



SGM3124

White LED Charge Pump Current Source with PWM Brightness Control

GENERAL DESCRIPTION

The SGM3124 is a charge pump with PWM brightness control for white LED supplies in LCD display backlight applications. The supply voltage ranges from 2.7V to 5.5V, it is ideally suited for all applications powered by a single Li-ion battery cell or three to four NiCd, NiMH, or alkaline battery cells.

The device provides a constant current for each LED, and the initial current value can be set by an external resistor. High efficiency is achieved by utilizing a 1×/1.5× fractional conversion technique in combination with very low dropout current sources.

The SGM3124 is capable of driving up to three channels of LEDs at 30mA per channel from a 2.7V to 5.5V input. Additionally, the current controlled charge pump ensures low input current ripple and EMI. A low external part count (two 0.47µF flying capacitors and two small 1µF capacitors at VIN and VOUT) makes this part ideally suited for small, battery-powered applications.

The SGM3124 is available in a Green, space-saving TQFN-3×3-16L package, and is rated over the -40°C to +85°C temperature range.

FEATURES

- **Input Voltage Range: 2.7V to 5.5V**
- **Drives up to 3 LEDs at 30mA Each**
- **LED Brightness Control Through PWM Control Signal**
- **High Efficiency by Fractional Conversion with 1× and 1.5× Modes**
- **Switching Frequency: 1MHz**
- **Regulated Output Current with 0.5% Matching**
- **Internal Soft-Start Limits Inrush Current**
- **Low Input Ripple and Low EMI**
- **Over-Current and Over-Temperature Protected**
- **Under-Voltage Lockout With Hysteresis**
- **Green TQFN-3×3-16L Package**

APPLICATIONS

Cellular Phones
Smart Phones
Digital Cameras
Handheld PCs
Camcorders
PDAs
Keypad Backlight



PACKAGE/ORDERING INFORMATION

| ORDER NUMBER | PACKAGE DESCRIPTION | SPECIFIED TEMPERATURE RANGE | PACKAGE OPTION | MARKING INFORMATION |
|------------------|---------------------|-----------------------------|---------------------|---------------------|
| SGM3124YTQ16G/TR | TQFN-3x3-16L | -40°C to +85°C | Tape and Reel, 3000 | 3124TQ |

ABSOLUTE MAXIMUM RATINGS

Supply Voltage.....-0.3V to 6.0V
 Voltages at EN1, EN2, VOUT, ISET.....-0.3V to V_{IN}
 Output Current at VOUT.....300mA
 Storage Temperature Range.....-65°C to +150°C
 Maximum Junction Temperature.....160°C
 Operating Temperature Range..... -40°C to +85°C
 Lead Temperature (Soldering 10 sec)
260°C
 ESD Susceptibility
 HBM.....4000V
 MM.....400V

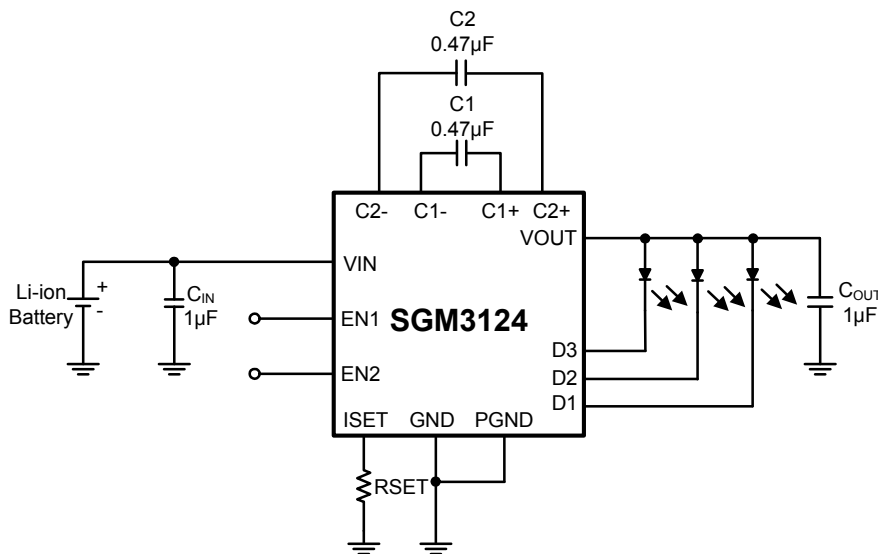
NOTE:
 Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

CAUTION

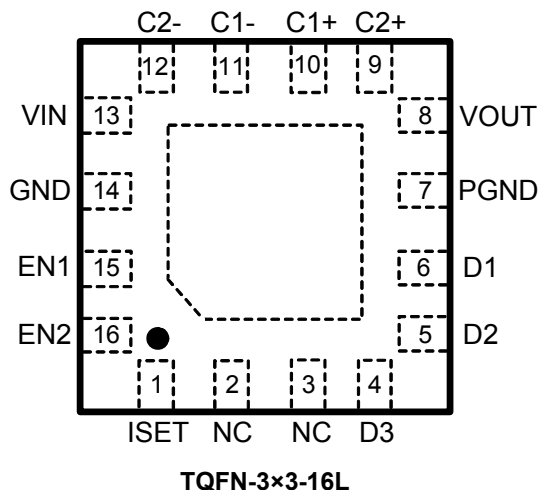
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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.

SGMICRO reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time. Please contact SGMICRO sales office to get the latest datasheet.

TYPICAL APPLICATION



PIN CONFIGURATION (TOP VIEW)



