SGM3791

6-Channel, 100mA, Adaptive Boost LED Driver with PWM Based Pulsating LED Current and Constant Input Current Regulation

GENERAL DESCRIPTION

The SGM3791 is an adaptive Boost LED driver with integrated Boost switch and 6-channel LED sink for PWM based LED current. It adaptively adjusts the LED anode voltage based on the sinking current and cathode voltage, ensuring sufficient headroom for optimal operation. The SGM3791 maintains a constant inductor current when the LED sinking channel turns off to minimize unnecessary inrush current drawn from the input source.

The SGM3791 is a non-synchronous Boost converter with integrated 2.45A/31.3V power FET. In addition, an external isolation PFET gate drive control is integrated to provide true load disconnection as well as Boost output short protection.

The SGM3791 supports up to 9V input for 2-cell Li-Ion batteries in series configuration. And V_{CC} UVLO rising threshold is 3.0V.

The device operates its six sink channels in a PWM-based current mode, controlled via external PWM input signals. These channels can be configured into two independent groups, each managed by separate PWM inputs, allowing flexible sink current programming.

The SGM3791 incorporates an I^2C interface, providing programmability to function setting and status reading.

The SGM3791 integrates various protection features such as programmable Boost over-voltage threshold, system fault indications, LED string open and short detection, and thermal shutdown.

The device is available in a Green WLCSP-1.73×2.06-20B package.

FEATURES

- **Up to 9V Input Voltage Range**
- **3.0V V_{CC} UVLO Threshold for Device Configuration**
- **Asynchronous Peak Control ACFT Boost**
  - **Up to 31.3V (TYP) Boost Output Voltage**
  - **Adaptive LED Anode Voltage**
  - **Constant Input Current Regulation during LED On and off**
- **Integrated 2.45A/31.3V Power MOSFET**
- **Integrated Isolation PFET Gate Driver**
  - **Programmable Gate Drive Voltage in External Component Selection**
  - **Built-in Soft-Start Function**
- **Six Current Sinking Channels**
  - **PWM Dimming Mode**
  - **Two Separate Groups with Independent PWM Input Control and Programmable Sink Current**
  - **Up to 100mA (TYP) Sinking Current Per Channel**
  - **Programmable PWM Time-Out Protection**
- **I^2C Interface**
  - **SGM3791A Slave Address: 0x28**
  - **SGM3791B Slave Address: 0x29**
- **Protections and Indications**
  - **Programmable Over-Voltage Protection**
  - **Over-Current Protection**
  - **Built-in LED Open and Short Protections**
  - **Boost Start-up Short-Circuit Protection**
  - **Fault Status Flags**
- **Available in a Green WLCSP-1.73×2.06-20B Package**

APPLICATIONS

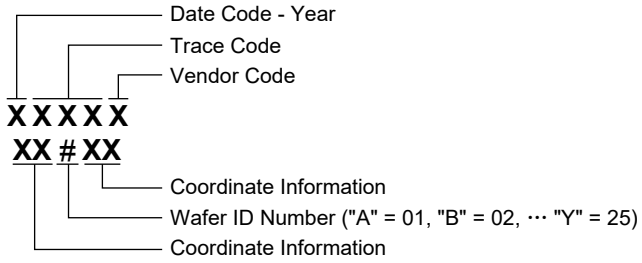
Virtual Reality Devices
IR and WLED Arrays

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM3791A	WLCSP-1.73×2.06-20B	-40℃ to +85℃	SGM3791AYG/TR	3791A XXXXX XX#XX	Tape and Reel, 3000
SGM3791B	WLCSP-1.73×2.06-20B	-40℃ to +85℃	SGM3791BYG/TR	3791B XXXXX XX#XX	Tape and Reel, 3000

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code. XX#XX = Coordinate Information and Wafer ID 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

Pin Voltage (with Respect to GND)
- VBAT, VIN, GD 11V
- VOUT ..... Up to 32.8V
- VCC, COMP, PWM1, PWM2, SCL, SDA, EN .... -0.3V to 6V
- SW ..... -0.3V to 33.3V
- LED1, LED2, LED3, LED4, LED5, LED6 ..... -0.3V to 22V

Package Thermal Resistance
- WLCSP-1.73×2.06-20B, θ_{JA} ..... 56.3℃/W
- WLCSP-1.73×2.06-20B, θ_{JB} ..... 10.2℃/W
- WLCSP-1.73×2.06-20B, θ_{JC} ..... 27.9℃/W

Junction Temperature ..... +150℃
Storage Temperature Range ..... -65℃ to +150℃
Lead Temperature (Soldering, 10s) ..... +260℃
ESD Susceptibility (1) (2)
HBM ..... ±2000V
CDM ..... ±1000V

NOTES:

