SGM3760/SGM3760A
40V High Efficiency Step-Up, Dual-Channel WLED Drivers with Flash Mode

GENERAL DESCRIPTION

The SGM3760 and SGM3760A are dual-channel screen flash WLED drivers which provide highly integrated solutions for single-cell Li-Ion battery powered smart phone backlight.

The SGM3760/A have a built-in high efficiency boost regulator with integrated 3.6A/40V power MOSFET and support as low as 2.7V input voltage. With two high current-matching capability current sink regulators, the devices can drive up to 10S2P WLEDs.

The SGM3760/A are quite suitable for smart phone image capture using display device as screen flash light sources, as they can output up to 80mA/60mA current per channel at 32V for 330ms when the strobe signal is active.

The backlight mode default white LED current is set with the external sensor resistor, as shown in the typical application. During the operation, the LED current can be controlled by a pulse width modulation (PWM) signal applied to the PWM pin.

When the device is working, if the STRB pin is pulled high, it will turn on flash mode within 50μs. And the output current is regulated to 4× for SGM3760 and 3× for SGM3760A of the backlight mode that is determined by the PWM signal duty cycle. And it will turn to backlight mode within 50μs when the STRB is pulled low or the strobe signal keeps high over the 330ms timer.

The SGM3760/A integrate built-in soft-start, over-voltage, over-current protection, and thermal shutdown protection.

The SGM3760/A are available in a Green WLCSP-1.32×1.32-9B package and operate over the -40℃ to +85℃ temperature range.

FEATURES

- **2.7V to 5.5V Input Voltage Range**
- **Integrated 3.6A/40V MOSFET**
- **1.15MHz Switching Frequency**
- **Optimized Rise Time and Fall Time to Control EMI for SW Pin**
- **Dual Current Sinks**
  - **Up to 30mA Current Each in Backlight Mode**
  - **4× Output Current in Screen Flash Mode for up to 330ms (SGM3760)**
  - **3× Output Current in Screen Flash Mode for up to 330ms (SGM3760A)**
- **1% Typical Current Matching and Accuracy**
- **Adaptive Boost Output to WLED Voltages**
- **Very Low Voltage Headroom Control (150mV)**
- **PWM Dimming Control Interface**
- **Up to 90% Efficiency**
- **Built-In Soft-Start Function**
- **41.5V Over-Voltage Protection**
- **Built-In WLED Open/Short Protection**
- **Dimming Stable in More than 1:500 PWM Range**
- **PFM Mode at Light Load**
- **Thermal Shutdown**
- **-40℃ to +85℃ Operating Temperature Range**
- **Available in Green WLCSP-1.32×1.32-9B Package**

APPLICATIONS

Smart Phones
PDAs, Handheld Computers
GPS Receivers
Backlight for Small and Media Form Factor
LCD Display with Single-Cell Battery Input

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM3760	WLCSP-1.32×1.32-9B	-40℃ to +85℃	SGM3760YG/TR	XXXX ME6	Tape and Reel, 3000
SGM3760A	WLCSP-1.32×1.32-9B	-40℃ to +85℃	SGM3760AYG/TR	XXXX C04	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXX = Date Code.

XXXX

Date Code - Week

Date Code - Year

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

ABSOLUTE MAXIMUM RATINGS

VIN....................0.3V to 6V
STRB, PWM to GND .... -0.3V to 6V
COMP, ISET to GND .... -0.3V to 3V
SW, IFB1, IFB2 to GND .... -0.3V to 40V
Package Thermal Resistance
WLCSP-1.32×1.32-9B, θ_{JA} .... 100℃/W
Junction Temperature....................+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering, 10s)....................+260℃
ESD Susceptibility
HBM 4000V
MM 300V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage Range ....2.7V to 5.5V
Operating Temperature Range ....-40℃ to +85℃
Operating Junction Temperature Range, T_J
....................-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

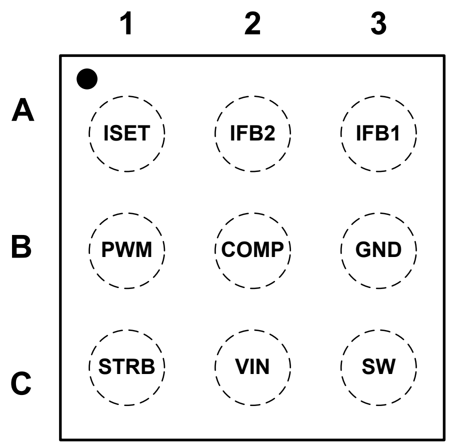
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance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

PIN CONFIGURATION

SGM3760/A (TOP VIEW)



WLCSP-1.32×1.32-9B

PIN DESCRIPTION

PIN	NAME	I/O	FUNCTION
A1	ISET	I	Full-Scale LED Current Set Pin. Connecting a resistor to the pin programs the full-scale LED current.
A2	IFB2	I	Regulated Current Sink Input Pin.
A3	IFB1	I	Regulated Current Sink Input Pin.
B1	PWM	I	PWM Dimming Signal Input.
B2	COMP	O	Output of the Transconductance Error Amplifier. Connect external capacitor to this pin to compensate the boost loop.
B3	GND	O	Ground.
C1	STRB	I	Strobe Signal Input. This pin synchronizes the flash pulse to the image capture. In most cases, this signal comes directly from the image sensor.
C2	VIN	I	Supply Input Pin.
C3	SW	I	Drain Connection of the Internal Power MOSFET.

NOTE: I: Input; O: Output.

TYPICAL APPLICATION

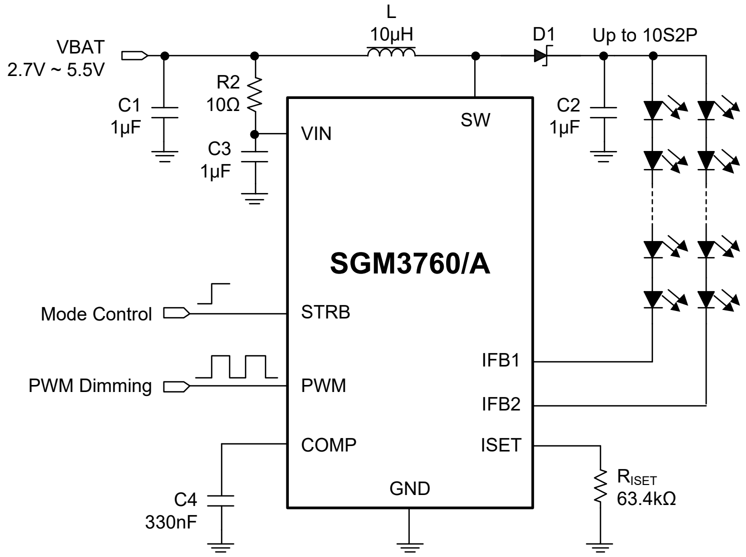


Figure 1. Typical Application

NOTES:

1. Backlight Mode: SGM3760/A can driver up to 10S2P LEDs with 30mA each channel.
2. Flash Mode: SGM3760 can driver up to 8S2P LEDs with 80mA each channel for 330ms.
   SGM3760/A can driver up to 10S2P LEDs with 60mA each channel for 330ms.

ELECTRICAL CHARACTERISTICS

(V_{IN} = 3.6V, PWM = high, STRB = low, I_{FB} = 20mA, Full = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise specified.)