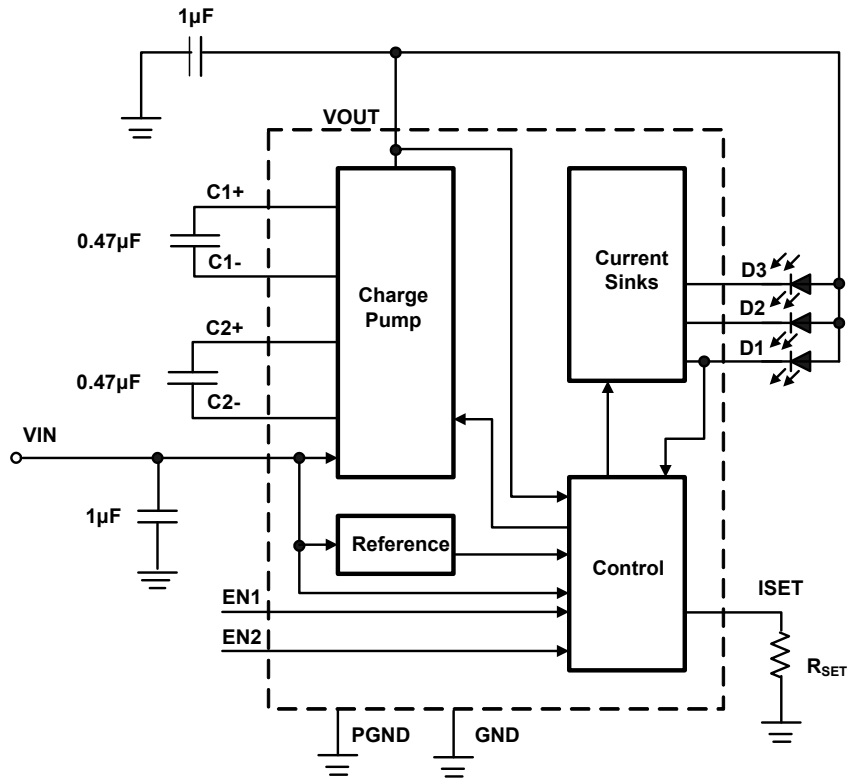
PIN DESCRIPTION

| PIN | NAME | I/O | FUNCTION |
|-------|-----------|-----|---|
| 1 | ISET | I | Connect a resistor between this pin and GND to set the maximum current through the LEDs. |
| 2 - 3 | NC | — | No internal connection. |
| 4 - 6 | D1 - D3 | I | Current sink input. Connect the cathode of the white LEDs to these inputs. |
| 7 | PGND | — | Power ground. |
| 8 | VOUT | O | Connect the output capacitor and the anode of the LEDs to this pin. |
| 9 | C2+ | — | Connect to the flying capacitor C2. |
| 10 | C1+ | — | Connect to the flying capacitor C1. |
| 11 | C1- | — | Connect to the flying capacitor C1. |
| 12 | C2- | — | Connect to the flying capacitor C2. |
| 13 | VIN | I | Supply voltage input. |
| 14 | GND | — | Analog ground. |
| 15 | EN1 | I | Enable input. A logic high enables the converter, logic low forces the device into shutdown mode reducing the supply current to less than 1 μ A if EN2 is tied to GND. |
| 16 | EN2 | I | An applied PWM signal reduces the LED current as a function of the duty cycle of the PWM signal. EN1 and EN2 can be tied together for PWM dimming between 0mA and the maximum set with ISET. EN1 and EN2 can also be used for digital dimming with 4 steps from 0mA to the maximum current set with ISET. |
| — | Power PAD | | Connect with PGND and GND. |

ELECTRICAL CHARACTERISTICS(V_{IN} = 3.6V, EN1 = EN2 = V_{IN}, T_A = 25°C, unless otherwise noted.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|--|---------------------|--|-----|------|-----|-------|
| SUPPLY VOULTAGE AND CURRENT | | | | | | |
| Input Voltage Range | V _{IN} | I _{LED} = 25mA | 2.7 | | 5.5 | V |
| Quiescent Power Supply Current | I _Q | V _{IN} = 4.2V, 1× mode, EN1 = EN2 = 1 I _{SET} = 0μA | | 100 | | μA |
| | | V _{IN} = 4.2V, 1× mode, EN1 = EN2 = 1 I _{SET} = 20μA | | 200 | | μA |
| | | I _{OUT} = 0mA, 1.5× mode | | 2 | | mA |
| Shutdown Supply Current | I _{SD} | EN1 = EN2 = GND | | 0.1 | 1 | μA |
| CHARGE PUMP STAGE | | | | | | |
| Over-Voltage Limit | V _{OUT} | LED1 unconnected, V _{IN} = 4.2V | | 5.3 | | V |
| Start-Up Time | | C _{OUT} = 1μF, I _{DX} ≥ 0.9 × I _{DX_SET} | | 150 | | μs |
| Soft-Start Duration | | | | 130 | | μs |
| Switching Frequency | f | | 0.6 | 1 | 1.4 | MHz |
| Efficiency | η | V _{IN} = 3.7V, I _{LED} = 15mA each, V _{DX} = 3.1V | | 83 | | % |
| Shutdown Temperature | | Temperature rising | | 160 | | °C |
| Shutdown Temperature Hysteresis | | | | 20 | | °C |
| Input Current Limit | | EN1 = EN2 = 1, I _{SET} = 100μA | | 300 | | mA |
| CURRENT SINKS | | | | | | |
| Recommended Maximum Current per Current Sink | I _{DX} | 3.2V ≤ V _{IN} ≤ 5.5V | | 30 | | mA |
| Current into Each Current Sink when ISET is Shorted to GND | I _{DX} | 3.0 V ≤ V _{IN} ≤ 5.5 V ISET shorted to GND | | 45 | | mA |
| Current Matching between Any Two Outputs | | V _{DX} = 3.1V, T _A = 25°C | -3 | 0.5 | 3 | % |
| Line Regulation | | 3V < V _{IN} < 5.5V, V _{LED} = 3.1V, EN1 = EN2 = 1, I _{SET} = 80μA | | 0.8 | | % |
| Reference Voltage for Current Set | V _{ISET} | EN2 = 0, EN1 = 1 | | 200 | | mV |
| | | EN2 = 1, EN1 = 0 | | 400 | | |
| | | EN2 = 1, EN1 = 1 | 580 | 600 | 620 | |
| Recommended ISET Pin Current Range | I _{set} | | 2 | | 130 | μA |
| I _{DX} to ISET Current Ratio | K | EN1 = EN2 = 1, I _{SET} = 80μA | 230 | 255 | 280 | |
| Voltage at D _x to GND | V _{SOURCE} | EN2 = 0, EN1 = 1 | | 200 | | mV |
| | | EN2 = 1, EN1 = 0 | | 300 | | |
| | | EN2 = 1, EN1 = 1 | | 400 | | |
| EN1, EN2 | | | | | | |
| EN1,EN2 High Level Input Voltage | V _{IH} | | 1.3 | | | V |
| EN1,EN2 Low Level Input Voltage | V _{IL} | | | | 0.3 | V |
| EN1,EN2 Trip Point Hysteresis | | | | 75 | | mV |
| EN2 Input Leakage Current | I _{IKG} | EN1, EN2 = GND or EN1, EN2 = V _{IN} = 5.5V | | 0.1 | 1 | μA |
| EN1 Input Leakage Current | I _{IKG} | EN1, EN2 = GND or EN1, EN2 = V _{IN} = 5.5V | | 0.1 | 1 | μA |
| Under-Voltage Lockout Threshold | V _(UVLO) | Input voltage falling | | 2.1 | | V |
| Under-Voltage Lockout Hysteresis | | | | 20 | | mV |
| Frequency Range at PWM | | | 0 | | 50 | kHz |
| Recommended ON-time for PWM Signal | | | | 2.5 | | μs |
| Shutdown Delay Time | | | | 0.85 | | ms |