1. For human body model (HBM), all pins comply with ANSI/ESDA/JEDEC JS-001 specifications.

2. For charged device model (CDM), all pins comply with ANSI/ESDA/JEDEC JS-002 specifications.

RECOMMENDED OPERATING CONDITIONS

Input Voltage Range (VBAT, VIN, GD) ..... 3V to 9V
Output Voltage Range ..... Up to 31.3V
VCC, COMP, PWM1, PWM2, SCL, SDA, EN ..... Up to 5.5V
SW ..... Up to 32V
LED1, LED2, LED3, LED4, LED5, LED6 ..... Up to 20V
Inductor Range ..... 1μH to 4.7μH (1 BAT), 10μH (2 BAT)
Output Capacitor Range (Effective) ..... 100μF to 470μF
Operating Junction Temperature Range ..... -40℃ to +85℃

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

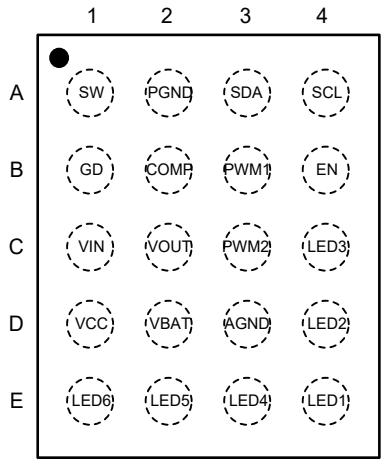
This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance 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 CONFIGURATION

(TOP VIEW)



WLCSP-1.73×2.06-20B

PIN DESCRIPTION

PIN	NAME	TYPE (1)	FUNCTION
A1	SW	AO	Switch Node. Drain connection of low-side power FET.
A2	PGND	P	Power Ground Pin.
A3	SDA	DIO	Date Line of the I^2C Bus.
A4	SCL	DI	Clock Line of the I^2C Bus.
B1	GD	AO	Gate Drive of the External Isolation PFET.
B2	COMP	AO	EA Compensation Capacitor Configuration Pin. Put C_{COMP} between this pin and AGND.
B3	PWM1	DI	External PWM Signal Input. PWM input to adjust sink turn-on duty cycle.
B4	EN	AI	Enable of the Analog Circuit.
C1	VIN	P	Input Power Supply Pin.
C2	VOUT	AI	Boost Output Voltage Detection.
C3	PWM2	DI	External PWM Signal Input. PWM input to adjust sink turn-on duty cycle.
C4	LED3	AO	Regulated Current Sink 3 Input Pin.
D1	VCC	AIO	LDO Input and Output Pin.
D2	VBAT	AI	Boost Input Voltage Detection.
D3	AGND	P	Analog Ground.
D4	LED2	AO	Regulated Current Sink 2 Input Pin.
E1	LED6	AO	Regulated Current Sink 6 Input Pin.
E2	LED5	AO	Regulated Current Sink 5 Input Pin.
E3	LED4	AO	Regulated Current Sink 4 Input Pin.
E4	LED1	AO	Regulated Current Sink 1 Input Pin.

NOTE: 1. AI = Analog Input, AO = Analog Output, AIO = Analog Input and Output, DI = Digital Input, DO = Digital Output, DIO = Digital Input and Output, P = Power.

ELECTRICAL CHARACTERISTICS

(V_{BAT} = 3.6V, V_{IN} = 5.85V, V_{CC} = 5V. T_J = -40℃ to +85℃, all typical values are measured at T_J = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply						
Boost Input Voltage Range	V_{BAT}		3		9	V
VCC Voltage Range	V_{CC}	2S Battery, V_{BAT}= V_{IN}, BATTERY = 0b		5		V
		1S Battery, V_{IN} > 5V, BATTERY = 0b		5		
		1S Battery, V_{CC} = V_{IN} ≤ 5V, BATTERY = 1b		V_{IN}		
VCC Under-Voltage Lockout	V_{CC_UVLO}	V_{CC} rising			3.0	V
		V_{CC} falling			2.9	V
Quiescent Current	I_Q	V_{BAT} = 3.6V, EN = 3.6V, no switching		1.9	2.8	mA
Shutdown Current	I_{SD}	V_{BAT} = 3.6V, EN = 0V, no switching		0.3	0.62	μA
Boost Converter						
Latch-off Switch Peak Current Limit	I_{LIM}	T_J = +25℃	1.67	2.45	3.23	A
Switch Minimum Current Limit	I_{NTRIP}			0.2		A
Low-side Switch On-Resistance	R_{DSON_LS}	I_{SW} = 250mA, V_{CC} = 5V		143		mΩ
Switching Frequency	f_{SW}	V_{BAT} = 3.6V,V_{OUT} = 29V, FSW[1:0] = 11b		925		kHz
Minimum Turn-off Time	t_{OFF_MIN}			68		ns
Minimum Turn-on Time	t_{ON_MIN}			70		ns
LEDx Voltage	V_{LEDx}	Channel headroom voltage for Boost operation without skip		500		mV
SW Leakage Current	I_{SW_LKG}	V_{SW} = 32V,V_{CC} = 5V			1	μA
Protection						
Boost Short-Circuit Threshold	V_{SHORT_BOOST}			V_{BAT} - 1.2		V
Over-Voltage Protection	V_{OVP}	BOOST_OVP[2:0] = 111b	30	31.3	32.5	V
Over-Voltage Hysteresis	V_{OVP_HYS}			2.6		V
Over-Temperature Protection		Rising edge		150		℃
Over-Temperature Hysteresis		Hysteresis		20		℃
LED Sink						
LED Current Accuracy	I_{LED_ACC}	T_J = +25℃, I_{LED} = 20mA	-2.8		2.8	%
		I_{LED} = 20mA	-4.2		4.2	
		T_J = 0℃ to +85℃, I_{LED} = 20mA	-3.2		3.2	
		T_J = +25℃, I_{LED} = 70mA	-1.6		1.6	
		I_{LED} = 70mA	-2.9		2.9	
		T_J = 0℃ to +85℃, I_{LED} = 70mA	-1.9		1.9	
LED Channel Matching	I_{LED_MATCH}	I_{LED} = 20mA	-2.3		2.3	%
		I_{LED} = 70mA	-1.2		1.2	
Sink Turn-on Time from PWM High to ILED	$t_{PWM\_LED\_ON}$	The rising edge delay between PWM signal and ILED		2.4		μs
Sink Turn-off Time from PWM Falling to ILED	$t_{PWM\_LED\_OFF}$	The falling edge delay between PWM signal and ILED		2.4		μs
LED Sink Rise Time	t_R	I_{LED} = 70mA, 10%-90%, V_{CC} = 3.3V		1		μs
		I_{LED} = 70mA, 10%-90%, V_{CC} = 5V		0.5		
LED Sink Fall Time	t_F	I_{LED} = 70mA, 90%-10%, V_{CC} = 3.3V		1		μs
		I_{LED} = 70mA, 90%-10%, V_{CC} = 5V		0.5		

