SGM6608
High Current Synchronous Step-Up Converter with Programmable Current Limit

GENERAL DESCRIPTION

The SGM6608 is a high current, synchronous step-up regulator with a programmable peak current limit. It is ideal to prevent the output current of SGM6608 from overloading. The SGM6608's internal compensation is optimized for the large output capacitors needed to support the output voltage during large load pulses.

The output voltage may be programmed from 3.0V to 5.0V by an external resistor divider. Light load switching frequency modulation and low quiescent current maintains high efficiency performance for light load mode conditions.

The peak current limit can be set by an external resistor RSET. The SGM6608 includes an internal over-voltage protection and a power-good indication. SGM6608 has an internal soft-start circuit to reduce the input peak current.

The SGM6608 is available in Green TDFN-3×3-12L package and is rated over the -40℃ to +85℃ temperature range.

FEATURES

- 2.4V to 5.0V Input Voltage Range
- Adjustable 3.0V to 5.0V Output Voltage
- Internal Compensation
- 660kHz Switching Frequency
- Synchronous P-Channel MOSFET
- Programmable Peak Current Limit (Up to 4A)
- True Load Disconnect in Shutdown
- Reverse Current Block When Enabled
- Up to 95% Efficiency
- Power-Good Indication
- Very Low 55µA No-Load Operating Current
- Less than 1µA Shutdown Current
- 5.55V Output Over-Voltage Protection
- Thermal Shutdown Protection
- Output Short-Circuit Protection
- Soft-Start to Reduce Input Peak Current
- Available in Green TDFN-3×3-12L Package
- -40℃ to +85℃ Operating Temperature Range

APPLICATIONS

Media Tablets
PCI-Express Cards
PCMCIA Cards
Modems
Wireless Data Cards

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	MARKING INFORMATION	PACKING OPTION
SGM6608	TDFN-3×3-12L	-40℃ to +85℃	SGM6608YTDF12G/TR	SGM 6608DF XXXXX	Tape and Reel, 4000

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

Input Supply Voltage Range .... -0.3V to 6V
Supply Voltage on SW, VOUT, EN, FB, $\overline{PG}$
.... -0.3V to 6V
PGND to AGND .... -0.3V to 0.3V
Package Thermal Resistance
TDFN-3×3-12L, θ_{JA} .... 52.1℃/W
Junction Temperature ....150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s) ....260℃
ESD Susceptibility
HBM...4000V
MM...200V

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range ....2.4V to 5.0V
Operating 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.
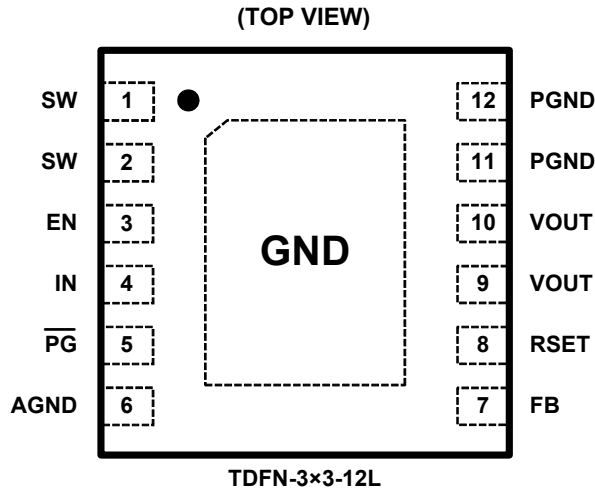
ESD SENSITIVITY CAUTION

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
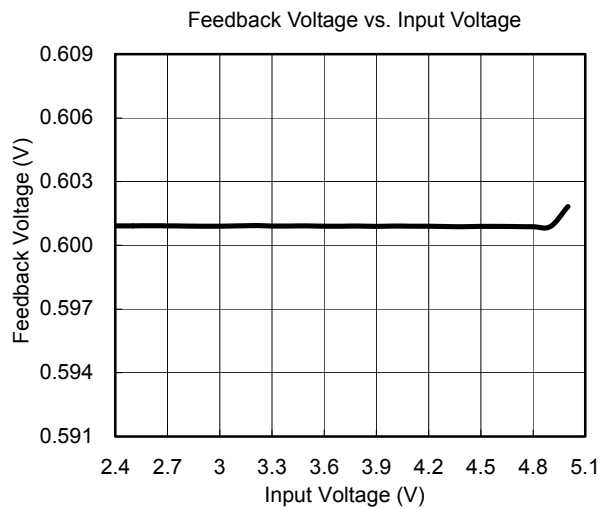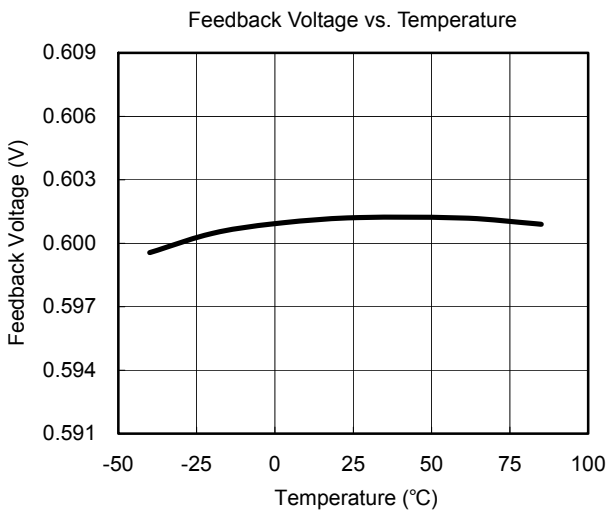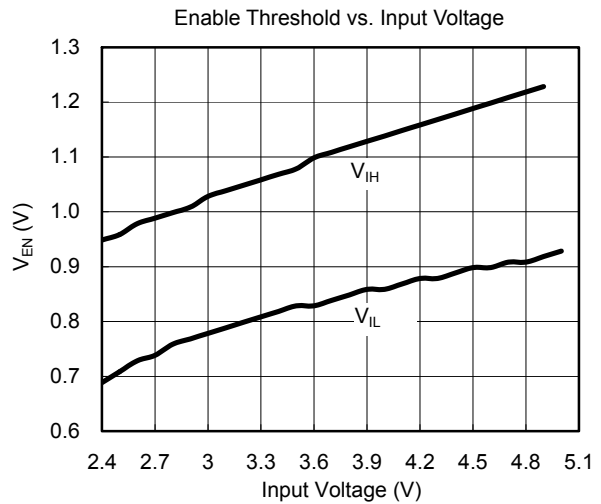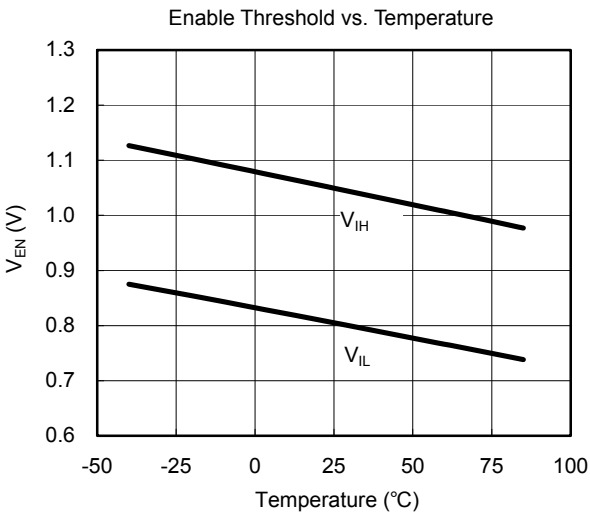
PIN CONFIGURATION