FUNCTIONAL BLOCK DIAGRAM



TYPICAL PERFORMANCE CHARACTERISTICS

Table of Graphs

| FIGURE | | |
|--------|---|--|
| 1 | Efficiency (η) | vs Input voltage ($I_{LED} = 25\text{mA}, 20\text{mA}, 15\text{mA}, 10\text{mA}, 5\text{mA}$ per LED), $EN2 = EN1 = 1$ The curve with higher efficiency is for Input voltage from high to low. |
| 2 | LED Current, I_{LED} | vs Duty cycle on PWM (I_{LED_MAX} set to 20mA) For $f = 32\text{kHz}$, and $f = 1\text{kHz}$, DC = 1% to 100%, $V_{IN} = 3.6\text{V}$. |
| 3 | Switching Frequency (f_s) | vs Free-Air Temperature ($T_A = -40^\circ\text{C}$ to 85°C , $V_{IN} = 3.6\text{V}$) |
| 4 | Quiescent Current (I_Q) | vs Input voltage ($T_A = 25^\circ\text{C}$) (measured with $I_{D1} = 5\text{mA}$) |
| 5 | LED Current Regulation | vs Input voltage $3 \times 20\text{mA}$ |
| 6 | Maximum Output Current from Charge Pump Stage | vs Input voltage ($T_A = 25^\circ\text{C}$) |
| 7, 8 | Dimming Response | PWM signal and current at D1 vs time on scope $f = 32\text{kHz}$ and $f = 1\text{kHz}$, $V_{IN} = 3.6\text{V}$, duty cycle = 50%, $EN1 = EN2 = \text{PWM}$ |
| 9, 10 | Startup Timing | $V_{IN} = 3.6\text{V}$, $3 \times 20\text{mA}$, $EN1 = EN2 = 00$ changed to $EN2 = EN1 = 11$ |
| 11 | Input and Output Ripple | $V_{IN} = 3.6\text{V}$, $3 \times 20\text{mA}$, $EN1 = EN2 = 1$ |
| 12 | Line Transient Response | V_{IN} and $ID1$ vs time on scope, LED current at D1 with $V_{IN} = 4.2\text{V}$ to 3.6V to 4.2V with $EN2 = EN1 = 11$, $3 \times 20\text{mA}$ |