ELECTRICAL CHARACTERISTICS (continued)

(V_{BAT} = 3.6V, V_{IN} = 5.85V, V_{CC} = 5V. T_J = -40℃ to +85℃, typical values are at T_J = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Minimum LED Current (Per String)	I_{LED_MIN}			1		mA
Maximum LED Current (Per String)	I_{LED_MAX}			100		mA
Digital Input						
Input Logic High	V_{IH}	EN, SCL, SDA, PWM inputs			1.2	V
Input Logic Low	V_{IL}	EN, SCL, SDA, PWM inputs	0.4			V
Pull-down Resistor	R_{PWM}, R_{HWEN}	EN ,PWM inputs		1000		kΩ

TYPICAL APPLICATION

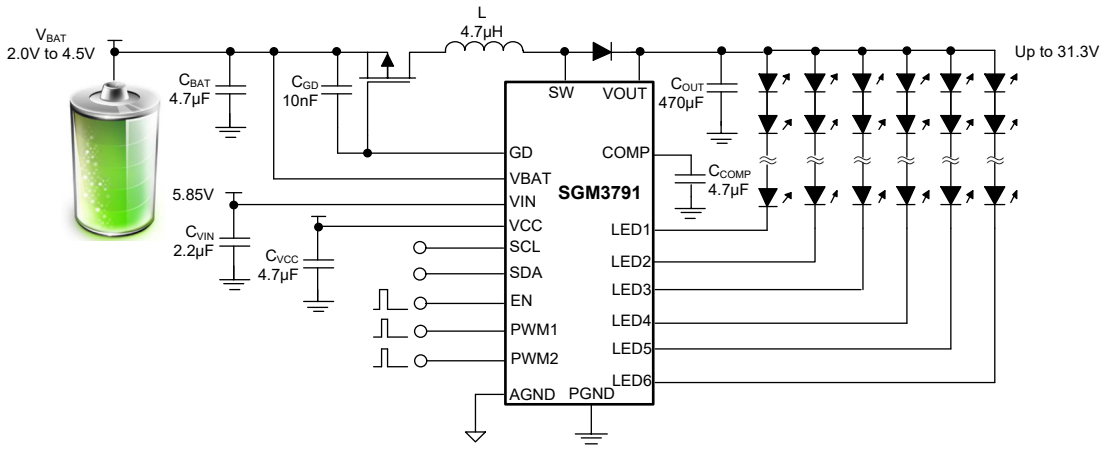
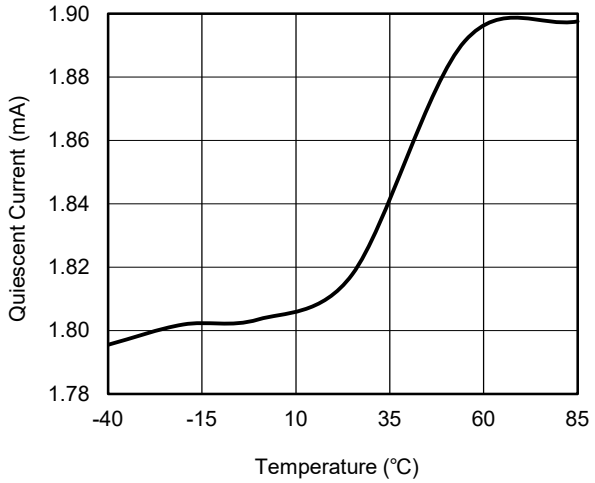