(TOP VIEW)

```
         ┌─────────────────────────┐
  SW  ───┤ 1  ●                 12 ├─── PGND
         │                         │
  SW  ───┤ 2                    11 ├─── PGND
         │    ┌ ─ ─ ─ ─ ─ ─ ┐      │
  EN  ───┤ 3  │             │   10 ├─── VOUT
         │    │    GND      │      │
  IN  ───┤ 4  │             │    9 ├─── VOUT
         │    │             │      │
  PG  ───┤ 5  │             │    8 ├─── RSET
         │    └ ─ ─ ─ ─ ─ ─ ┘      │
 AGND ───┤ 6                     7 ├─── FB
         └─────────────────────────┘
```

TDFN-3×3-12L

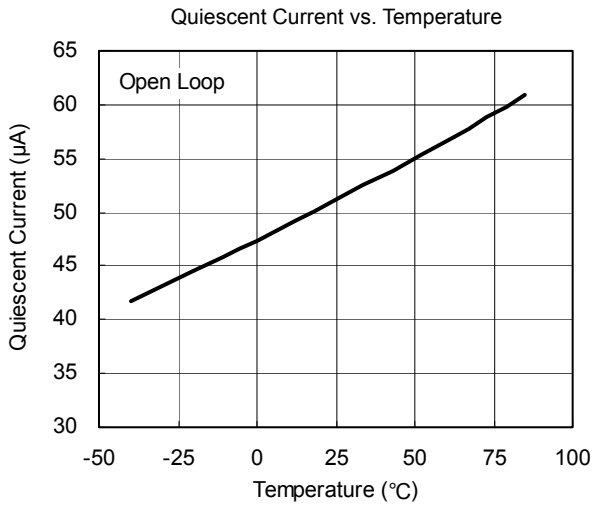# PIN DESCRIPTION

PIN	NAME	FUNCTION
1, 2	SW	Inductor Switching Node. SW is internally connected to the source of the internal low-side N-Channel MOSFET (NMOS), and synchronous high-side P-Channel MOSFET (PMOS). Externally connected to the switching side of the power inductor.
3	EN	Enable Input. A logic high enables the SGM6608 regulator. A logic low forces the SGM6608 into shutdown mode, placing the output into a high-impedance state (true load disconnect) and reducing the quiescent current to less than 1µA.
4	IN	Input Supply. IN powers the analog control circuitry during start-up. Bypass IN to GND should with a 10µF or greater ceramic capacitor.
5	$\overline{PG}$	Power-Good Signal (Active Low). $\overline{PG}$ is an open-drain, active-low output. $\overline{PG}$ is pulled low when the feedback voltage exceeds 95% of the target voltage.
6	AGND	Analog Ground. AGND is internally connected to the analog ground of the control circuitry.
7	FB	Output Voltage Feedback Pin. FB senses the output voltage for regulation control. For adjustable output version, connect a resistive divider network from the output to FB to GND to set the output voltage accordingly. The FB regulation threshold is 0.6V.
8	RSET	Program the Current Limit with R_{SET}. An external resistor from RSET to ground is adopted to program the low-side MOSFET peak current limit.
9, 10	VOUT	Output of Step-Up Regulator. VOUT internally connects to the synchronous high-side P-Channel MOSFET.
11, 12	PGND	Power Ground. PGND is internally connected to the source of the low-side N-Channel MOSFET.
Exposed Pad	GND	Power Ground Exposed Pad. Must be connected to ground plane.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.3V, V_{OUT} = 3.8V, L = 2.2µH, AGND = PGND, T_A = +25℃, unless otherwise noted.)

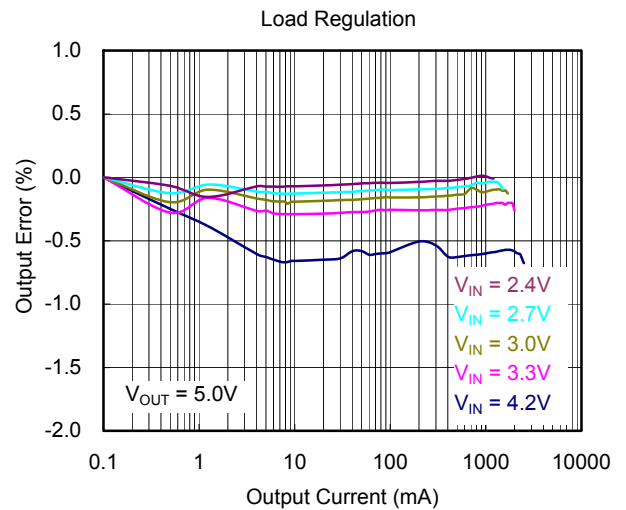| PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage Range	V_{IN}		2.4		5.0	V
Minimum Start-Up Voltage	$V_{IN(MIN)}$			2.3		V
Output Voltage Range	V_{OUT}		3.0		5.0	V
Input Under-Voltage Lockout	V_{UVLO}	V_{IN} Rising, Hysteresis = 0.2V	2.15	2.25	2.35	V
Quiescent Supply Current	I_Q	No-Load Current; Not Switching		55	75	µA
Shutdown Supply Current	I_{SHDN}	V_{EN} = GND, V_{IN} = 5.0V			1	µA
Feedback Accuracy	V_{FB}	T_A = +25℃	0.588	0.600	0.612	V
		T_A = -40℃ to +85℃	0.583	0.600	0.618	
Feedback Leakage Current	I_{FB}	V_{FB} = 0 to 1.0V	-1		+1	µA
Load Regulation	$\Delta V_{OUT}/I_{OUT}$	V_{IN} = 3.3V, V_{OUT} = 3.8V, 0 to 2.5A Load		1		%/A
Line Regulation	$\Delta V_{OUT}/V_{IN}$	V_{IN} = 2.4V to V_{OUT}, I_{OUT} = 10mA		0.3		%/V
Output Over-Voltage Protection Threshold	V_{OVP}		5.25	5.55	5.85	V
Switching Frequency	f_{SW}		560	660	760	kHz
Maximum Duty Cycle	D			90		%
Minimum On-Time	$t_{ON(MIN)}$			80		ns
High-side P-Channel On-Resistance	$R_{ON(PMOS)}$			100		mΩ
Low-side N-Channel On-Resistance	$R_{ON(NMOS)}$			80		mΩ
Low-side Peak Current Limit Threshold	I_{LIMPK}	T_A = +25℃, R_{SET} = 60.4kΩ	2	2.8	3.7	A
ENABLE, POWER-GOOD AND START-UP FEATURES						
Logic Input Threshold High for EN	V_{IH}		1.5			V
Logic Input Threshold Low for EN	V_{IL}				0.4	V
EN Input Low Current	I_{EN}	V_{EN} = GND or 5.0V	-1	0.01	4	µA
Power-Good Threshold		FB Rising, Hysteresis = 10%		95		%
$\overline{PG}$ On-Resistance	$R_{\overline{PG}}$	V_{FB} = 0.62V, I_{SINK} = 10µA		135		Ω
THERMAL						
Over-Temperature Shutdown Threshold	T_{SD}	Temperature Rising		150		℃
Over-Temperature Shutdown Hysteresis	T_{HYS}			20		℃