TYPICAL PERFORMANCE CHARACTERISTICS

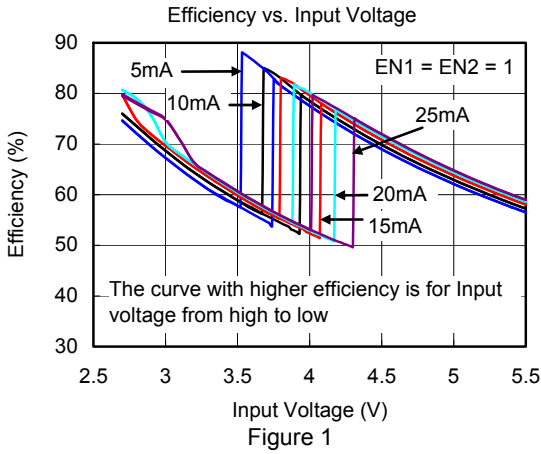


Figure 1

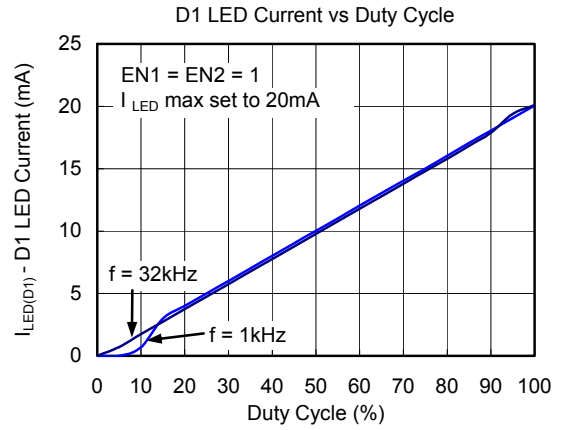


Figure 2

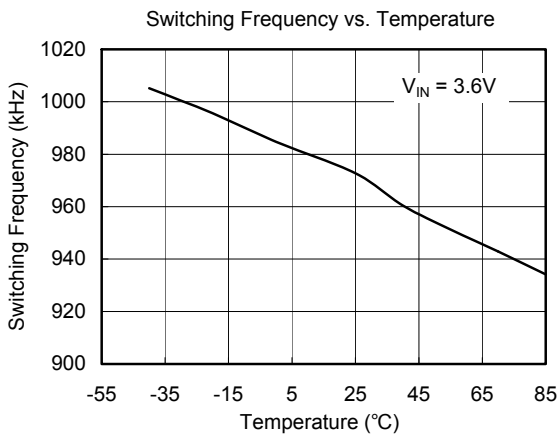


Figure 3

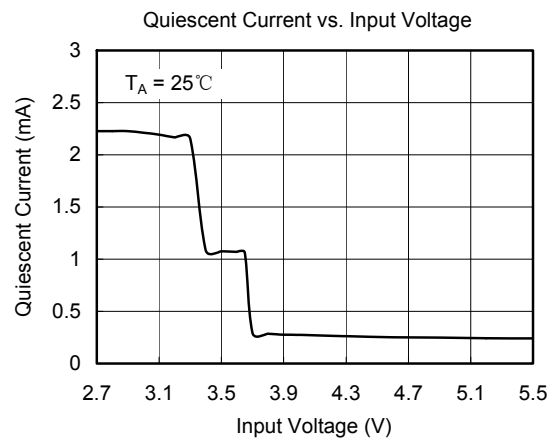


Figure 4

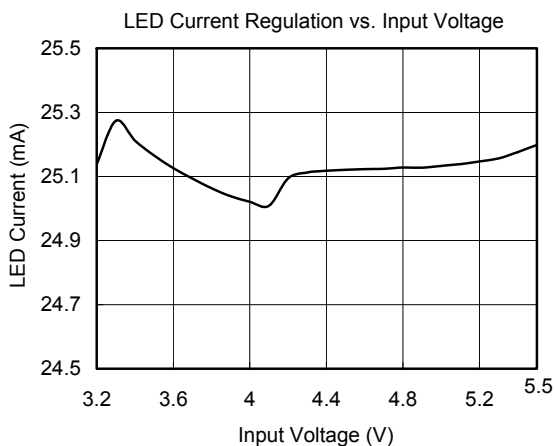


Figure 5

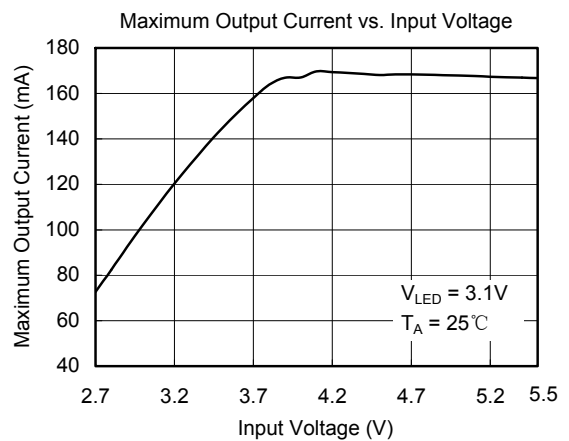
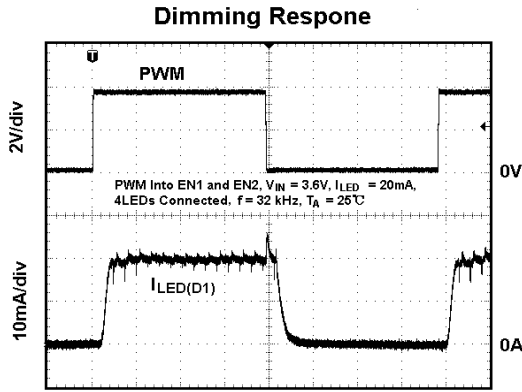
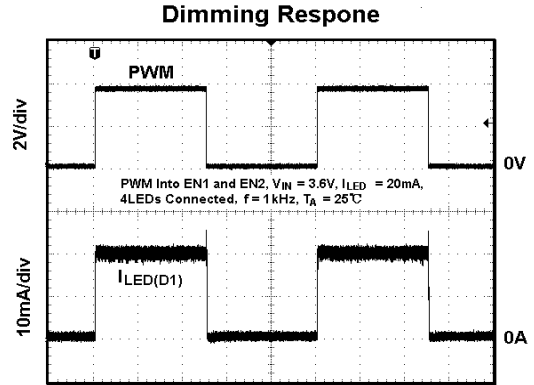


Figure 6

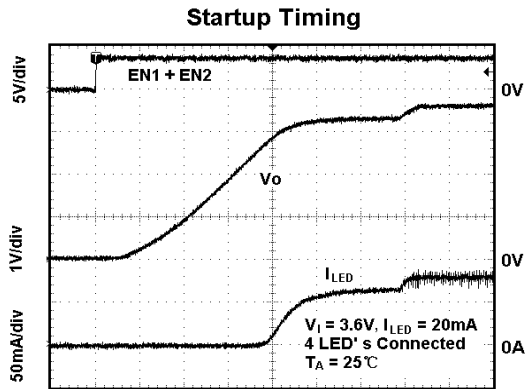
TYPICAL PERFORMANCE CHARACTERISTICS



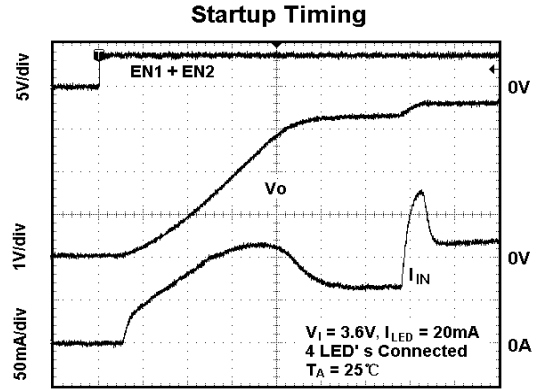
4 μ s/div
Figure 7



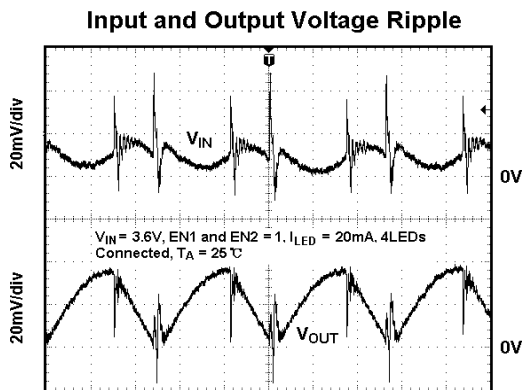
200 μ s/div
Figure 8



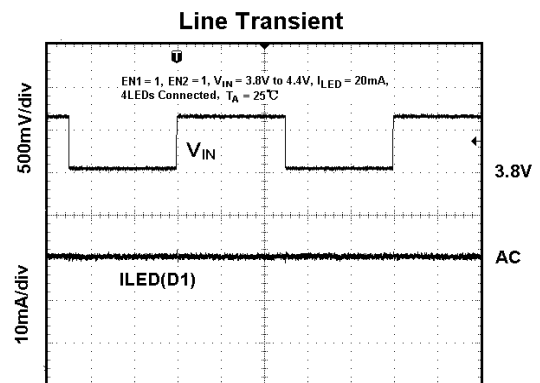
20 μ s/div
Figure 9



20 μ s/div
Figure 10



0.4 μ s/div
Figure 11



100 μ s/div
Figure 12

DETAILED DESCRIPTION

Operation

The SGM3124 uses a fractional conversion charge pump to generate a supply voltage for the integrated current sinks. These current sinks are used to ensure a constant current for each LED. Depending on the input voltage and programmed LED current, the charge pump either operates in the 1× mode or in the 1.5× mode. By switching automatically between these two modes, the circuit optimizes power conversion efficiency as well as extends operating time by allowing the discharge of the battery completely.

The charge pump can generate 90mA of output current, so each of the 3 LED outputs can be powered with up to 30mA of current. The maximum LED current is set by a resistor connected to the ISET pin. This resistor programs a reference current, which is current mirrored to set the LED current.

Applying a PWM signals to the EN1 pin and/or the EN2 pin controls the LED brightness. See a detailed description in the section Analog Dimming Using ISET Pin.

LED Current Adjustment (ISET)

A resistor programs a reference current, which is current mirrored to set the LED current. The voltage at the ISET pin depends on the status of EN1 and EN2. The current in each LED is typically 255 times the current through the resistor at ISET (see Table 2).

$$R_{ISET} = \frac{V_{ISET}}{I_{LED}} \times K$$

V_{ISET} — Voltage from ISET pin (0.2V, 0.4V or 0.6V) to GND, see Table 1

I_{LED} — Current per LED from D_x pin to GND

K — D_x to ISET current ratio (typically 255)

The LED current varies linearly from 0mA to I_{LED} (max) by applying a PWM signal with 0% to 100% duty cycle.

