads if present). Considering a proper airflow in the system can complete the thermal relief for reliable operation of the power supply.

Layout

A critical component of a high frequency switching power supply is the PCB layout. A good layout can improve the overall performance of the system and a poor layout may result in stability issues and EMI problems. The following guidelines are provided for designing a power supply layout with the SGM61032.

Place the input/output capacitors and the inductor as close as possible to the IC pins and keep the power traces short. Use direct and wide traces for routing power paths to assure low trace parasitic resistance and inductance.

Connect the ground returns of the input and output capacitors close to the PGND pin and at the same point to avoid a ground potential shift and to minimize high frequency current path.

Keep the output voltage sense trace and FB pin connections away from the high frequency and noisy conductors such as power traces and SW node to avoid magnetic and electric noise coupling.

Use a ground plane on the same layer for all returns. Ground planes in the mid layers can be used to shield the switching noises.
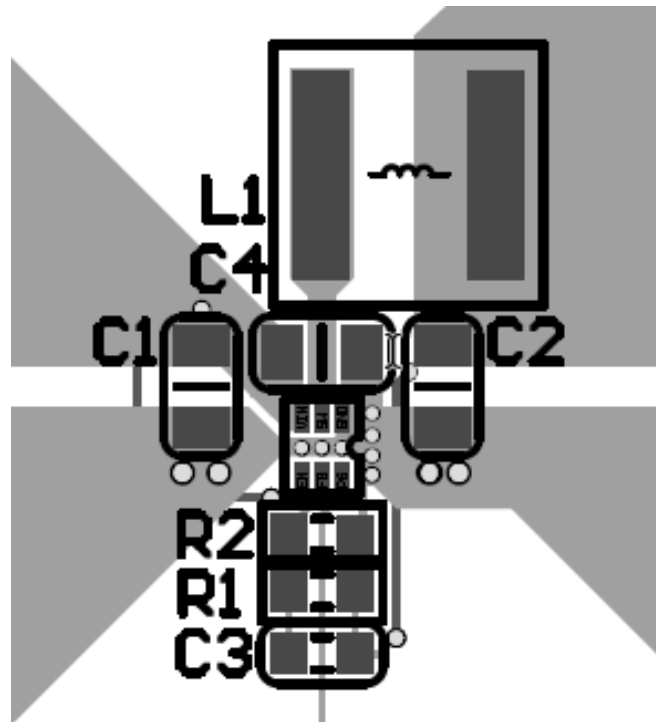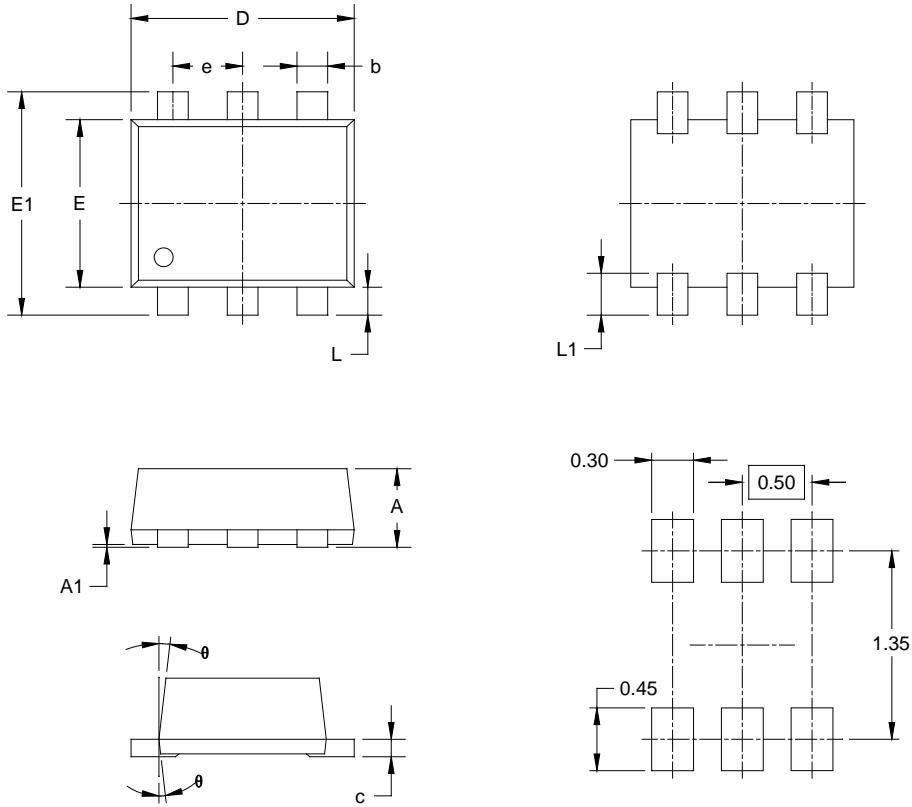
APPLICATION INFORMATION (continued)