Figure 1. Typical Application for 1S Battery

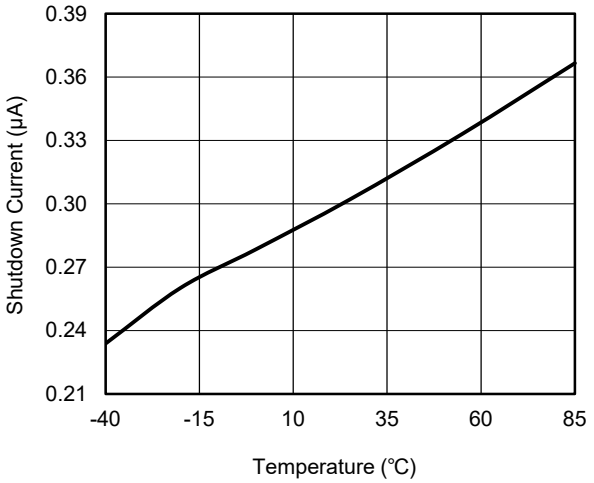
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = +25℃, V_{BAT} = 3.6V, V_{IN} = 5.85V and V_{CC} = 5V, unless otherwise noted.

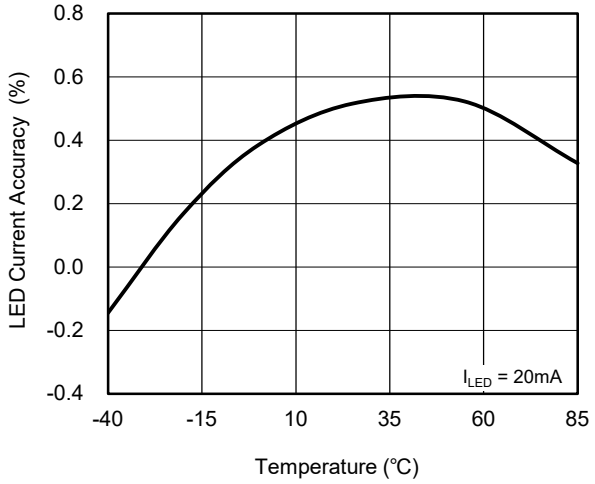
Quiescent Current vs. Temperature



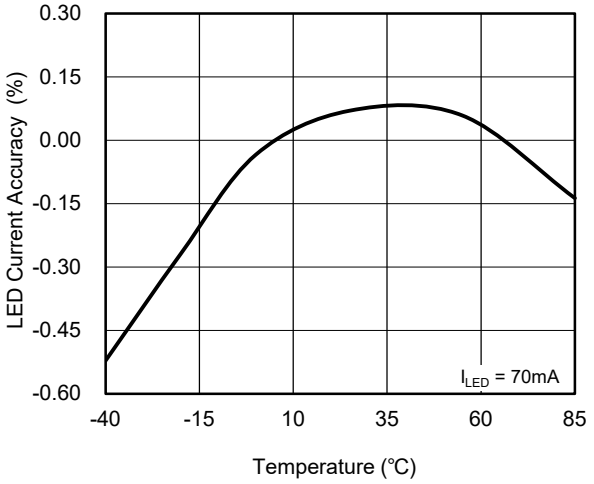
Shutdown Current vs. Temperature



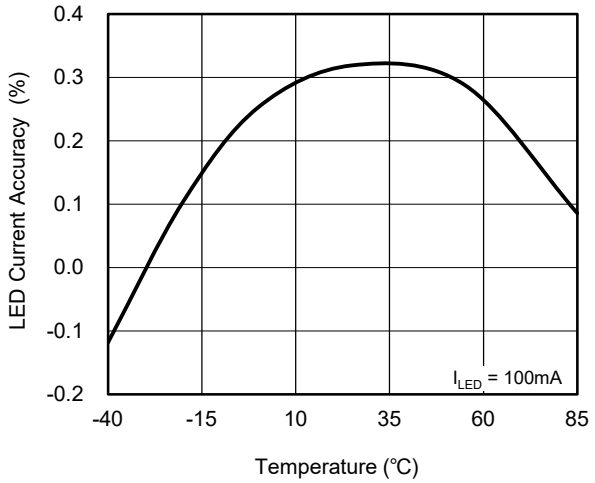
LED Current Accuracy vs. Temperature



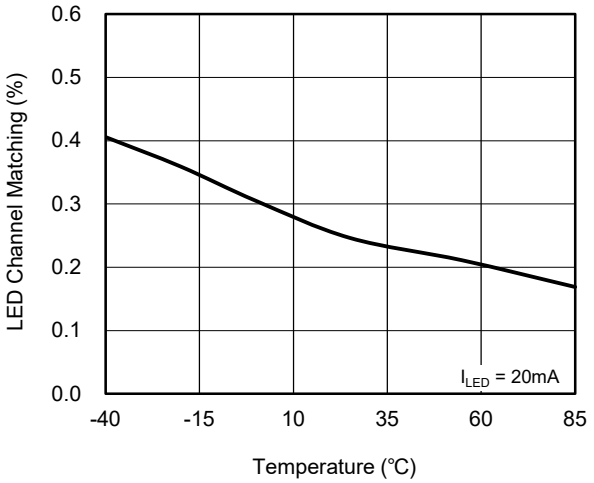
LED Current Accuracy vs. Temperature



LED Current Accuracy vs. Temperature



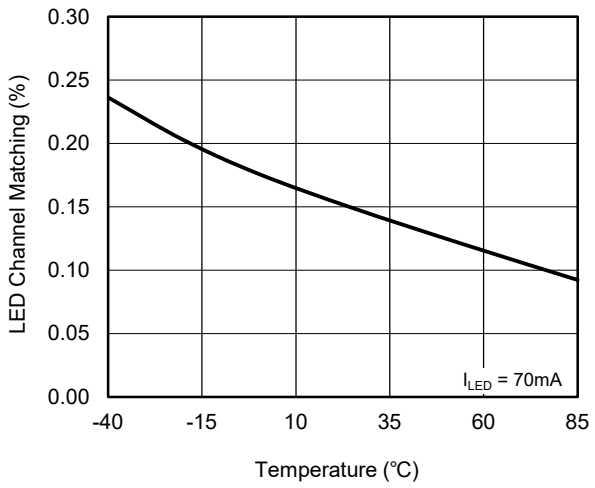
LED Channel Matching vs. Temperature



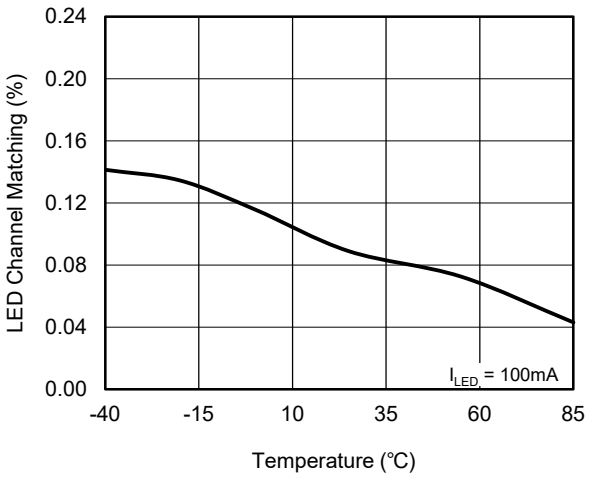
TYPICAL PERFORMANCE CHARACTERISTICS (continued)

T_A = +25℃, V_{BAT} = 3.6V, V_{IN} = 5.85V and V_{CC} = 5V, unless otherwise noted.