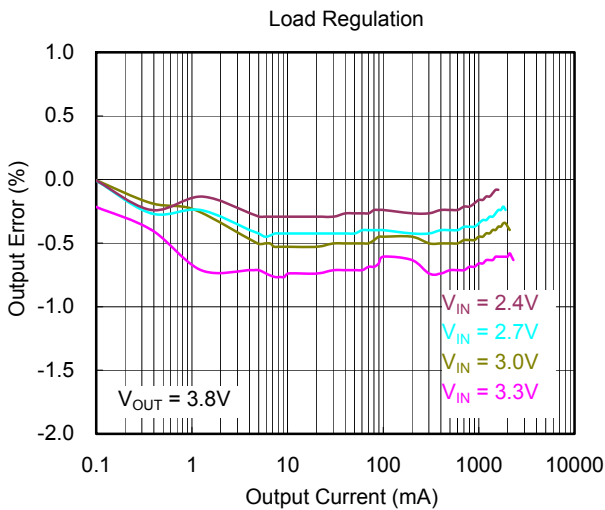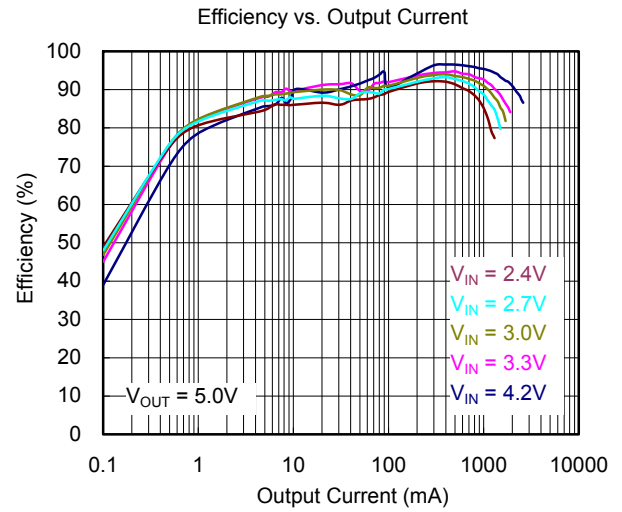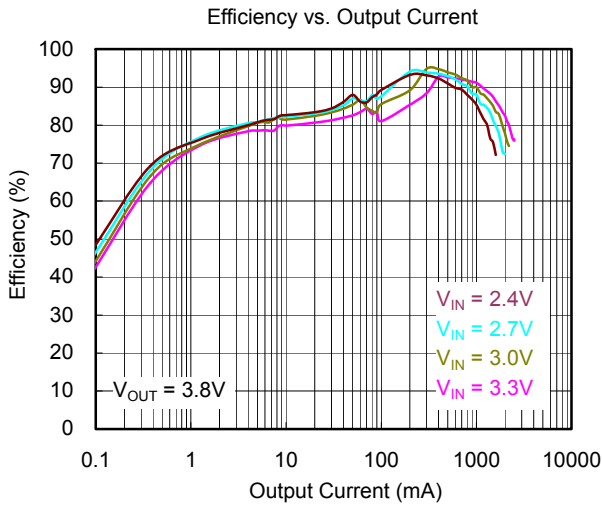# TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.3V, V_{OUT} = 3.8V, L = 2.2µH, AGND = PGND, T_A = +25℃, unless otherwise noted.

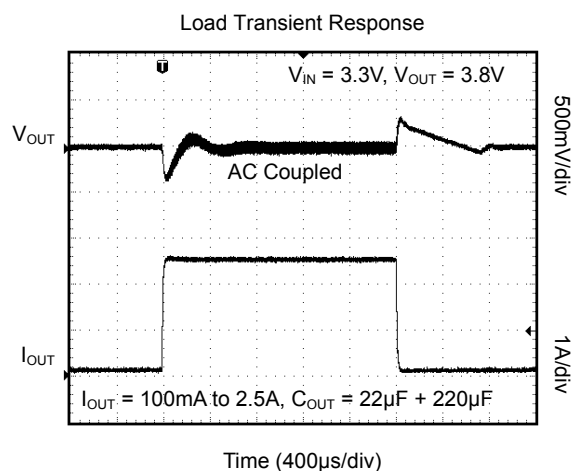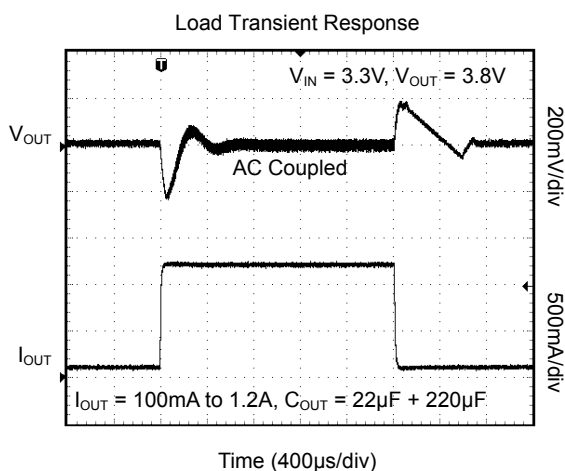Quiescent Current vs. Temperature