The LED brightness can however also be controlled by an analog control signal that is fed into the ISET pin.

Soft-Start

The SGM3124 has an internal soft-start circuit to limit the inrush current during startup. This prevents possible voltage drops of the input voltage if a high impedance power source is connected to the input of the SGM3124. When the device starts up with an output voltage that is below the input voltage, the output capacitor is charged directly from the input with a current source. The output current increases linearly until the output reaches within 300 mV of the input voltage. When the programmed output current can be reached with the 1× mode, the SGM3124 terminates the soft-start and begins normal operation. When the desired output current cannot be reached, the charge pump begins operation in 1.5× mode and pumps the output voltage up to the needed level to reach the programmed output current.

Enable (EN1, EN2)

The enable pins EN1 and EN2 are used to enable the device or set it into shutdown. The SGM3124 is enabled if one of the enable pins is pulled higher than the enable trip point of 1.3V. The device starts up by going through the soft-start routine as described in the section Soft-Start. Pulling both pins to GND, after a delay, programs the device to shutdown. In shutdown, the charge pump, current sources, voltage reference, oscillator, and all other functions are turned off and the supply current is reduced to 0.1µA.

EN1 and EN2 can also be used for dimming. The logic levels at EN1 and EN2 set the minimum voltage at the current mirrors and the voltage at the ISET pin to GND. This sets the current at the LEDs to be either the full current or a fraction of the full current. See Table 1 for further details. The maximum current through the LEDs is set by a resistor connected between ISET and GND.

EN1 and EN2 can also be used for PWM dimming. The PWM signal can either be applied to EN1 or EN2, or both inputs can be tied together and the PWM signal can be applied to both pins. Depending on the configuration, the current during PWM dimming is switched between 0mA and its maximum (EN1 and EN2 connected to the PWM signal) or between 0mA and 1/3 of the full LED current if $EN2 = 0$ and EN1 is toggled. When $EN1 = 0$ and EN2 is toggled, the output current can be changed between 0mA and 2/3 of the full range.

DETAILED DESCRIPTION

Table 1. Enable Levels

| ENABLE LEVEL | | V _{ISET} | LED CURRENT |
|--------------|-----|-------------------|-------------|
| EN2 | EN1 | | |
| 0 | 0 | 0 | 0 |
| 0 | 1 | 200 mV | 1/3 |
| 1 | 0 | 400 mV | 2/3 |
| 1 | 1 | 600 mV | Full |

Table 2. R_{ISET} Values

| SET DRIVE CURRENT (Full) | R _{ISET} COMPUTATION VALUE (k Ω) | STANDARD RESISTOR VALUE (k Ω) |
|--------------------------|---|---------------------------------------|
| 30mA | 5.1 | 5.1 |
| 25mA | 6.12 | 6.19 |
| 20mA | 7.65 | 7.68 |
| 10mA | 15.3 | 15.4 |
| 5mA | 30.6 | 30.9 |

Under-Voltage Lockout

The under-voltage lockout circuit shuts down the device when the voltage at VIN drops below a typical threshold of 2.15V. This prevents damage to the device. The UVLO circuit allows the device to start up again after the voltage on the VIN pin has increased by about 50mV above the UVLO lockout threshold.

Short-Circuit and Over-Temperature Protection

The current at the VOUT pin is limited typically to 300mA. When the junction temperature exceeds 160°C, the device shuts down to protect the device from damage. After the temperature decreases to about 140°C, the device starts up again if it is enabled.

Over-Voltage Protection at VOUT

The device uses the voltage at D1 to regulate voltage at VOUT. In case D1 is not connected, an over-voltage protection circuit ensures that the output voltage at VOUT does not exceed its limits. The connection of the LEDs must be started using D1 first. For all other LEDs there is no restriction in the sequence. For example, if there are only 2 LEDs used, the first LED is connected to D1 and the other LED can be connected to any other of the D2 to D3 pins.

THEORY OF OPERATION/DESIGN PROCEDURE

Capacitor Selection

Ceramic capacitors such as X5R or X7R are recommended to be used with the SGM3124. For the two flying capacitors C1 and C2, it is important to use low ESR capacitors to avoid unnecessary efficiency losses. Low ESR capacitors on VOUT reduce the ripple voltage on the supply of the current sources. Table 3 lists capacitor types that have been tested with the SGM3124.

Table 3. Capacitors

| PART | VALUE | VOLTAGE | MANUFACTURER | SIZE | WEBSITE |
|----------------|--------------|---------|--------------|------|-----------------------|
| C1608X5R1A105M | 1 μ F | 10V | TDK | 0603 | www.component.tdk.com |
| C1608X5R1A474M | 0.47 μ F | 10V | | 0603 | |
| C2012X7R1C105M | 1 μ F | 16V | | 0805 | |
| LMK107BJ105MA | 1 μ F | 10V | Taiyo Yuden | 0603 | www.t-yuden.com |
| LMK107BJ474MA | 0.47 μ F | 10V | | 0603 | |
| LMK212BJ105MG | 1 μ F | 10V | | 0805 | |

Power Dissipation

The maximum power dissipation inside the SGM3124 can be calculated based on the following equation:

$$P_{D_MAX} = [(1.5 \times V_{IN}) - V_O + 0.4 V] \times I_O$$

The maximum power dissipation occurs when the input voltage is just low enough to operate in 1.5 \times mode, with a forward voltage of the white LED at maximum. This is typically for $V_{IN} = 4.2V$ and a forward voltage of 3.6V.

This needs to be lower than the maximum allowed power dissipation of the package, which can be calculated using the following equation:

$$P_{D_MAX, \text{ package}} = \frac{T_{Jmax} - T_A}{R_{\theta JA}}$$

For example, the worst case power dissipation occurs at the input voltage level where the charge pump switches from the 1 \times mode to the 1.5 \times mode. At this operating point, the supply voltage to the current sources is at its maximum and the current sources must drop the most voltage in order to maintain a regulated output current.

The worst case power dissipation occurs when all 3 LED outputs are fully loaded with 30mA of LED current.