PARAMETER		SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
POWER SUPPLY								
Input Voltage Range		V_{IN}		+25℃	2.7		5.5	V
Operating Quiescent Current into VIN		I_Q	Device enable, V_{IN} = 3.6V, switching 1.15MHz and no load	+25℃		1.7	2.1	mA
Shutdown Current		I_{SD}	PWM = low	+25℃		0.01	1	μA
Under-Voltage Lockout Threshold		UVLO	V_{IN} falling	+25℃		2.25		V
			V_{IN} rising	+25℃		2.35	2.45	
Under-Voltage Lockout Hysteresis		V_{HYS}		+25℃		100		mV
STRB and PWM								
STRB/PWM Threshold	Logic High Voltage	V_{IH}		Full	1.65			V
	Logic Low Voltage	V_{IL}		Full			0.50	V
PWM Pin Internal Pull-Down Resistor		R_{PD1}		+25℃		900		kΩ
PWM Logic High Time to Backlight Mode		t_{RP1}		+25℃		55		ms
PWM Logic Low Time to Shutdown		t_{SD1}	CTRL high to low	+25℃	2.5			ms
STRB Pin Internal Pull-Down Resistor		R_{PD2}		+25℃		55		kΩ
STRB Logic High Time to Flash Mode		t_{RP2}		+25℃		50		μs
STRB Logic Low Time to Backlight Mode		t_{SD2}		+25℃		50		μs
Flash Mode Timer		t_P		+25℃	280	330	380	ms
PWM Dimming Signal Frequency		f_{PWM}		+25℃	10		100	kHz
Minimum PWM On-Time		$t_{PWM\_ON(MIN)}$		+25℃	30			ns
REGULATION								
ISET Pin Voltage		V_{ISET_FULL}	Backlight mode full brightness	Full	1.184	1.220	1.256	V
Backlight Mode Current Multiplier		K_{ISET_BL}	Backlight mode Full brightness	+25℃		1050		
Flash Mode Current Multiplier		K_{ISET_FL}	Flash mode full brightness (SGM3760)	+25℃		4200		
			Flash mode full brightness (SGM3760A)	+25℃		3150		
Current Accuracy		I_{FB_AVG}	I_{ISET} = 20μA, D = 100%	+25℃	-5		5	%
$(I_{MAX} - I_{AVG}) / I_{AVG}$		K_M	D = 100%	+25℃			2.5	%
Backlight Mode Current Sink Maximum Output Current		I_{IFB_MAXBL}	I_{ISET} = 30μA, each IFBx pin	+25℃		30		mA
Flash Mode Current Sink Maximum Output Current		I_{IFB_MAXFL}	I_{ISET} = 30μA, each IFBx pin (SGM3760)	+25℃		120		mA
			I_{ISET} = 30μA, each IFBx pin (SGM3760A)	+25℃		90		
POWER SWITCH								
Switch MOSFET On-Resistance		$R_{DS(ON)}$	V_{IN} = 3.6V	+25℃		0.18		Ω
			V_{IN} = 3V	+25℃		0.2		
OSCILLATOR								
Oscillator Frequency		f_S		Full	950	1150	1350	kHz
Maximum Duty Cycle		D_{MAX}	Measured on the drive signal of switch MOSFET	+25℃		96		%

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 3.6V, PWM = high, STRB = low, I_{FB} = 20mA, Full = -40℃ to +85℃, typical values are at T_A = +25℃, unless otherwise specified.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
BOOST VOLTAGE CONTROL							
Backlight Mode IFBx Feedback Regulation Voltage	V_{IFB_REGB}	I_{IFBx} = 20mA, measured on IFBx pin which has a lower voltage	+25℃		150		mV
Flash Mode IFBx Feedback Regulation Voltage	V_{IFB_REGF}	I_{IFBx} = 80mA, measured on IFBx pin which has a lower voltage	+25℃		450		mV
PROTECTION							
Flash Mode Switch MOSFET Current Limit	I_{LIMFL}	D = D_{MAX}	+25℃		3.6		A
Backlight Mode Switch MOSFET Current Limit	I_{LIMBL}	D = D_{MAX}	+25℃	1.35	1.70	2.10	A
Switch MOSFET Start Up Current Limit	I_{LIM_START}	D = D_{MAX}	+25℃		0.6		A
Time Window for Half Current Limit	t_{HALF_LIM}		+25℃		6		ms
SW Pin Over-Voltage Threshold	V_{OVP_SW}		Full	40.0	41.5	43.0	V
IFBx Pin Over-Voltage Threshold	V_{OVP_IFB}	Measured on IFBx pin	+25℃		4.5		V
THERMAL SHUTDOWN							
Thermal Shutdown Threshold	T_{SHDN}				150		℃
Thermal Shutdown Hysteresis	T_{HYS}				15		℃

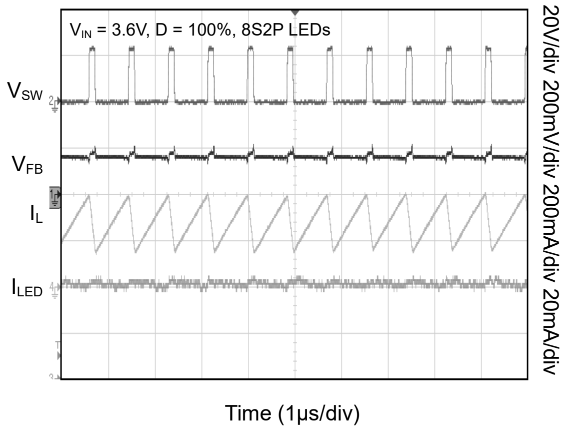
RECOMMENDED COMPONENTS OF TEST CIRCUITS

	COMPONENT		COMPONENT
INDUCTOR	10µH/CD75NP-100KC	CAPACITOR	1µF/C2012X7R1H105JT
DIODE	MBR0540		

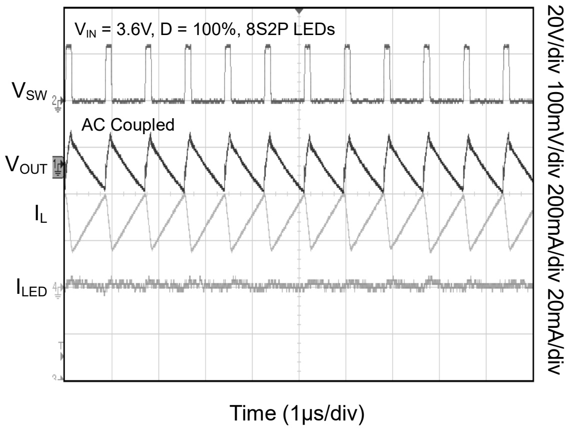
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, L = 10µH, C_{IN} = 1µF, C_{OUT} = 1µF, unless otherwise noted.