Quiescent Current vs. Input Voltage

Enable Threshold vs. Temperature

Enable Threshold vs. Input Voltage

Feedback Voltage vs. Temperature

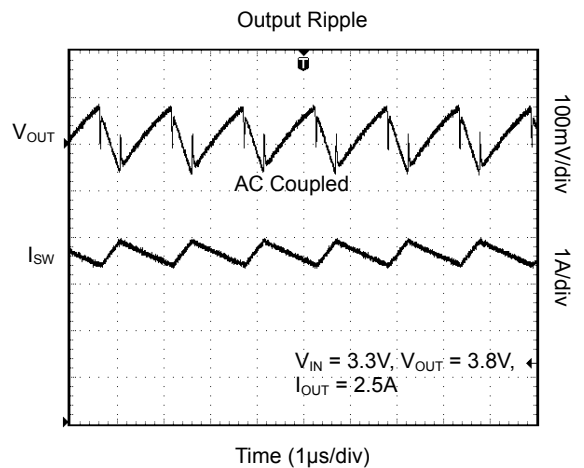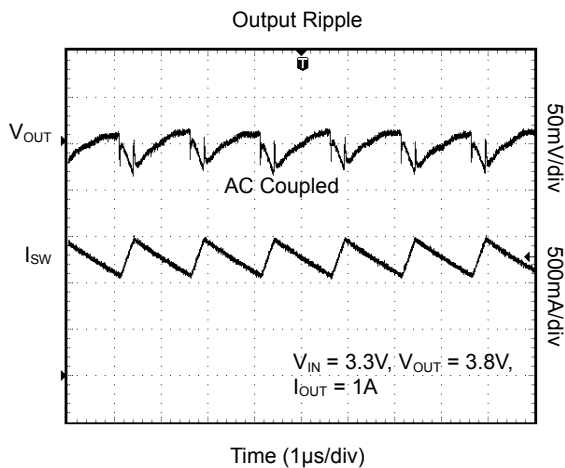

Feedback Voltage vs. Input Voltage

TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.3V, V_{OUT} = 3.8V, L = 2.2µH, AGND = PGND, T_A = +25°C, unless otherwise noted.

Efficiency vs. Output Current

Efficiency vs. Output Current

Load Regulation

Load Regulation

Line Regulation

Switching Frequency vs. Temperature

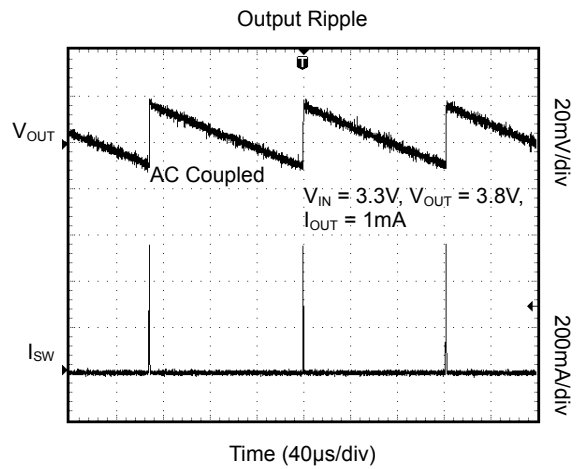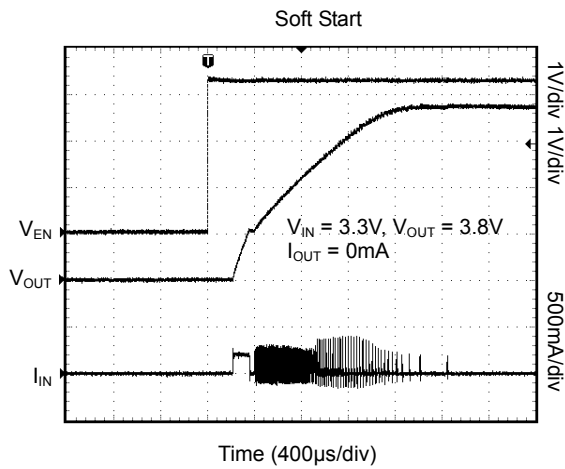# TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.3V, V_{OUT} = 3.8V, L = 2.2µH, AGND = PGND, T_A = +25°C, unless otherwise noted.

Soft Start

Output Ripple

Output Ripple

Output Ripple

Load Transient Response

Load Transient Response

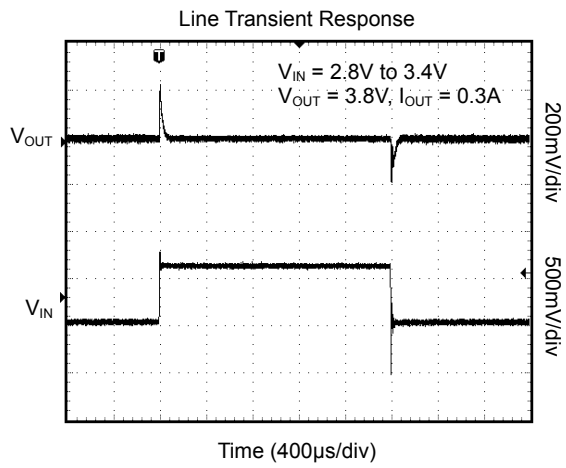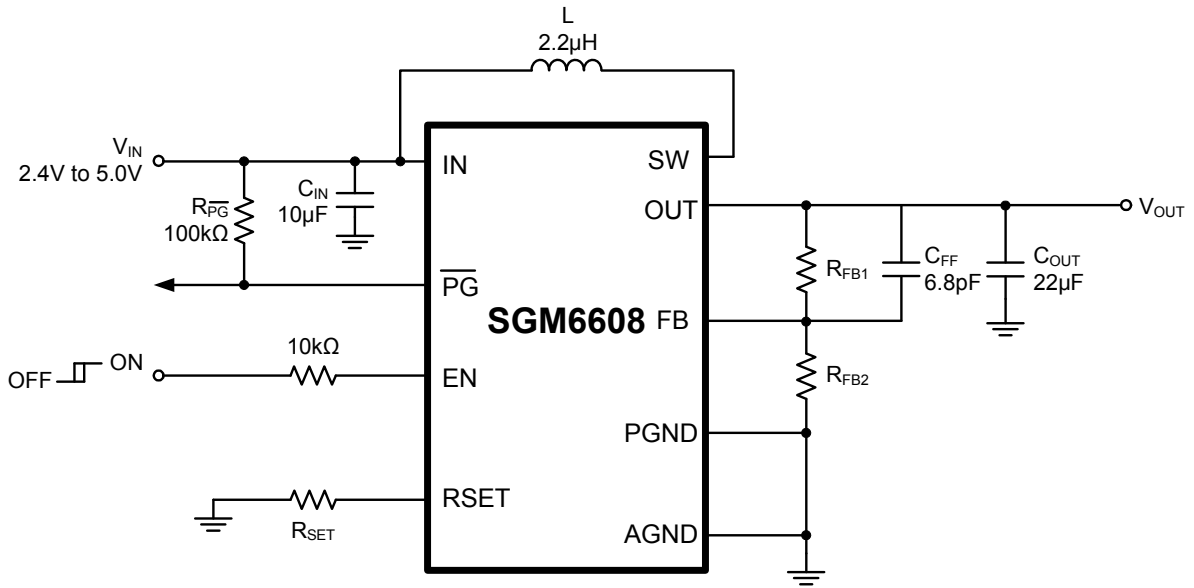# TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.3V, V_{OUT} = 3.8V, L = 2.2µH, AGND = PGND, T_A = +25℃, unless otherwise noted.