- With: $V_{IN} = 4.2V$, $V_f = 3.6V$, $I_O = 75mA$ (1.5 \times mode)
- $P_{D_MAX} = 0.203W$

Power Efficiency

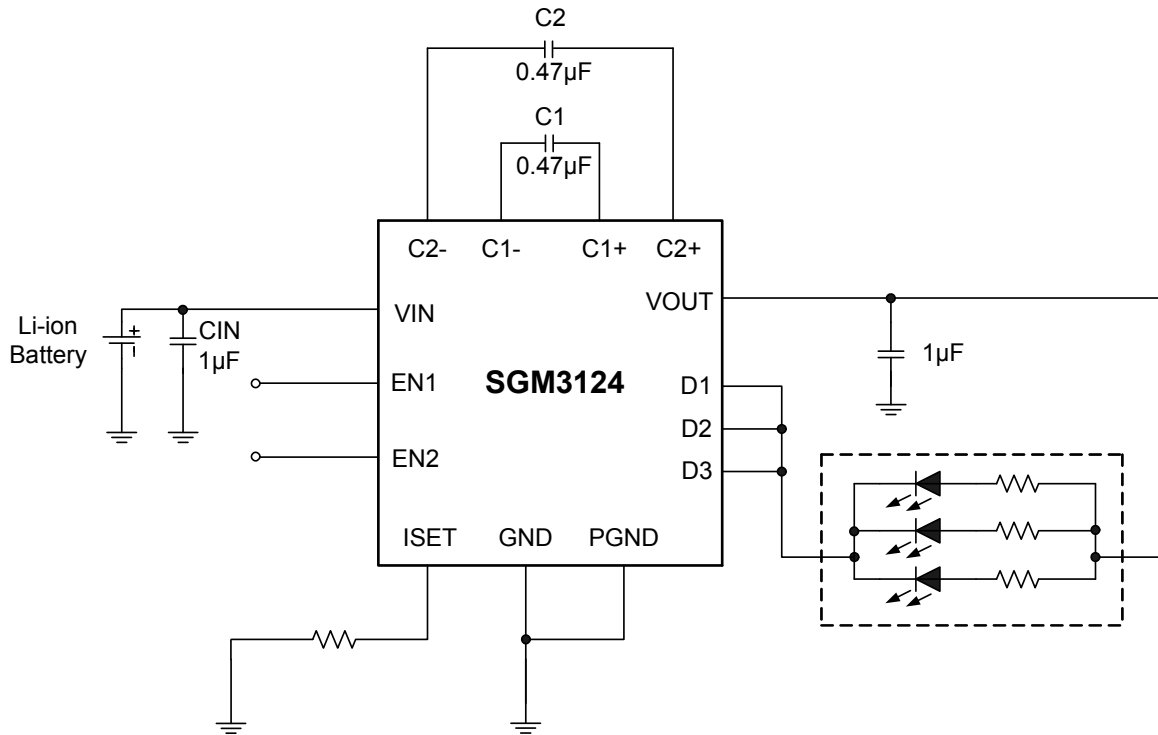
The power conversion efficiency of the SGM3124 can be calculated by adding up the products of each LED current and voltage and dividing it by the product of the input voltage and current. With a fully charged battery where the input voltage is typically above the LED forward voltage, the charge pump operates in the 1 \times mode and efficiency is very high. As the battery discharges, there is a point where the current sources no longer have enough voltage overhead to maintain a constant current regulation.

At that point, the charge pump switches into the 1.5 \times mode. The conversion efficiency is lowest at the crossover. As the battery discharges further, the efficiency again increases until at about 3.2V where it reaches a second maximum. Below 3.2V input voltage, the maximum current per LED is less than 30mA.

APPLICATION INFORMATION

Typical Application of a Smart Phone Display with Resistors Connected In Parallel

If more than 30mA of output current is needed, then the input pins to the current sinks can be connected in parallel as shown in the following application figure. This method can also be used to connect a LC display with only two connections for the white LEDs.

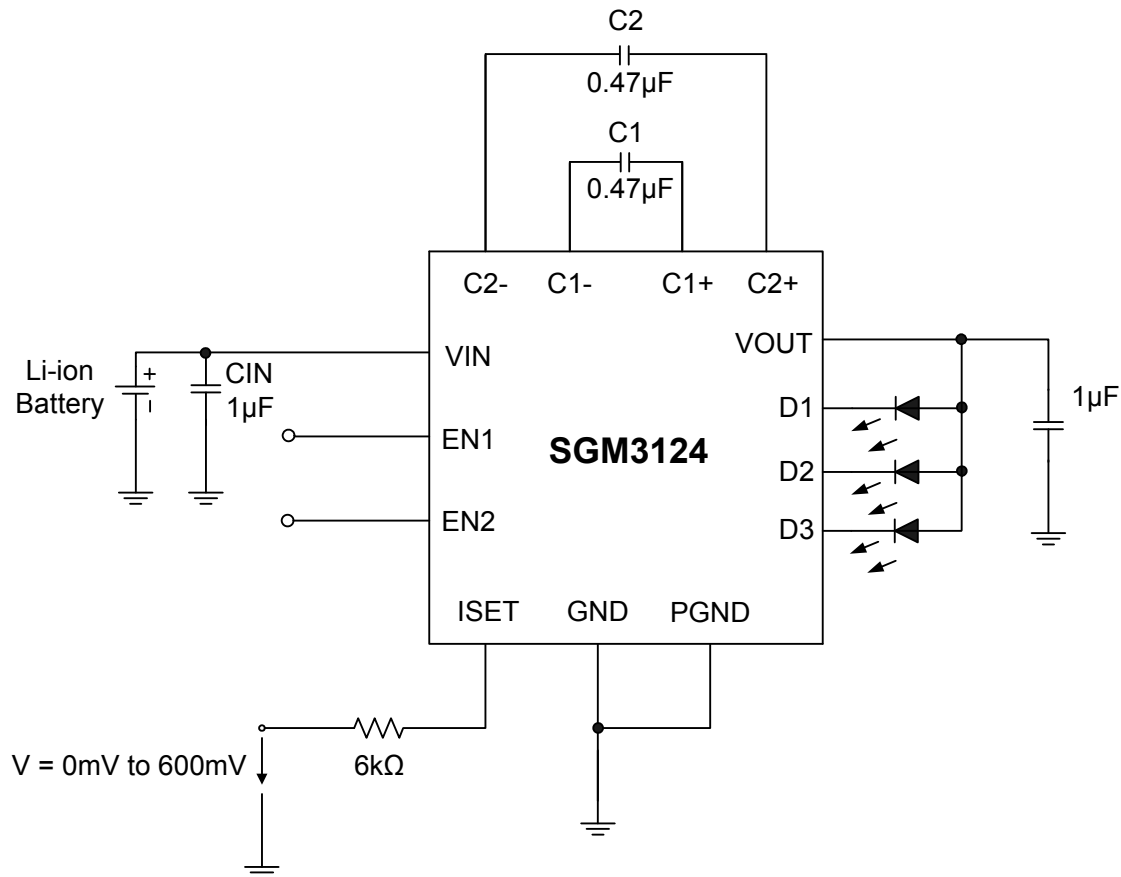


APPLICATION INFORMATION

Analog Dimming Using ISET Pin

The ISET pin can be used to connect an analog dc signal in the range of 0mV to 600mV (EN1 = EN2 = 1) for analog dimming of the white LEDs. For an input voltage of 0V at ISET, the current is at its maximum, whereas at 600mV, the LED current is zero. The maximum current is:

- For EN2 = EN1 = 1: $I_{LED} = V_{SET}/R_{SET} \times K = 0.6V/6000 \times 255 = 25.5mA$ per LED
- For EN2 =1, EN1 = 0: $I_{LED} = V_{SET}/R_{SET} \times K = 0.4V/6000 \times 255 = 17mA$ per LED
- For EN2 = 0, EN1 = 1: $I_{LED} = V_{SET}/R_{SET} \times K = 0.2V/6000 \times 255 = 8.5mA$ per LED
- With EN2, EN1 set to 10 or 01, a voltage of 400mV or 200mV is required to set the LED current to zero.



APPLICATION INFORMATION

Typical Application Using 2 White LEDs and 6 Green LEDs for LCD Backlight and Keyboard Lighting

The SGM3124 can be used to power any kind of LED. It is also possible to mix white LEDs with color LEDs which have a lower forward voltage. The LED with the highest forward voltage (typically the white LED) has to be connected to D1, because the output voltage of the charge pump is regulated in such a way to keep the voltage drop from D1 to GND at 400mV (with EN1 = EN2 = 1). Therefore the output voltage of the charge pump is regulated to:

$$V_{OUT} = V_{D1} + V_{FLEDD1}$$

V_{OUT} — Output voltage at V_{OUT}

V_{D1} — Voltage from D1 to GND (V_{source} at D1 pin, see electrical characteristics)

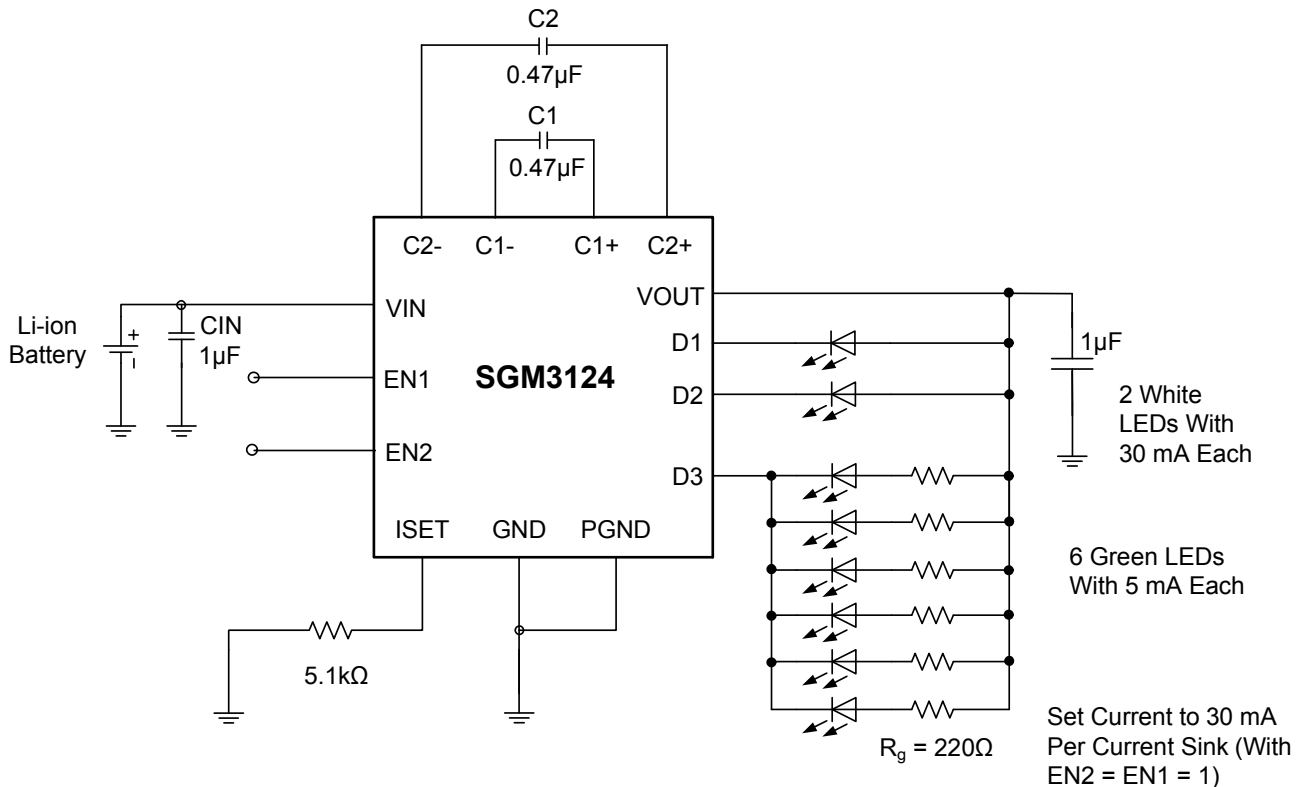
V_{FLEDD1} — Forward voltage of the LED connected to D1

Resistor R_g is used to provide current sharing between the 6 green LEDs. The upper value is calculated using:

$$R_g = \frac{V_{FLEDD1} - V_{Fg}}{I_g}$$

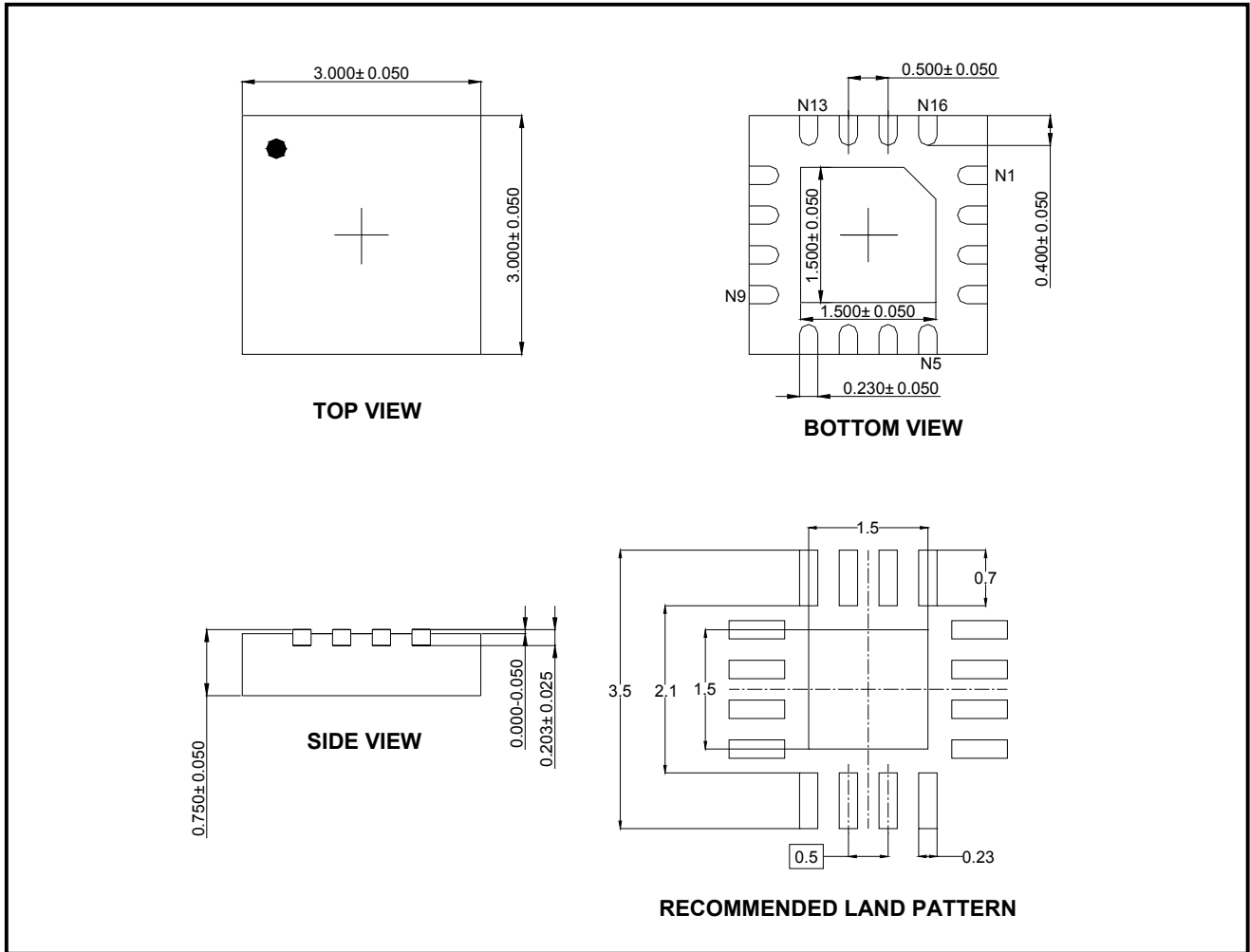
V_{Fg} — Forward voltage of a green LED

I_g — Current per green LED



PACKAGE OUTLINE DIMENSIONS

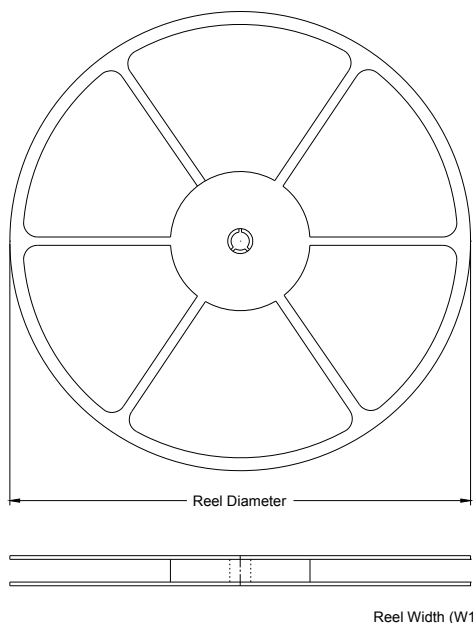
TQFN-3x3-16L



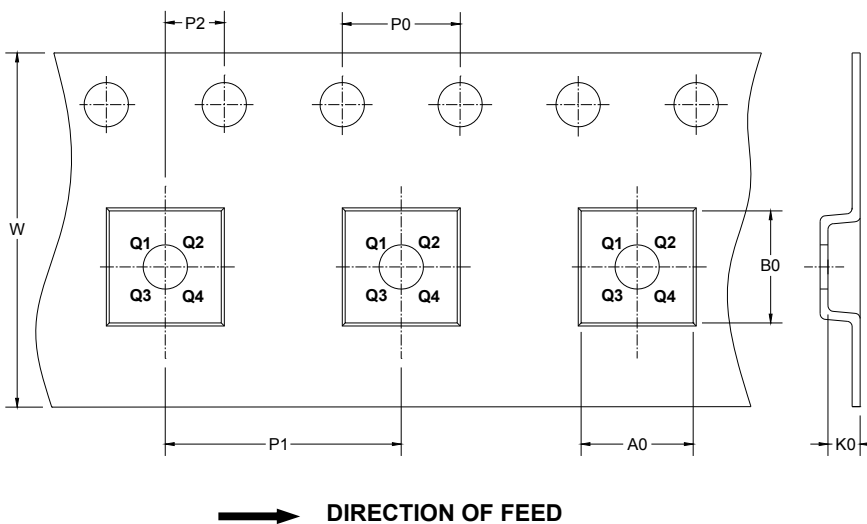
NOTE: All linear dimensions are in millimeters.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



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

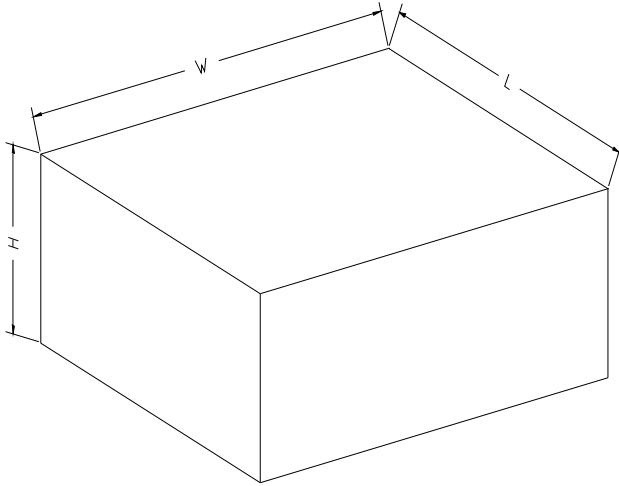
KEY PARAMETER LIST OF TAPE AND REEL

| 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-3×3-16L | 13" | 12.40 | 3.35 | 3.35 | 1.13 | 4.00 | 4.00 | 2.00 | 12.00 | Q1 |

SGM3124

White LED Charge Pump Current Source with PWM Brightness Control

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 |