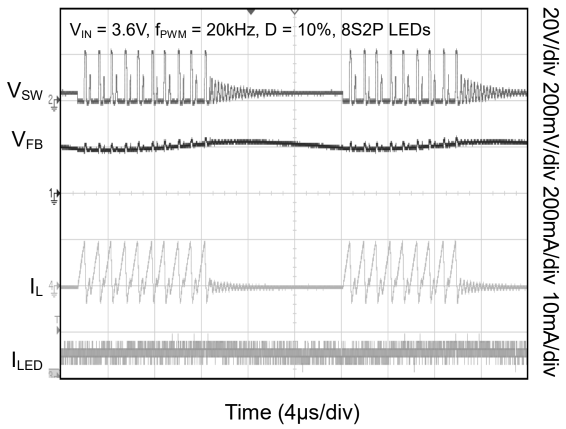
Switching Waveform



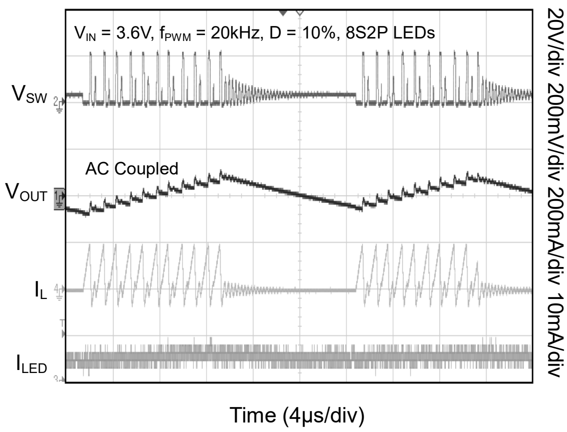
Switching Waveform



Switching Waveform



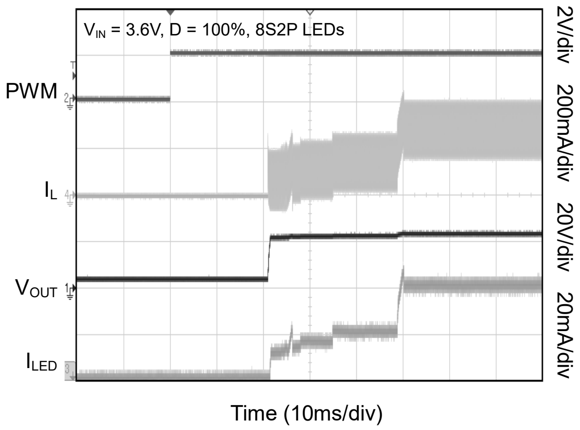
Switching Waveform



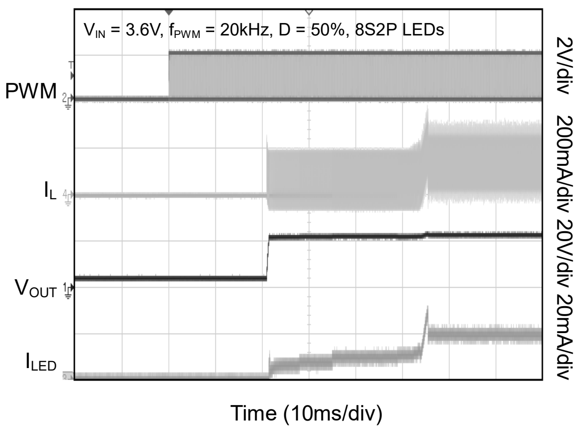
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, L = 10μH, C_{IN} = 1μF, C_{OUT} = 1μF, unless otherwise noted.

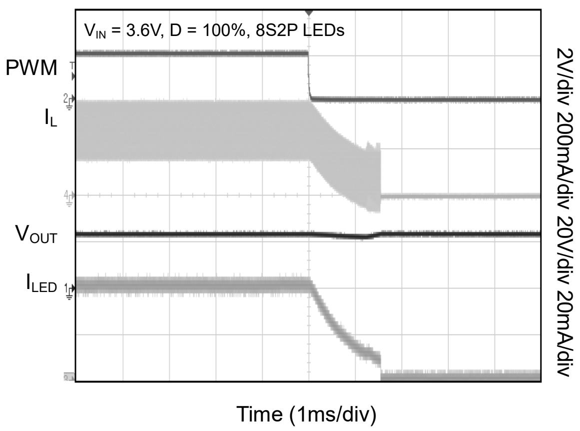
Startup Waveform



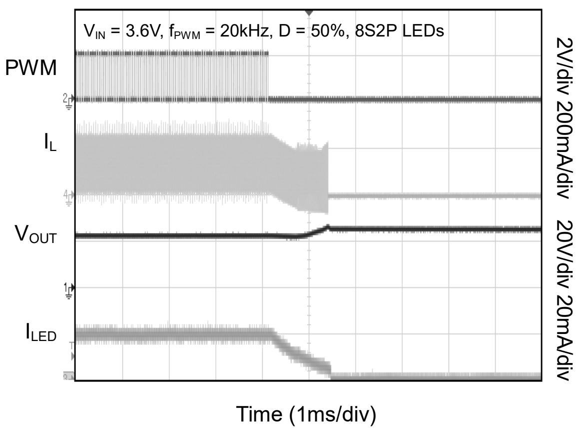
Startup Waveform



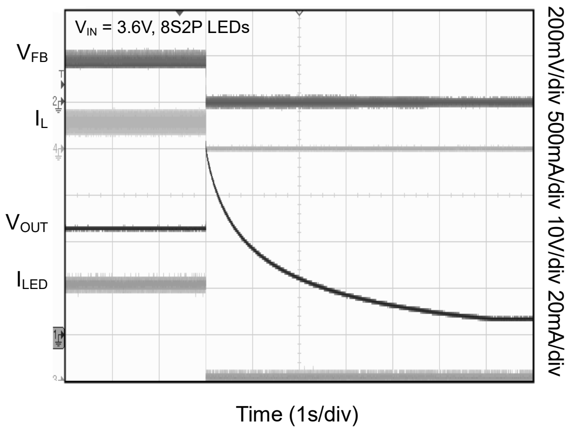
Shutdown Waveform



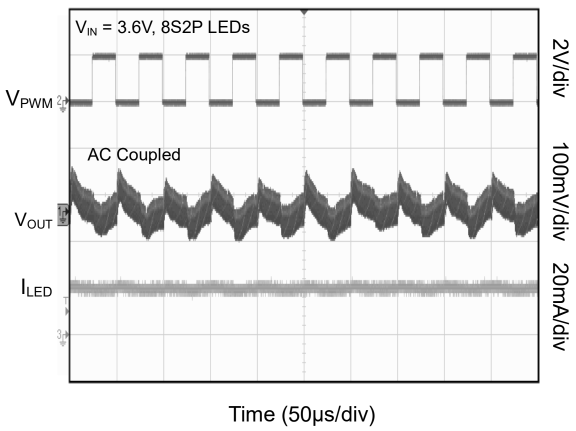
Shutdown Waveform



Open LED Protection



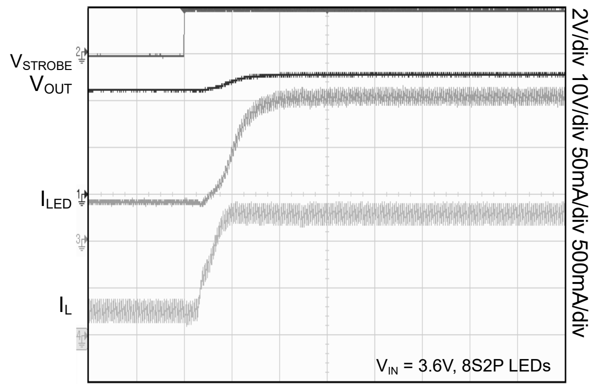
Output Ripple at PWM Dimming



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

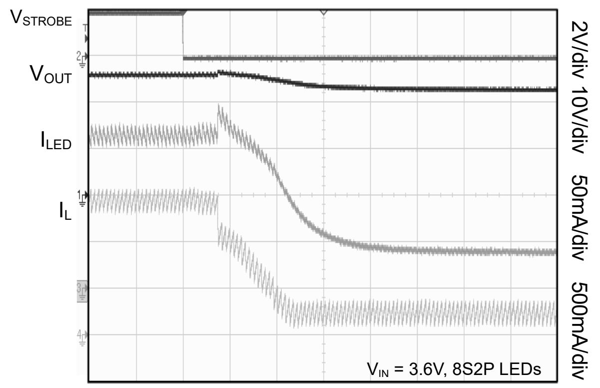
T_A = +25℃, L = 10μH, C_{IN} = 1μF, C_{OUT} = 1μF, unless otherwise noted.

Flash Mode Startup



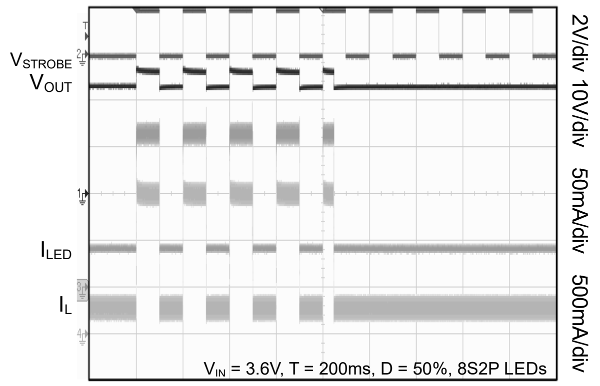
Time (20μs/div)

Flash Mode Shutdown



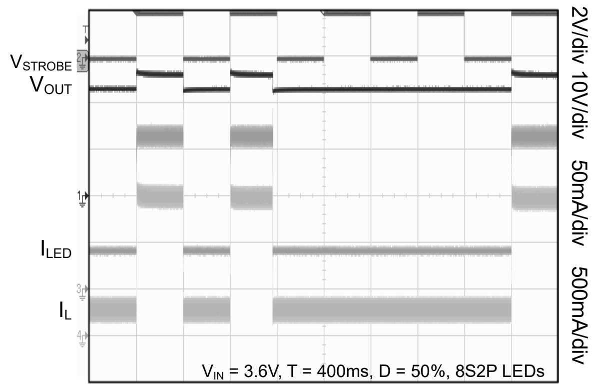
Time (10μs/div)