Line Transient Response

V_{IN} = 2.8V to 3.4V
V_{OUT} = 3.8V, I_{OUT} = 0.3A

V_{OUT} 200mV/div

V_{IN} 500mV/div

Time (400µs/div)
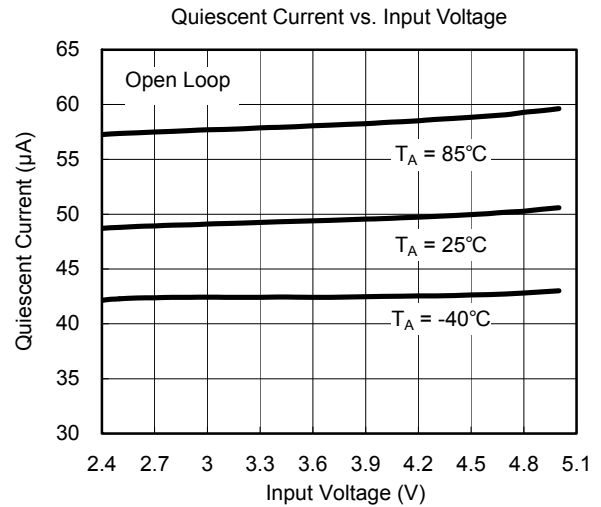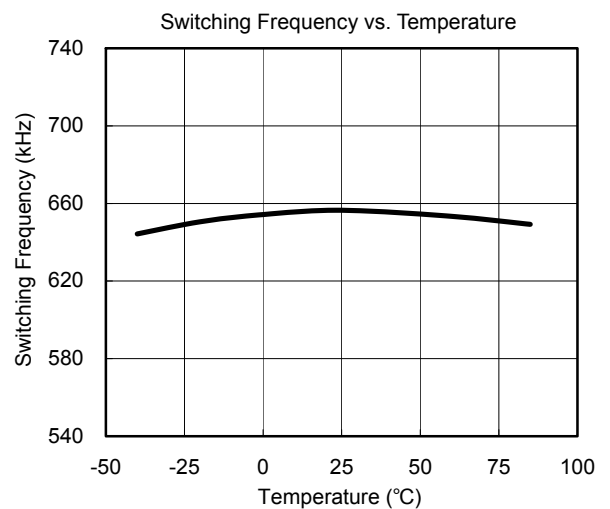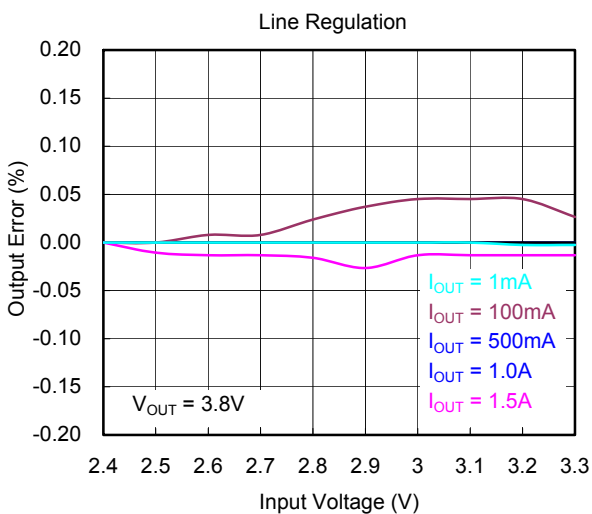
TYPICAL APPLICATION