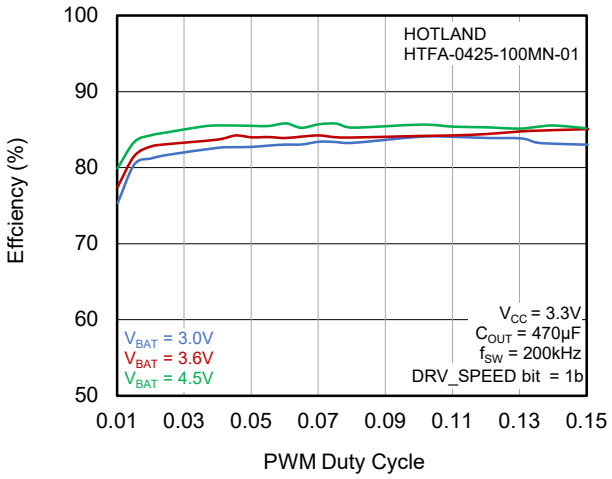
LED Channel Matching vs. Temperature



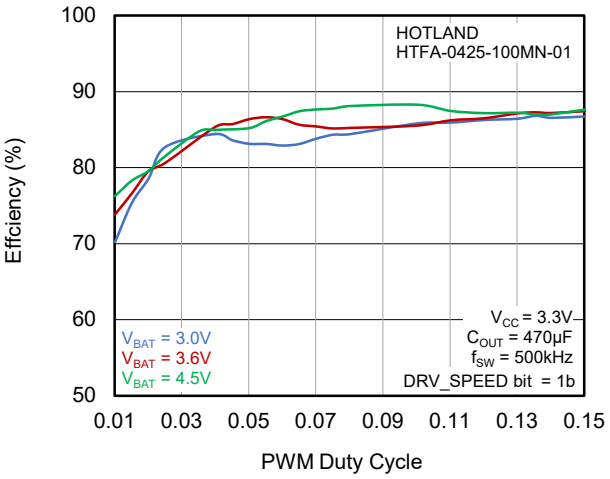
LED Channel Matching vs. Temperature



Efficiency vs. PWM Duty Cycle

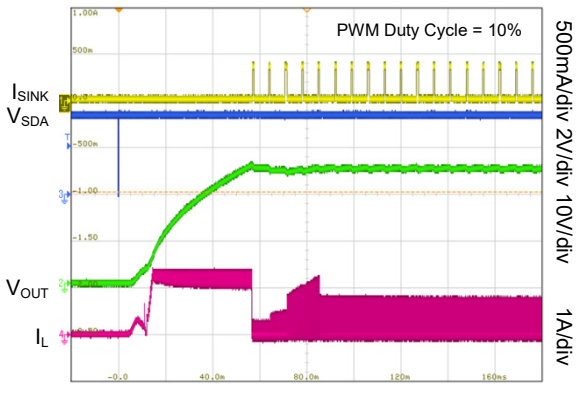


Efficiency vs. PWM Duty Cycle

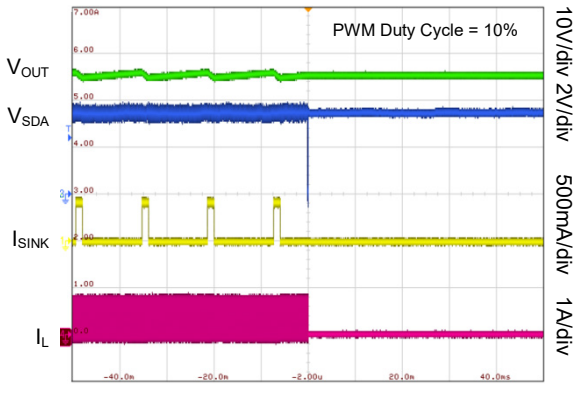


V_{BAT} = 3.6V, V_{IN} = V_{CC} = 3.3V, FSW[1:0] bits = 00b (200kHz), ISO_PRECHG[2:0] bits = 100b (1.32V), DRV_SPEED bit =1b, BATTERY bit = 1b, I_{SINK} = 70mA/CH, FPWM = 72Hz, unless otherwise noted.