Flash Mode Over Time Protection



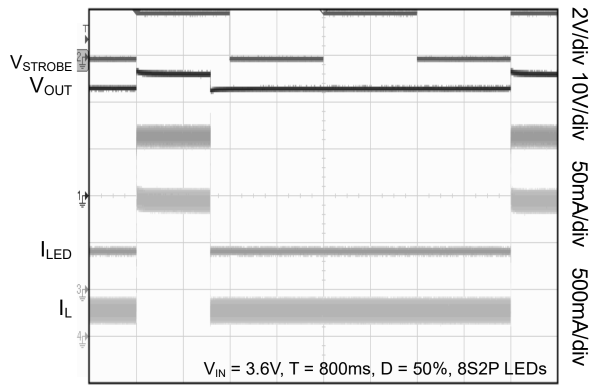
Time (200ms/div)

Flash Mode Over Time Protection



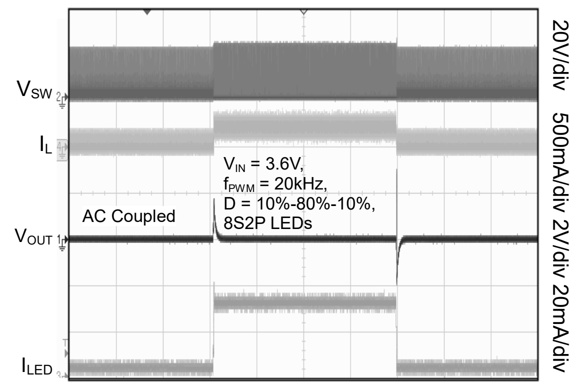
Time (200ms/div)

Flash Mode Over Time Protection



Time (200ms/div)

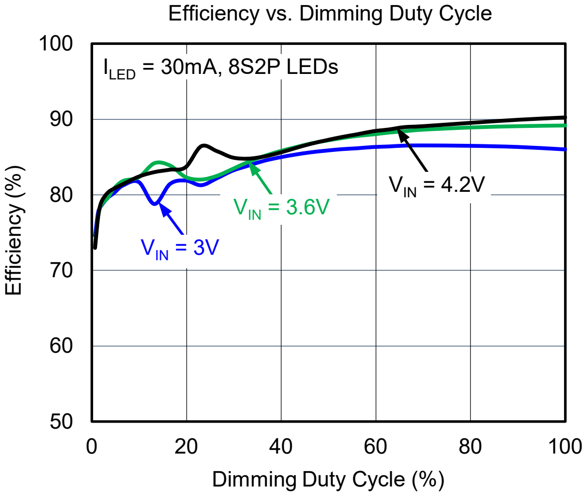
Dimming Transient Waveform

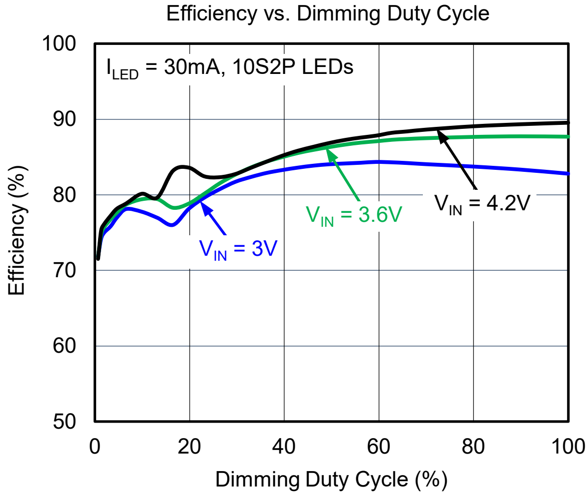


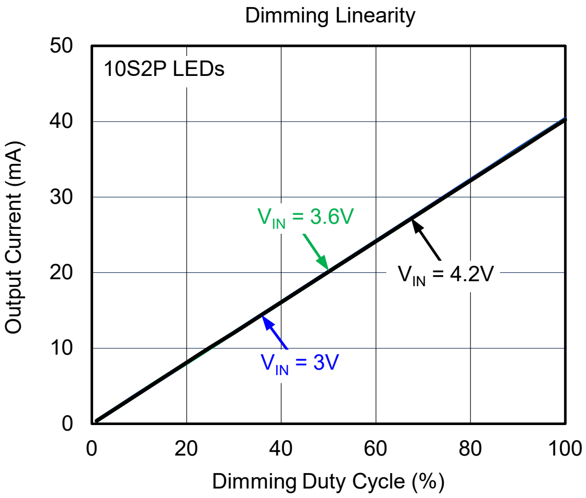
Time (400ms/div)

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, L = 10μH, C_{IN} = 1μF, C_{OUT} = 1μF, unless otherwise noted.







FUNCTIONAL BLOCK DIAGRAM

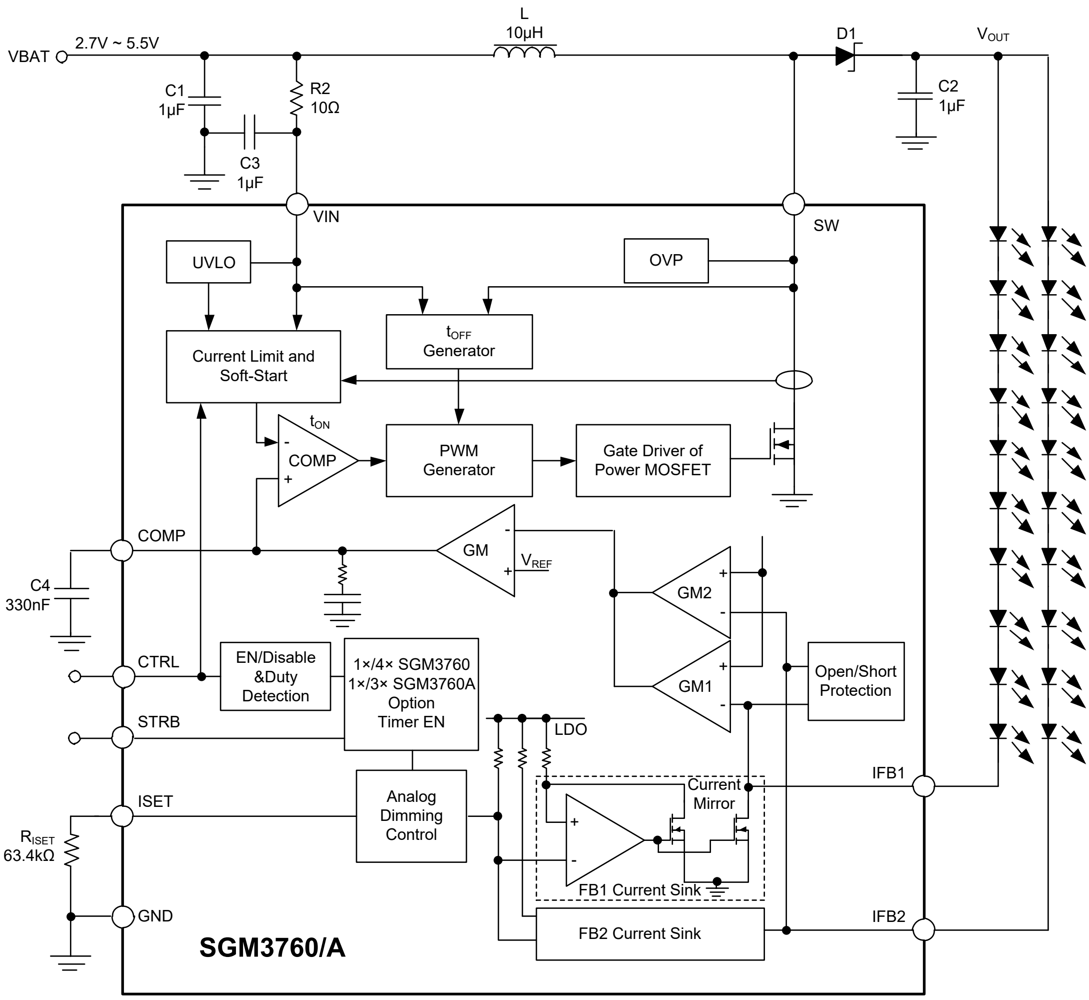


Figure 2. SGM3760/A Block Diagram

DETAILED DESCRIPTION

Normal Operation

In order to provide high brightness backlighting for big size or high resolution smart phone panels, more and more white LED diodes are used. Having all LED diodes in a string improves overall current matching; however, the output voltage of a boost converter will be limited when input voltage is low, and normally the efficiency will drop when output voltage goes very high. Thus the LED diodes are arranged in two parallel strings.