FUNCTIONAL BLOCK DIAGRAM
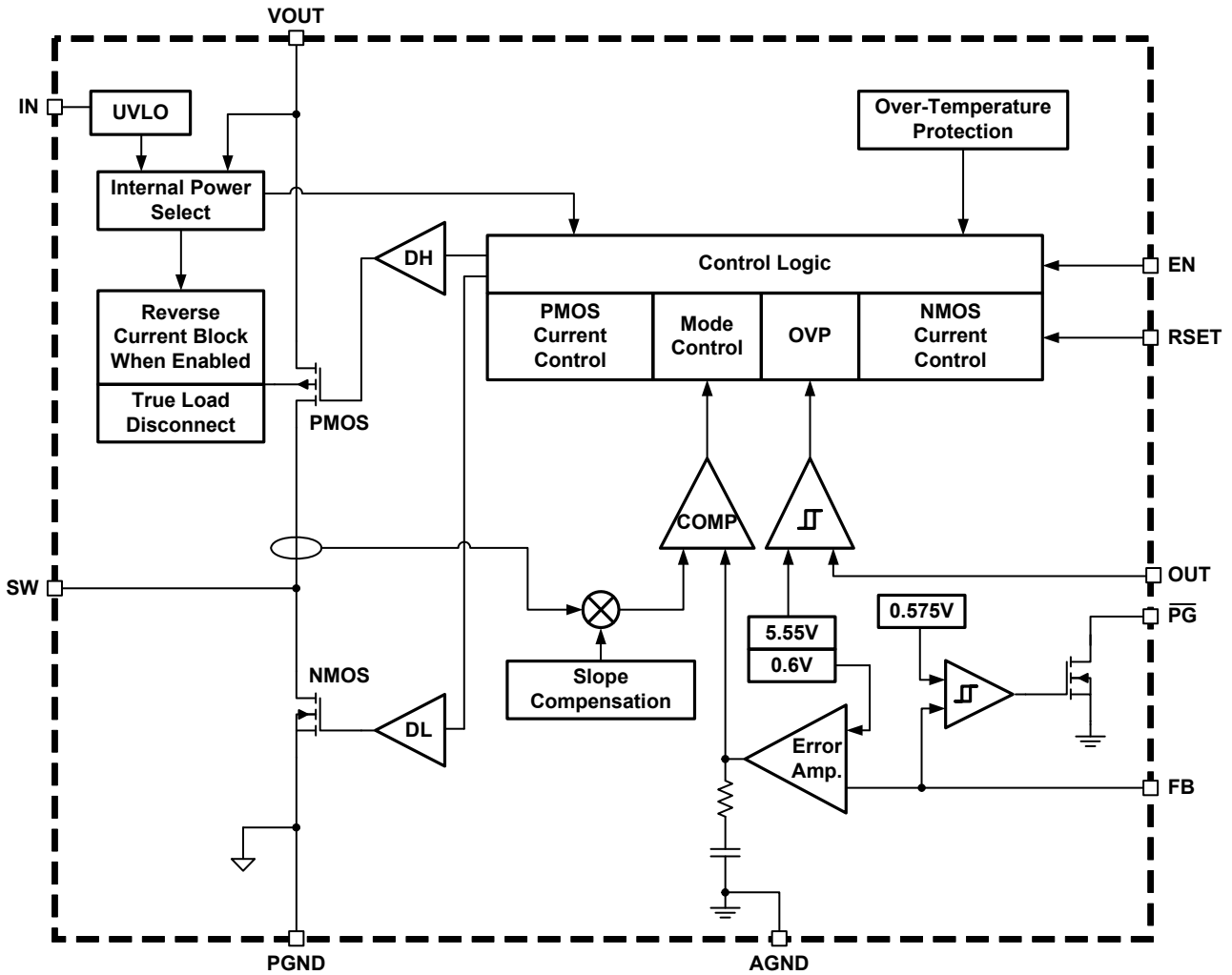
OPERATION

The SGM6608 synchronous step-up converter is designed for boosting battery or interface (such as PCI-E, PCMCIA) power to a higher voltage. SGM6608 has current sense circuit to limit peak current up to 4A, current limit is programmable by the external resistor R_{SET}.

The 660kHz switching frequency of the SGM6608 facilitates output filter component size reduction for improved power density and reduced overall footprint. It also provides greater bandwidth and improved transient response over other lower frequency step-up converters. The compensation is integrated with three external components C_{IN}, C_{OUT} and L. Low $R_{DS(ON)}$ synchronous power switches provide high efficiency for heavy load conditions. Switching frequency modulation and low quiescent current maintains high efficiency for light load mode conditions. In addition to the improved efficiency, the synchronous step-up has the added performance advantage of true load disconnect during shutdown (<1μA shutdown current), reverse current blocking when enabled, and short-circuit protection.

PWM Control Scheme for Light Load

The SGM6608 is a fixed frequency PWM peak current mode control step-up converter. For light load condition, the converter stays in a variable frequency (light load) mode to reduce the dominant switching losses. In addition to light load operation, a zero current comparator blocks reverse current in the synchronous P-Channel MOSFET, forcing DCM operation at light load. These controls, along with very low quiescent current, help to maintain high efficiency over the complete load range without increased output voltage ripple during light load conditions.

Shutdown and True Load Disconnect

A typical synchronous step-up converter has a conduction path from the input to the output via the parasitic body diode of the P-Channel MOSFET when the converter shuts down. The SGM6608 design uses a special power selection for the substrate to keep the parasitic body diode in off-state during shutdown and startup. This enables the SGM6608 to provide true load disconnect during shutdown. When the output voltage of the SGM6608 enters step-up mode ($V_{IN} \approx V_{OUT}$), the step-up control circuitry draws power directly from the output supply to ensure sufficient voltage head-room.

When EN is set to logic low, the step-up converter is forced into shutdown state with less than 1μA input current.

Start-Up

When initially powering up, the load disconnect feature allows the output voltage to be less than the input voltage. In order to avoid large surge current when the regulator is enabled, the SGM6608 operates a soft-start mode to softly charge the large output capacitor.

Peak Inductor Current Limit

The current limit of the internal low-side NMOS power switch is programmable by an external resistor. During the inductor charge cycle, the current through the NMOS device is sensed. When this current reaches the value set by the R_{SET} resistor, the low-side NMOS switch is turned off. The NMOS current limit is an instantaneous peak current measurement and should be set high enough to allow the desired average current. The application section discusses proper selection of R_{SET} resistor values.

Power-Good Indication

To indicate the output voltage is in regulation, an active low open-drain output pin ($\overline{PG}$) pulls down when the feedback voltage is above 95% of the nominal regulation voltage level. $\overline{PG}$ changes to a high-impedance output if the feedback voltage drops below 85% of the nominal regulation voltage level.

Over-Voltage Protection

The SGM6608's over-voltage protection function prevents the output voltage from exceeding the fixed 5.55V (TYP) over-voltage point, which would exceed the absolute maximum rating of the regulator. If V_{OUT} exceeds 5.55V, the regulator will stop switching until the output voltage drops below 5.53V and FB is below its regulation threshold.

Thermal Shutdown

When the junction temperature exceeds the over-temperature threshold, the SGM6608 thermal protection circuitry shuts down the regulator. Thermal shutdown disables switching to control the current flowing through to avoid any damage of the step-up converter. When the over-temperature fault condition is removed, the step-up recovers regulation automatically.

APPLICATION INFORMATION

R$_{SET}$ Selection for Programmable Current Limit

The current limit of the internal low-side NMOS power switch is programmable by an external resistor connected from RSET to ground.
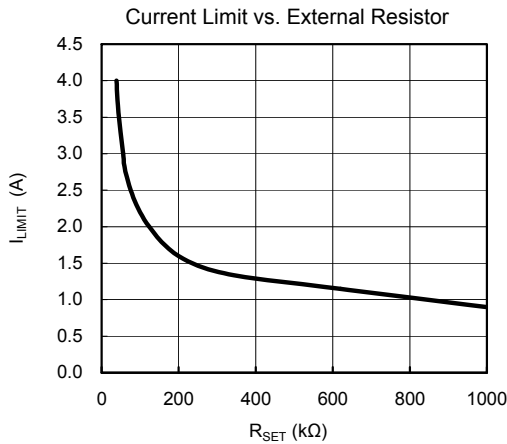
Current Limit vs. External Resistor

Table 1 gives standard 1% standard metal film resistor example values for NMOS current limit programming.

Table 1. Examples of 1% Standard Resistor Value of R$_{SET}$

R$_{SET}$ (kΩ)	I$_{LIMIT}$ (A)
1000	0.9
620	1.15
330	1.35
200	1.6
124	2
82	2.4
60.4	2.8
56	3
43	3.6
39	4

Output Voltage Programming

The output voltage of the SGM6608 may be programmed from 3.0V to 5.0V with an external resistive voltage divider. Resistors R$_{FB1}$ and R$_{FB2}$ in Figure 1 program the output voltage as shown by the following equation:

$$R_{FB1} = \left(\frac{V_{OUT}}{V_{FB}} - 1 \right) \times R_{FB2}$$

where V$_{FB}$ is the 0.6V feedback reference voltage.