I2C_EN Start-up



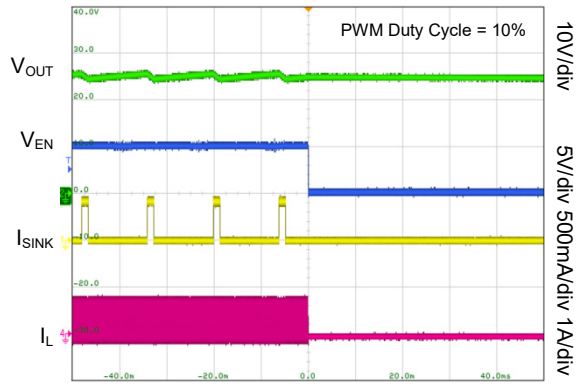
I2C_EN Shutdown



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

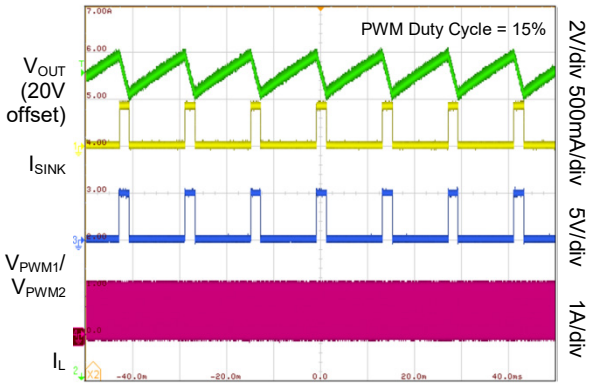
V_{BAT} = 3.6V, V_{IN} = V_{CC} = 3.3V, FSW[1:0] bits = 00b (200kHz), ISO_PRECHG[2:0] bits = 100b (1.32V), DRV_SPEED bit =1b, BATTERY bit = 1b, I_{SINK} = 70mA/CH, FPWM = 72Hz, unless otherwise noted.

EN Shutdown



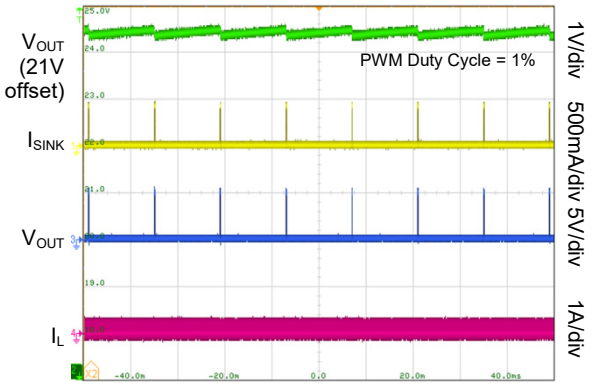
Time (10ms/div)

SYNC Steady State



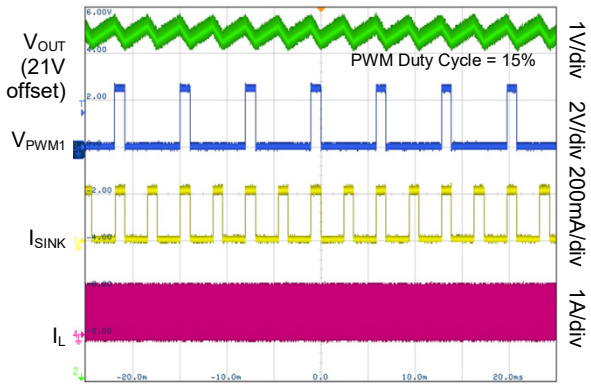
Time (10ms/div)