The SGM3760/A are high efficiency, dual-channel white LED drivers for such smart phone backlighting applications. They can work in backlight mode, and their large driving capability can drive LED strings in screen flash mode specially.

Two current sink regulators of high current-matching capability are integrated in the SGM3760/A to support dual LED strings connection and to improve the current balance and protect the LED diodes when either LED string is open or short.

SGM3760/A have integrated all of the key function blocks to power and control up to 20 white LED diodes. It includes a 40V/3.6A boost converter, two current sink regulators and protection circuit for over-current, over-voltage and thermal shutdown protection.

Boost Converter

The boost converter of the SGM3760/A integrates 40V/3.6A low side switch MOSFET and has a fixed switching frequency of 1.15MHz. The control architecture is based on traditional current-mode PWM control. For operation see the Functional Block Diagram. Two current sinks regulate the dual-channel current and the boost output is automatically set by regulating IFBx pin’s voltage. The output of error amplifier and the sensed current of switch MOSFET are applied to a control comparator to generate the boost switching duty cycle; slope compensation is added to the current signal to allow stable operation for duty cycles larger than 50%.

The forward voltages of two LED strings are normally different due to the LED diode forward voltage inconsistency, thus the IFB1 and IFB2 voltages are normally different. The SGM3760/A can select out the IFBx pin which has a lower voltage than the other and regulates its voltage to a very low value (typical: Backlight mode 150mV, Flash mode 450mV), which is enough for the two current sinks' headroom. In this way, the output voltage of the boost converter is automatically set and adaptive to LED strings' forward voltages, and the power dissipation of the current sink regulators can be reduced remarkably with this very low headroom voltage.

IFBx Pin Unused

If only one channel is needed, a user can easily disable the unused channel by connecting its IFBx pin to ground. If both IFBx pins are connected to ground, the IC will not start up.

Enable and Start Up

In order to enable the IC from shutdown mode, two conditions have to be met:

1. POR (Power On Reset, that is, VIN voltage is higher than UVLO threshold);
2. PWM signal (logic high or PWM pulses) on PWM pin.

When these conditions are all met, an internal LDO linear regulator is enabled to provide supply to internal circuits and the IC can start up.

Pulling PWM pin low for more than 2.5ms can disable the device and the SGM3760/A enter into shutdown mode.

DETAILED DESCRIPTION (continued)

Soft-Start

Soft-start is implemented internally to prevent voltage over-shoot and in-rush current. After the IFBx pin status detection, the COMP pin voltage starts ramp up and the boost starts switching. During the beginning 6ms (t_{HALF_LIM}) of the switching, the peak current of the switch MOSFET is limited at I_{LIM_START} (0.6A typical) to avoid the input inrush current. After the 6ms, the current limit is changed to I_{LIMBL} (1.7A typical) to allow the normal operation of the boost converter. And then if STRB changes active, the current limit is changed to I_{LIMFL} (3.6A typical) to allow the flash mode operation.

Backlight and Flash Mode Control

Refer to Figure 3 for a graphical explanation.

The PWM pin of the device is used to enable and disable the IC: pulling PWM pin high or apply PWM signals at PWM pin to enable the IC within t_{RP1} and pulling PWM pin low for more than t_{SD1} to disable the IC.

When the device is working in backlight mode, if the STRB is pulled up from Low to High, the device will change to work in Flash light mode within t_{RP2}, and the current of IFBx pin changes from $I_{FB(BL)}$ to $I_{FB(FL)}$.

A strobe signal alone will be ignored.

Backlight Mode Full-Scale Current

When SGM3760/A work in backlight mode, the dual channels device can provide up to 30mA current each. The full-scale current (current when dimming duty cycle is 100%) of each channel should be programmed by an external resistor R_{ISET} at ISET pin according to Equation 1.

$$I_{FB\_FUBL} = \frac{V_{ISET\_FULL}}{R_{ISET}} \times K_{ISET\_BL} \quad (1)$$

where:

I_{FB_FUBL} = full-scale current of each channel in backlight mode

K_{ISET_BL} = 1050 (Current multiple when dimming duty cycle = 100% in backlight mode)

V_{ISET_FULL} = 1.220V (ISET pin voltage when dimming duty cycle = 100%)

R_{ISET} = ISET pin resistor

Flash Mode Full-Scale Current

When SGM3760/A work in screen flash mode, the dual channels device can provide up to 80mA/60mA current each for up to 330ms. The full-scale current (current when dimming duty cycle is 100%) of each channel is also programmed by the external resistor R_{ISET} at ISET pin according to Equation 2.

$$I_{FB\_FUFL} = \frac{V_{ISET\_FULL}}{R_{ISET}} \times K_{ISET\_FL} \quad (2)$$

where:

I_{FB_FUFL} = full-scale current of each channel in flash mode

K_{ISET_FL} = 4200 for SGM3760 and 3150 for SGM3760A (Current multiple when dimming duty cycle = 100% in flash mode)

V_{ISET_FULL} = 1.220V (ISET pin voltage when dimming duty cycle = 100%)

R_{ISET} = ISET pin resistor

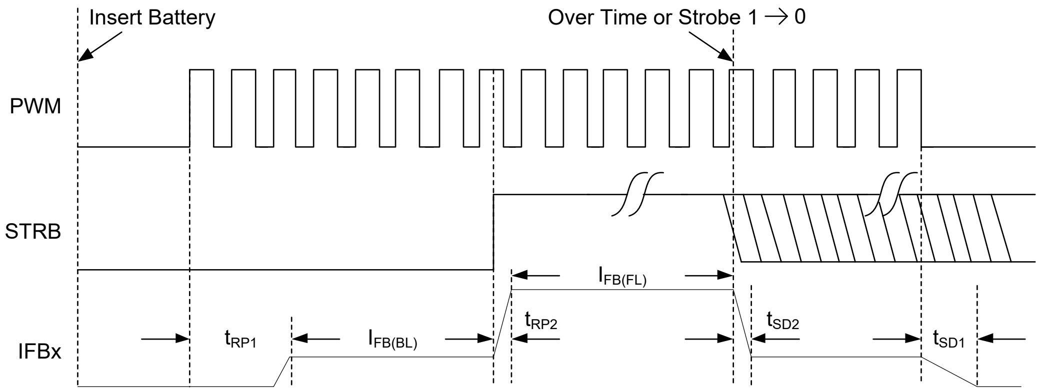


Figure 3. SGM3760/A Interface Timing Diagram

DETAILED DESCRIPTION (continued)

PWM Brightness Control

The SGM3760/A control the DC current of the dual channels to realize the brightness dimming. The DC current control is normally referred to as analog dimming mode. When the DC current of LED diode is reduced, the brightness is dimmed.

The SGM3760/A receive PWM dimming signals on the PWM pin to control the backlight and flash mode brightness. When the PWM pin is constantly high, the dual channel current is regulated to full-scale according to Equation 1 and Equation 2. The PWM pin allows PWM signals to reduce this regulation current according to the PWM duty cycle; therefore, it achieves LED brightness dimming.

The relationship between the PWM duty cycle and IFBx current in backlight mode is given by Equation 3.

$$I_{FBx\_BL} = I_{FB\_FUBL} \times Duty \quad (3)$$

The relationship between the PWM duty cycle and IFBx current in screen flash mode is given by Equation 4.

$$I_{FBx\_FL} = I_{FB\_FUFL} \times Duty \quad (4)$$

where:
I_{FBx_BL} = current of each current sink in backlight mode
I_{FB_FUBL} = full-scale LED current in backlight mode
I_{FBx_FL} = current of each current sink in flash mode
I_{FB_FUFL} = full-scale LED current in flash mode
Duty: duty cycle of PWM signal. The PWM frequency is in the range from 10kHz to 100kHz.