To limit the bias current required for the external feedback resistor string while maintaining good noise immunity, the suggested value for R$_{FB2}$ is 100kΩ. Table 2 summarizes the resistor values with R$_{FB2}$ set to 100kΩ for good noise immunity and 6µA increased load current and gives some 1% standard metal film resistor values for R$_{FB1}$ at different output voltage settings.

Table 2. 1% Standard Resistor Examples for Different Output Voltages

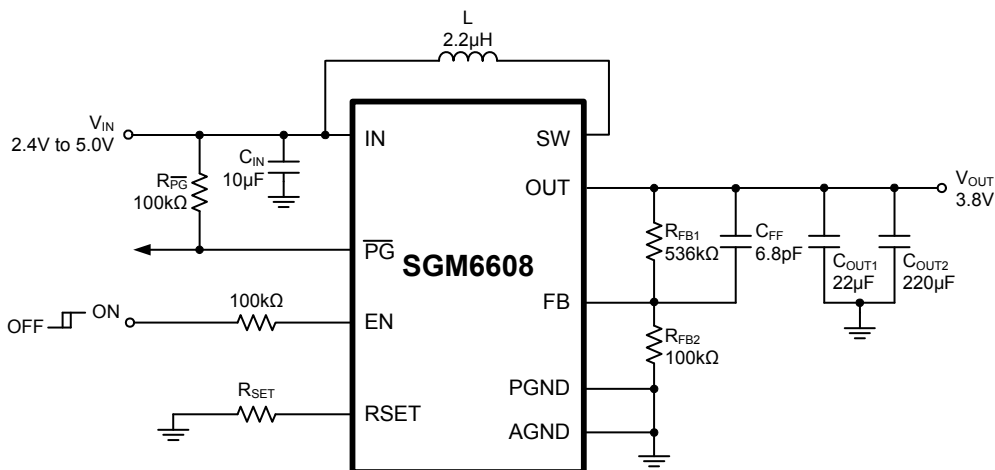| V$_{OUT}$ (V)	R$_{FB2}$ = 100kΩ R$_{FB1}$ = (kΩ)
3	402
3.3	453
3.6	499
3.8	536
4.2	604
4.5	649
5	732

Figure 1. SGM6608 Evaluation Board Schematic

APPLICATION INFORMATION

Inductor Selection

The SGM6608 is designed to operate with a 2.2µH inductor for all input/output voltage combinations. For high efficiency, choose a ferrite inductor with a high frequency core material to reduce core losses. The inductor should have low ESR (equivalent series resistance) to reduce the I^2R losses, and must be able to handle the peak inductor current without saturating. To minimize radiated noise, use a shielded inductor.

Input Capacitor

Select a low ESR ceramic capacitor with a value of at least 10µF as the input capacitor. Place the input capacitor as close to the IN and PGND pins as possible in order to minimize the stray resistance from the converter to the input power source.

Output Capacitor

The output capacitor provides energy to the load when the high-side MOSFET is switched off. The output capacitance together with the boost switching frequency, duty cycle, and load current value determine the capacitive output voltage ripple when the boost operation is in the continuous PWM state.

$$\Delta V_{OUT} = \frac{I_{OUT} \times D}{C_{OUT} \times f_{SW}}$$

where D is the duty ratio of low-side MOSFET turn-on time divided by the switching period. It is calculated using the equation:

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

The output capacitor's ESR increases the output ripple by $I_{OUT} \times$ ESR. The total output ripple is:

$$\Delta V_{OUT} = I_{OUT} \times ESR + \frac{I_{OUT} \times D}{C_{OUT} \times f_{SW}}$$

So the minimum recommended output capacitor value may be determined by:

$$C_{OUT} \geq \frac{I_{OUT} \times D}{\Delta V_{OUT} - I_{OUT} \times ESR} \times \frac{1}{f_{SW}}$$

High Load Pulse Application

Together with a large value output capacitor or super-cap, the SGM6608 can support a higher load pulse in lower input current limited applications such as GSM burst mode in WCDMA, Edge, GPRS and TD-SCDMA applications. The large capacitance is determined by NMOS peak current limit, inductor current ripple, V_{IN}, V_{OUT}, load pulse high current level and elapsed time. The capacitor value can be calculated using the following three steps as follows:

First calculate the SGM6608's load-on current from the expected I_{LIM}. Assume the input current equals I_{LIM} because the inductor current ripple is low enough when compared to the input current:

$$I_{OUT\_BOOST} = \frac{V_{IN} \times I_{LIM} \times \eta}{V_{OUT}}$$

Second, calculate the maximum current the large capacitor C_{OUT} should provide:

$$I_{COUT} = I_{LOAD\_PEAK} - I_{OUT\_BOOST}$$

Finally, derive the C_{OUT} at a certain load-on period t_{ON}:

$$C_{OUT} = \frac{I_{OUT} \times t_{ON}}{\Delta V_{OUT}}$$

To consider a real capacitor may have 20% tolerance, the selected capacitance should be 20% higher than the calculated value. Example: A 2.0A, 217Hz 12.5% duty cycle load pulse is applied on 3.8V V_{OUT} at 3.3V V_{IN}. An input peak current limit of 2.4A and a V_{OUT} drop of less than 400mV are required. Under these conditions, with 90% efficiency, the SGM6608's output current is:

$$I_{OUT\_BOOST} = \frac{3.3 \times 2.4 \times 90\%}{3.8} = 1.876A$$

The maximum current necessary for the large capacitor value is:

$$I_{COUT} = 2.0 - 1.876 = 0.124A$$

APPLICATION INFORMATION

t_{ON} is 593µs for a 217Hz 12.5% duty cycle load pulse. Considering a 20% capacitance tolerance, the minimum capacitance should be 220µF. Figure 2 shows the SGM6608 operating waveform under a 2.0A 593µs load pulse with a 220µF capacitor as C_{OUT}, as well as a 22µF ceramic capacitor to closely filter the output voltage.