Layout Example

Figure 4. Recommended PCB Layout

PACKAGE OUTLINE DIMENSIONS

SOT-563-6

RECOMMENDED LAND PATTERN (Unit: mm)

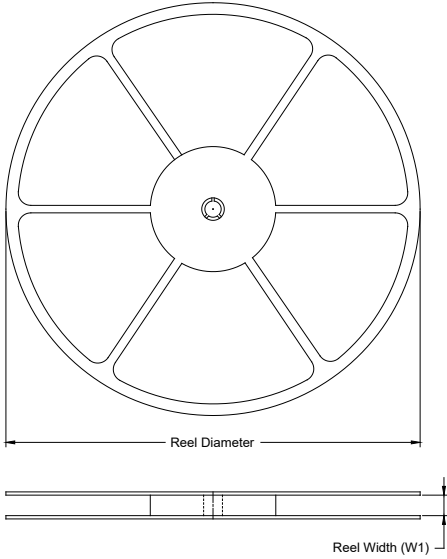| Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.525	0.600	0.021	0.024
A1	0.000	0.050	0.000	0.002
b	0.170	0.270	0.007	0.011
c	0.090	0.180	0.004	0.007
D	1.500	1.700	0.059	0.067
E	1.100	1.300	0.043	0.051
E1	1.500	1.700	0.059	0.067
e	0.450	0.550	0.018	0.022
L	0.100	0.300	0.004	0.012
L1	0.200	0.400	0.008	0.016
θ	9° REF		9° REF	

NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

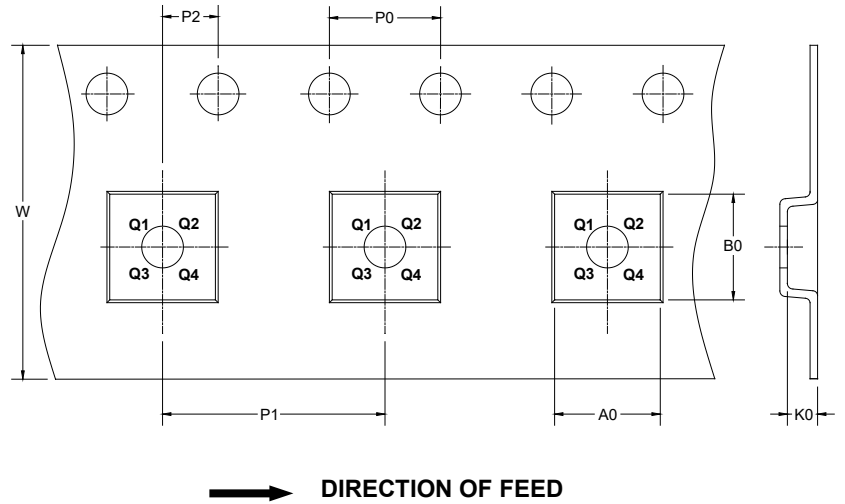# TAPE AND REEL INFORMATION

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
SOT-563-6	7″	9.5	1.78	1.78	0.69	4.0	4.0	2.0	8.0	Q3

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

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