Flash Mode Over Time Protection

As shown in Figure 4, after the SGM3760/A is enable by PWM, the first rising edge of STRB can trigger the SGM3760/A into flash mode. Then the strobe signal is monitored by an internal cumulative timer. The timer increases with all of the HIGH pulses and decreases with 1/3 of the LOW pulses. Once the timer reaches 330ms, it turns the device to backlight mode automatically to protect the LEDs from damage due to overheat. Then the device will remain in the backlight mode for 990ms (typical), for the die temperature to be lowered enough. If the PWM pin turns to low, the device changes to standby mode within t_{SD1}, while the timer keeps cumulating till zero, and then the device will be shut down.

The relationship between the timer and STRB is given by Equation 5:

$$T_C = T_1 - t_1/3 + T_2 - t_2/3 + \ldots + T_{n-1} - t_{n-1}/3 + \ldots \quad (5)$$

Where:
T_C = cumulative time of timer
T_n = high pulse time of STRB
t_n = low pulse time of STRB

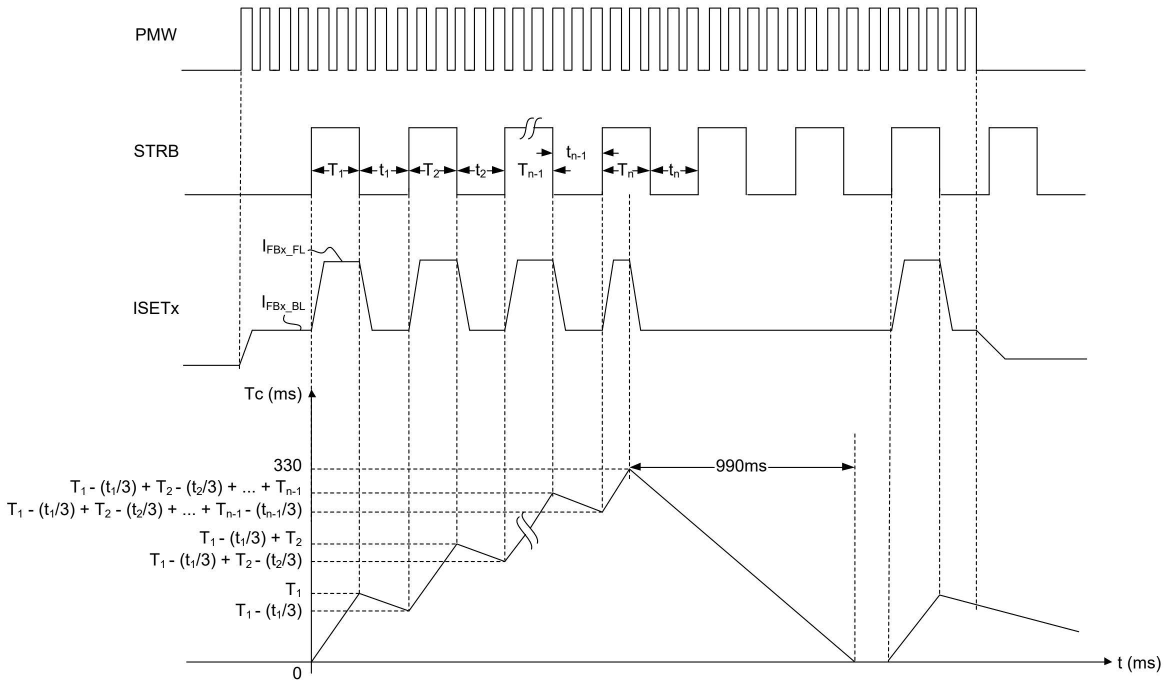


Figure 4. Timing Diagram

DETAILED DESCRIPTION (continued)

PWM Duty Cycle Changing

In order to avoid the device output current blinks when the PWM signal chops, there is a filter in the PWM signal path, and this affects the time from the duty cycle changes to output current becomes stable. The typical time is 10ms.

As a result, if you want to use the flash mode by strobe signal and the output current needs a different PWM duty cycle, you should change the duty cycle at least 10ms before rising edge of the strobe signal.

Under-Voltage Lockout

An under-voltage lockout circuit prevents the operation of the device at input voltages below under-voltage threshold (2.25V typical). When the input voltage is below the threshold, the device is shut down. If the input voltage rises by under-voltage lockout hysteresis, the IC restarts.

Over-Voltage Protection

Over-voltage protection circuitry prevents IC damage as the result of white LED string disconnection or shortage.

The SGM3760/A monitor the voltages at SW pin and IFBx pin during each switching cycle. No matter either SW OVP threshold V_{OVP_SW} or IFBx OVP threshold V_{OVP_FB} is reached due to the LED string open or short issue, the protection circuitry will be triggered. Refer to Figure 5 and Figure 6 for the protection actions.

If one LED string is open, its IFBx pin voltage drops, and the boost output voltage is increased by the control loop as it tries to regulate this lower IFBx voltage to the target value (Backlight mode 150mV typical; Flash mode 450mV typical). For the normal string, its current is still under regulation but its IFBx voltage increases along with the output voltage. During the process, either the SW voltage reaches its OVP threshold V_{OVP_SW} or the normal string's IFBx pin voltage reaches the IFBx OVP threshold V_{OVP_FB}, then the protection circuitry will be triggered accordingly.

If both LED strings are open, both IFBx pins' voltages drop to ground, and the boost output voltage is increased by the control loop until reaching the SW OVP threshold V_{OVP_SW}, the SW OVP protection circuitry is triggered. Only VIN POR or EN/PWM pin toggling can restart the IC.

One LED diode short in a string is allowed for the SGM3760/A. If one LED diode in a string is short, the normal string's IFBx voltage is regulated to about 150mV, and the abnormal string's IFBx pin voltage will be higher. Normally with only one diode short, the higher IFBx pin voltage does not reach the IFBx OVP threshold V_{OVP_FB}, so the protection circuitry will not be triggered.

If more than one LED diodes are short in a string, as the boost loop regulates the normal string's IFBx voltage to 150mV, this abnormal string's IFBx pin voltage is much higher and will reach V_{OVP_FB}, then the protection circuitry is triggered.

The SW OVP protection will also be triggered when the forward voltage drop of an LED string exceeds the SW OVP threshold.

Over-Current Protection

The SGM3760/A have a pulse-by-pulse over-current limit. The boost switch turns off when the inductor current reaches this current threshold and it remains off until the beginning of the next switching cycle. This protects the SGM3760/A and external component under overload conditions.

Thermal Shutdown

An internal thermal shutdown turns off the device when the typical junction temperature of +150℃ is exceeded. The device is released from shutdown automatically when the junction temperature decreases by 15℃.