SYNC Steady State



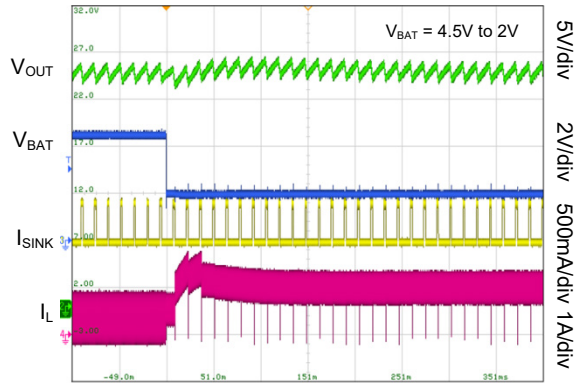
Time (10ms/div)

ASYNC Steady-State (Phase Difference between PWM1 and PWM 2 = 180°)



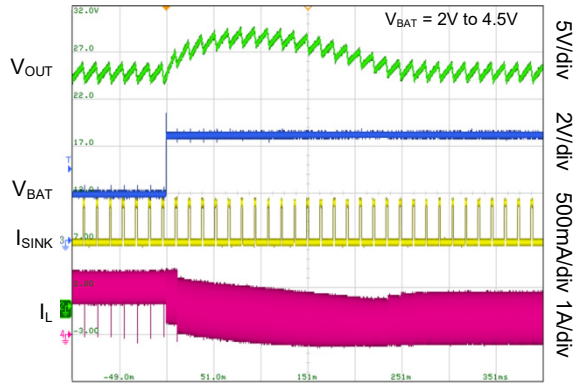
Time (5ms/div)

VBAT Transient



Time (50ms/div)

VBAT Transient

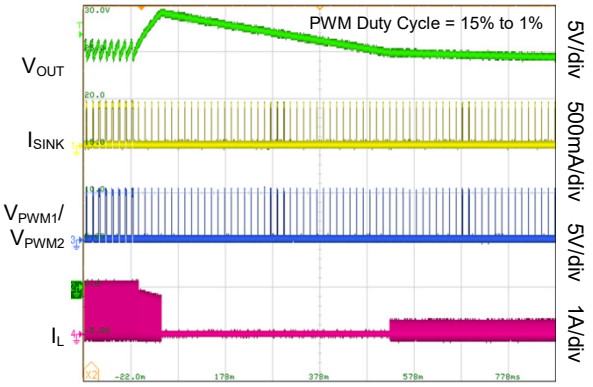


Time (50ms/div)

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

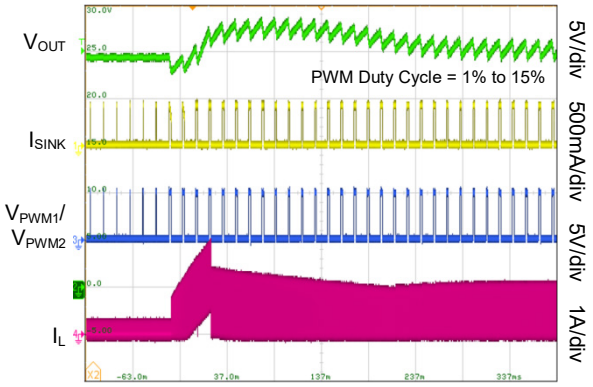
V_{BAT} = 3.6V, V_{IN} = V_{CC} = 3.3V, FSW[1:0] bits = 00b (200kHz), ISO_PRECHG[2:0] bits = 100b (1.32V), DRV_SPEED bit =1b, BATTERY bit = 1b, I_{SINK} = 70mA/CH, FPWM = 72Hz, unless otherwise noted.

Brightness Transient



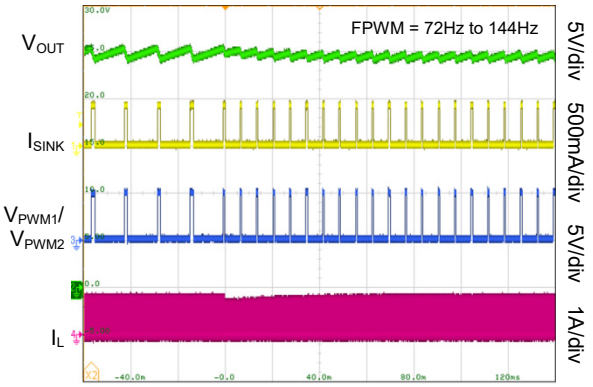
Time (100ms/div)

Brightness Transient



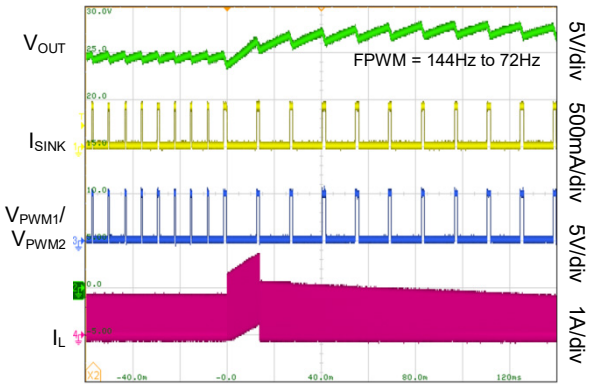
Time (50ms/div)