Load Pulse Response

V_{IN} = 3.3V, V_{OUT} = 3.8V, I_{OUT} = 0A to 2A, C_{OUT} = 22µF + 220µF

V_{OUT}

AC Coupled

500mV/div

500mA/div
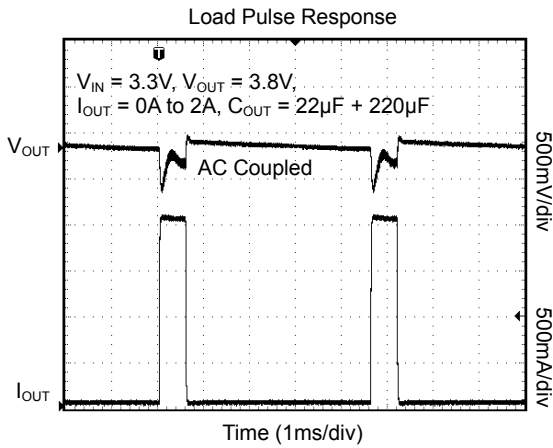
I_{OUT}

Time (1ms/div)

Figure 2. SGM6608 Operation Waveform When 2.0A 217Hz 593µs Load Pulse is Applied

Layout Guidance

For best performance of the SGM6608, the following guidelines should be followed when designing the PCB layout:

1. Make the power trace as short and wide as possible, including the input/output power lines and switching node, etc.

2. Connect the analog and power grounds together with a single short line and connect all low current loop grounds to analog ground to decrease the power ground noise on the analog ground and achieve better load regulation.

3. For good power dissipation, connect the exposed pad under the package to the top and bottom ground planes by PCB pads.

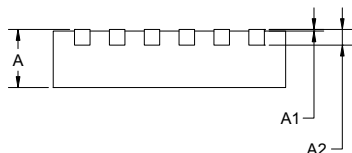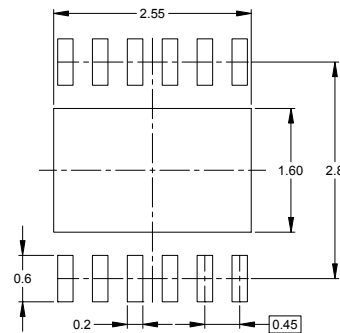# PACKAGE OUTLINE DIMENSIONS
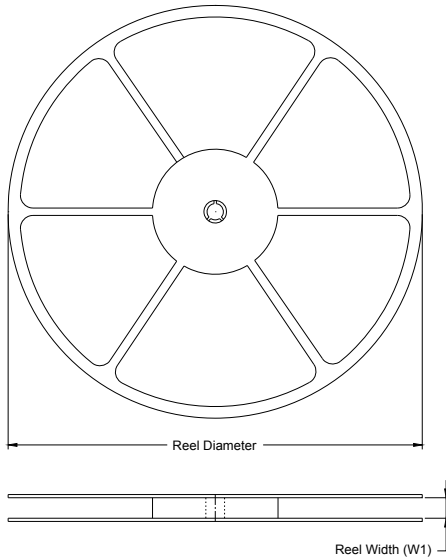
TDFN-3×3-12L
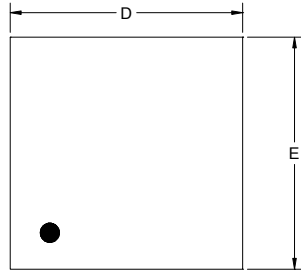
TOP VIEW
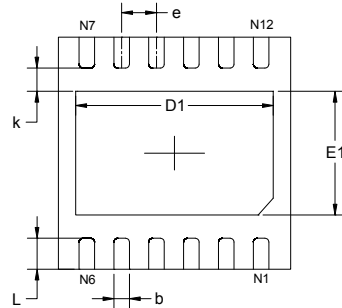
BOTTOM VIEW

SIDE VIEW

RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	2.924	3.076	0.115	0.121
D1	2.450	2.650	0.096	0.104
E	2.924	3.076	0.115	0.121
E1	1.500	1.700	0.059	0.067
k	0.200 MIN		0.008 MIN	
b	0.150	0.250	0.006	0.010
e	0.450 TYP		0.018 TYP	
L	0.324	0.476	0.013	0.019

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS
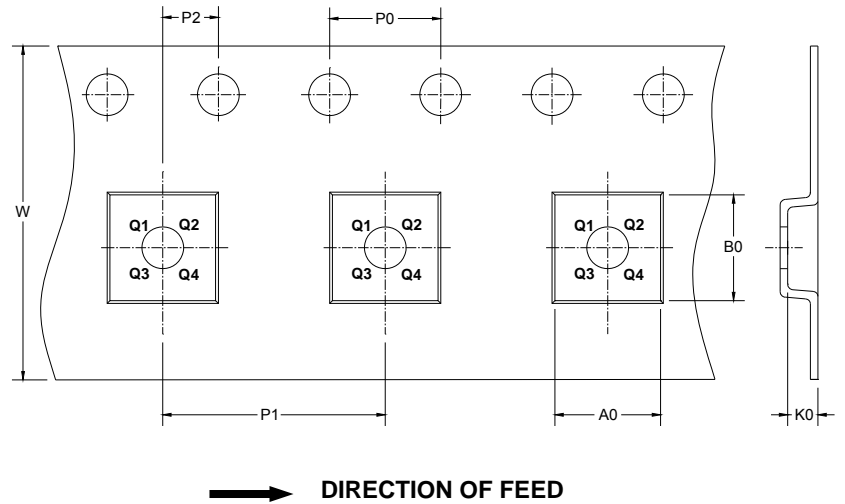
Reel Diameter

Reel Width (W1)

P2   P0

W

Q1 | Q2
Q3 | Q4

Q1 | Q2
Q3 | Q4

Q1 | Q2
Q3 | Q4

B0

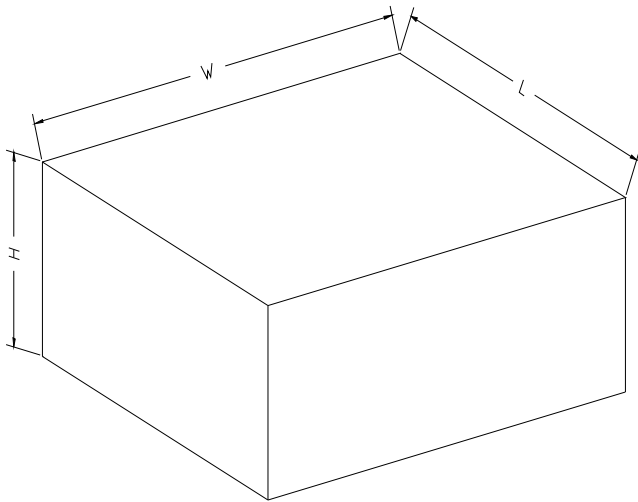P1   A0   K0

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-3×3-12L	13″	12.4	3.3	3.3	1.1	4.0	8.0	2.0	12.0	Q1

DD0001

CARTON BOX DIMENSIONS

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

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

DD0002

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