DETAILED DESCRIPTION (continued)

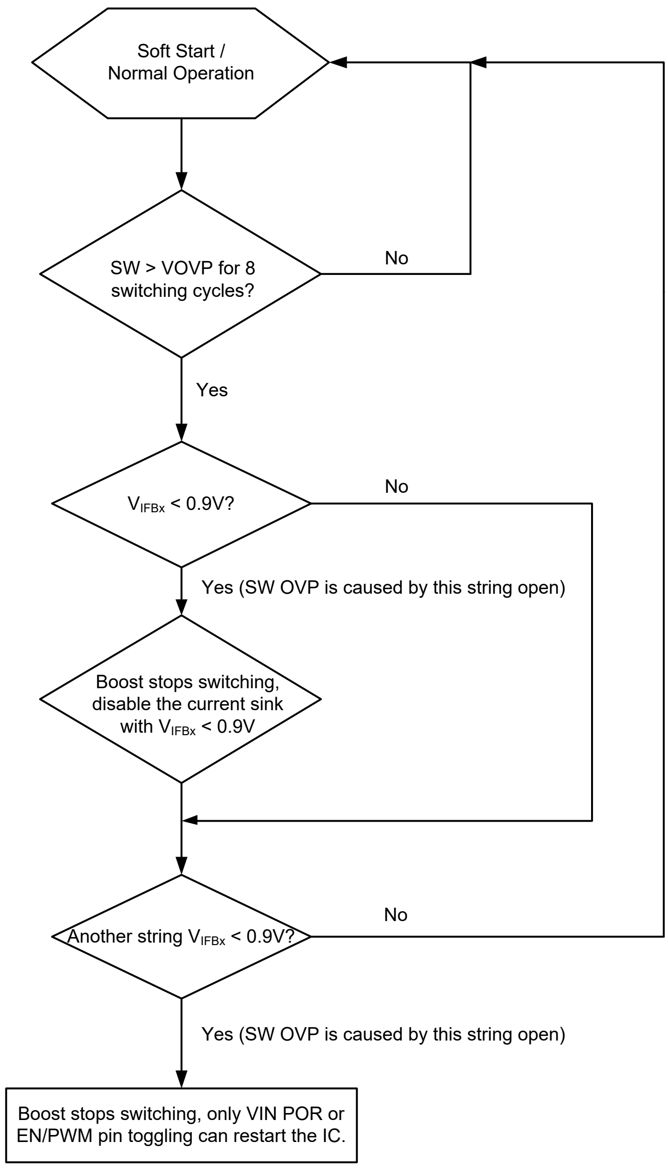


Figure 5. SW OVP Protection Action

DETAILED DESCRIPTION (continued)

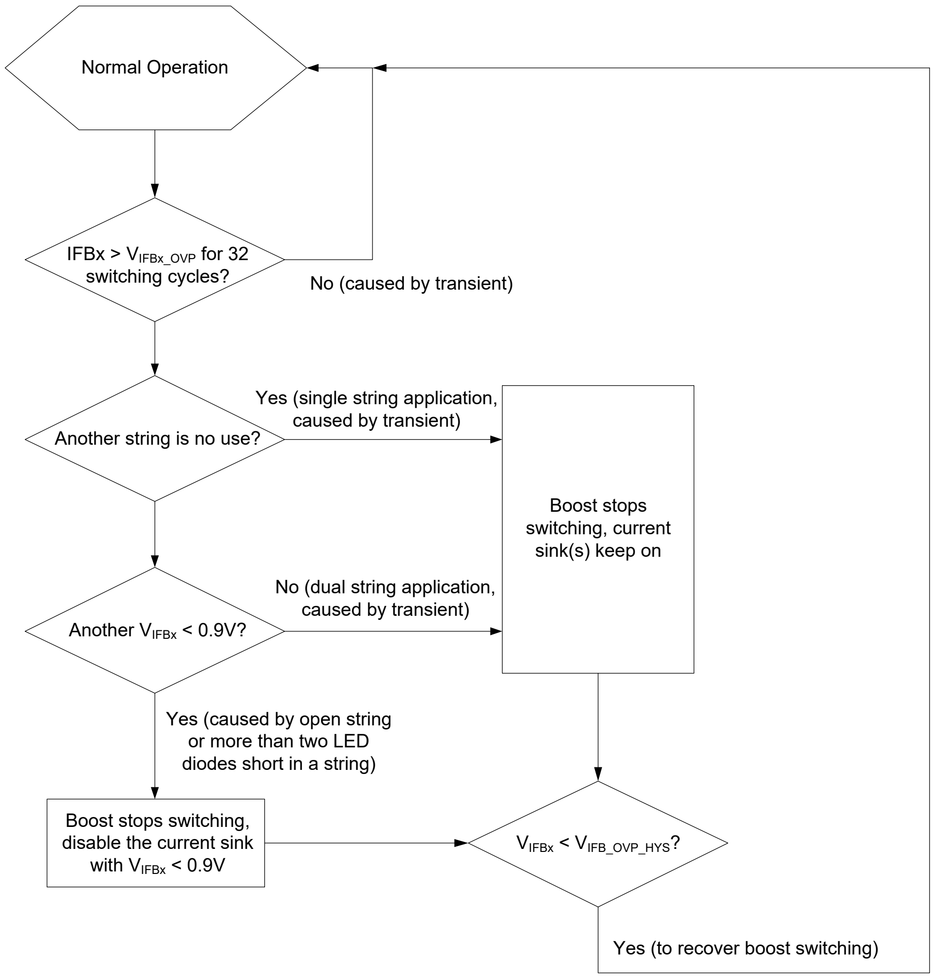


Figure 6. V_{IFBx} OVP Protection Action

APPLICATION INFORMATION

Inductor Selection

Because the selection of inductor affects power supply's steady state operation, transient behavior, loop stability and the boost converter efficiency, the inductor is one of the most important components in switching power regulator design. There are three specifications most important to the performance of the inductor: inductor value, DC resistance, and saturation current. The SGM3760/A are designed to work with inductor values from 4.7μH to 10μH. A 4.7μH inductor is typically available in a smaller or lower profile package, while a 10μH inductor produces lower inductor ripple. If the boost output current is limited by the over-current protection of the IC, using a 10μH inductor may 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 0A value depending on how the inductor vendor defines saturation. When selecting an inductor, please make sure its rated current, especially the saturation current, is larger than its peak current during the operation.

Follow Equation 4 to Equation 6 to calculate the inductor's peak current. To calculate the current in the worst case, use the minimum input voltage, maximum output voltage and maximum load current of the application. In order to leave enough design margin, the minimum switching frequency (1.15MHz), the inductor value with -30% tolerance, and a low power conversion efficiency, such as 80% or lower are recommended for the calculation.

In a boost regulator, the inductor DC current can be calculated as Equation 4.

$$I_{DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \quad (4)$$

where
V_{OUT} = boost output voltage
I_{OUT} = boost output current
V_{IN} = boost input voltage
η = boost power conversion efficiency

The inductor current peak to peak ripple can be calculated as Equation 5.

$$I_{PP} = \frac{1}{L \times \left(\frac{1}{V_{OUT} - V_{IN}} + \frac{1}{V_{IN}}\right) \times f_S} \quad (5)$$

where
I_{PP} = inductor peak-to-peak ripple
L = inductor value
f_S = boost switching frequency
V_{OUT} = boost output voltage
V_{IN} = boost input voltage

Therefore, the peak current I_P seen by the inductor is calculated with Equation 6.

$$I_P = I_{DC} + \frac{I_{PP}}{2} \quad (6)$$

Select an inductor with saturation current over the calculated peak current. If the calculated peak current is larger than the switch MOSFET current limit I_{LIM}, use a larger inductor, such as 10μH, and make sure its peak current is below I_{LIM}.

APPLICATION INFORMATION (continued)

Boost converter efficiency is dependent on the resistance of its current path, the switching losses associated with the switch MOSFET and power diode and the inductor's core loss. The SGM3760/A have optimized the internal switch resistance, however, the overall efficiency is affected a lot 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/ESR conduction losses as well as higher core loss. Normally a datasheet of an inductor does not provide the ESR and core loss information. If needed, consult the inductor vendor for detailed information. Generally, an inductor with lower DCR/ESR is recommended for SGM3760/A application. However, there is a tradeoff among inductor's inductance, DCR/ESR resistance, and its footprint; furthermore, shielded inductors typically have higher DCR than unshielded ones. Table 1 lists some recommended inductors for the SGM3760/A. Verify whether the recommended inductor can support your target application by the calculations above as well as bench validation.

Table 1. Recommended Inductors

PART NUMBER	L (μH)	DCR MAX (mΩ)	SATURATION CURRENT (A)	SIZE (L × W × H mm)	VENDOR
PCMB051B-4R7M	4.7	163	2.7	5.4 × 5.2 × 1.2	Cyntec
PCMB051B-6R8M	6.8	250	2.3	5.4 × 5.2 × 1.2	Cyntec
CMLE061E-100MS	10	100	3.0	7.4 × 6.7 × 1.5	Cyntec
MHCI05020-100M-R8	10	180	4.0	5.0 × 5.0 × 2.0	Chilisin

Schottky Diode Selection

The SGM3760/A demand a low forward voltage, high-speed and low capacitance schottky diode for optimum efficiency. Ensure that the diode average and peak current rating exceeds the average output current and peak inductor current. In addition, the diode's reverse breakdown voltage must exceed the open LED protection voltage. ONSemi MBR0540 and NSR05F40, and Vishay MSS1P4 are recommended for the SGM3760/A.

Compensation Capacitor Selection

The compensation capacitor C4 (refer to Additional Application Circuits) connected from the COMP pin to GND, is used to stabilize the feedback loop of the SGM3760/A. A 330nF ceramic capacitor for C4 is suitable for most applications.

Output Capacitor Selection

The output capacitor is mainly selected to meet the requirement for the output ripple and loop stability. A 1μF to 2.2μF capacitor is recommended for the loop stability consideration. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). Due to its low ESR, V_{RIPPLE_ESR} could be neglected for ceramic capacitors. Assuming a capacitor with zero ESR, the output ripple can be calculated with Equation 7.

$$V_{RIPPLE} = \frac{(V_{OUT} - V_{IN}) \times I_{OUT}}{V_{OUT} \times f_S \times C_{OUT}} \quad (7)$$

Where: V_{RIPPLE} = peak-to-peak output ripple. The additional part of ripple caused by the ESR is calculated using $V_{RIPPLE\_ESR} = I_{OUT} \times R_{ESR}$ and can be ignored for ceramic capacitors.

Note that capacitor degradation increases the ripple much. Select the capacitor with 50V rated voltage to reduce the degradation at the output voltage. If the output ripple is too large, change a capacitor with less degradation effect or with higher rated voltage could be helpful.

APPLICATION INFORMATION (continued)

Layout Consideration

As for all switching power supplies, especially those providing high current and using high switching frequencies, layout is an important design step. If layout is not carefully done, the regulator could show instability as well as EMI problems. Therefore, use wide and short traces for high current paths. The input capacitor, C1 in Additional Application Circuits, needs to be close to the inductor, as well as the VIN pin and GND pin in order to reduce the input ripple seen by the IC. If possible, choose higher capacitance value for it. If the ripple seen at VIN pin is so large that it affects the boost loop stability or internal circuits operation, R2 and C3 are recommended to filter and decouple the noise. In this case, C3 should be placed as close as possible to the VIN and GND pins. The SW pin carries high current with fast rising and falling edges. Therefore, the connection between the SW pin to the inductor and schottky diode should be kept as short and wide as possible. The trace between schottky diode and the output capacitor C2 should also be as short and wide as possible. It is also beneficial to have the ground of the output capacitor C2 close to the GND pin since there is a large ground return current flowing between them. When laying out signal grounds, it is recommended to use short traces separated from power ground traces, and connect them together at a single point close to the GND pin.

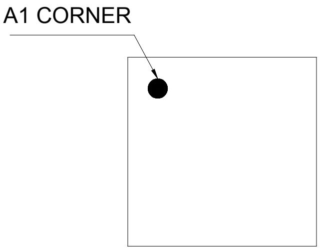
REVISION HISTORY

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

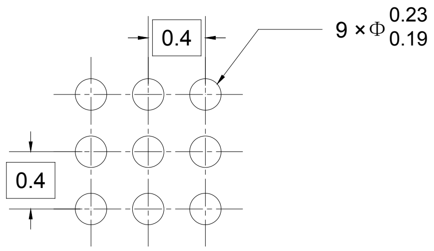
Changes from Original (MARCH 2019) to REV.A	Page
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

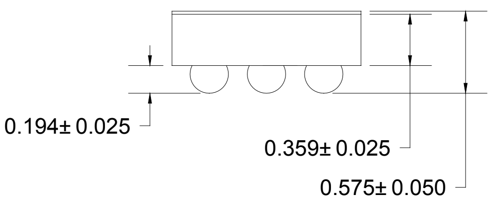
WLCSP-1.32×1.32-9B



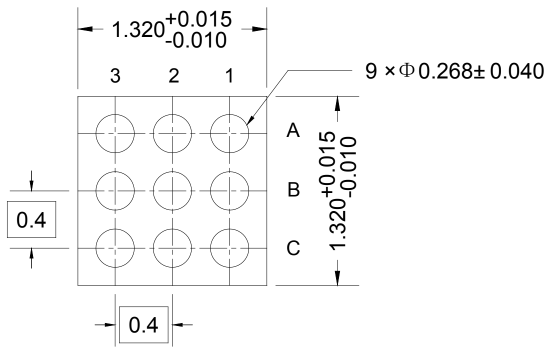
TOP VIEW



RECOMMENDED LAND PATTERN



SIDE VIEW

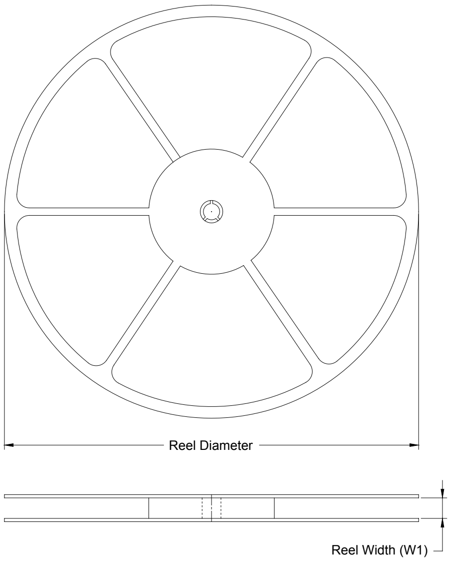


BOTTOM VIEW

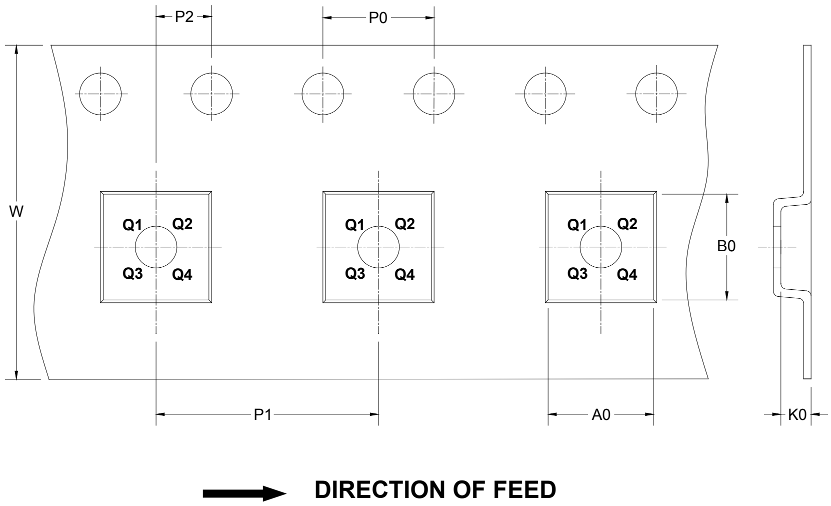
NOTE: All linear dimensions are in millimeters.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



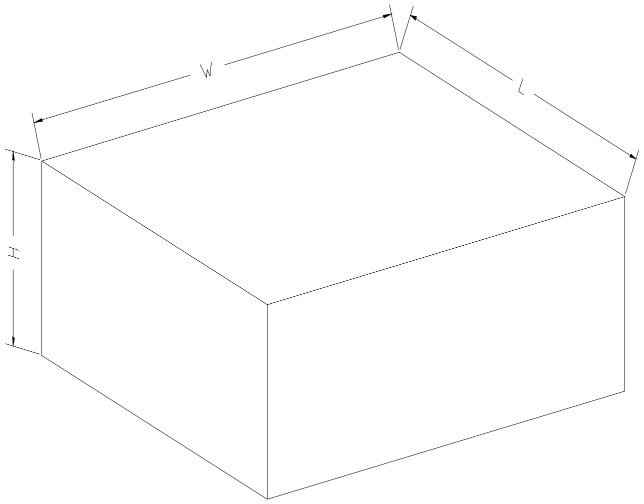
NOTE: The picture is only for reference. Please make the object as the standard.

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
WLCSP-1.32×1.32-9B	7″	9.5	1.38	1.38	0.70	4.0	4.0	2.0	8.0	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
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002