Frame Rate Transient



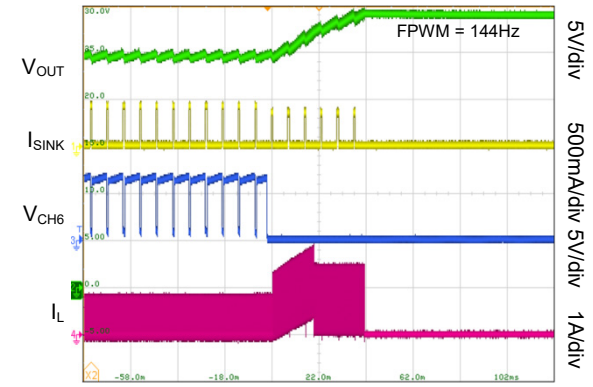
Time (20ms/div)

Frame Rate Transient



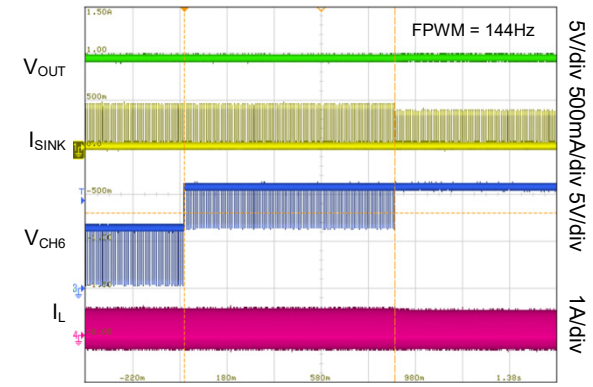
Time (20ms/div)

LED OPEN Protection
(FAULT_SHUTDOWN bit = 1)



Time (20ms/div)

LED Short-Circuit Protection
(FAULT SHUTDOWN bit = 0)

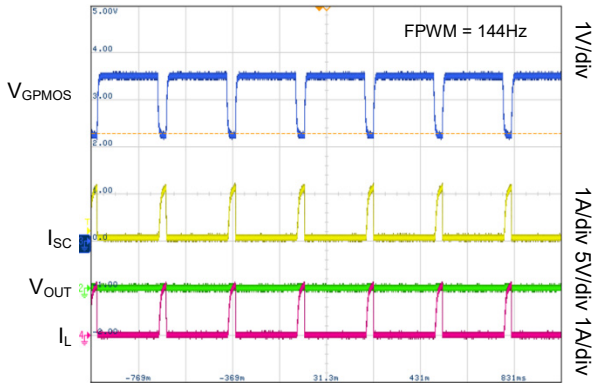


Time (200ms/div)

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

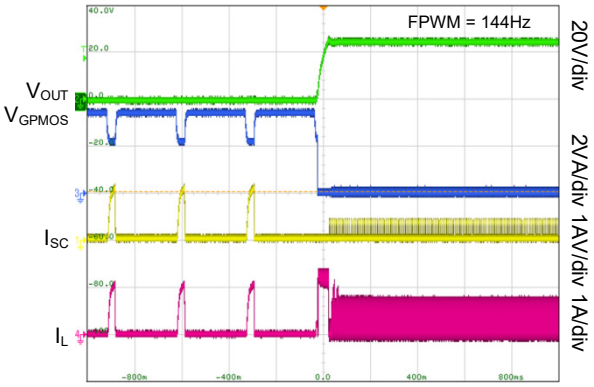
V_{BAT} = 3.6V, V_{IN} = V_{CC} = 3.3V, FSW[1:0] bits = 00b (200kHz), ISO_PRECHG[2:0] bits = 100b (1.32V), DRV_SPEED bit =1b, BATTERY bit = 1b, I_{SINK} = 70mA/CH, FPWM = 72Hz, unless otherwise noted.

Boost Short-Circuit Protection



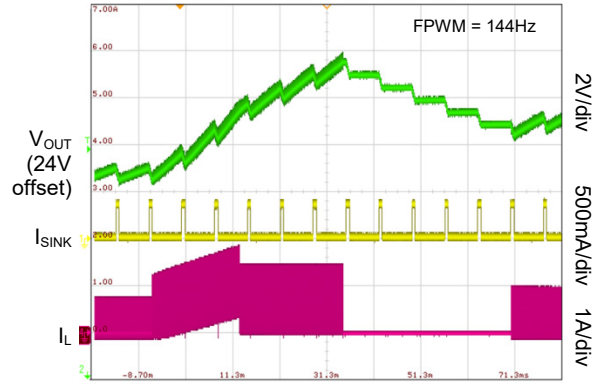
Time (200ms/div)

Boost Short-Circuit Recovery



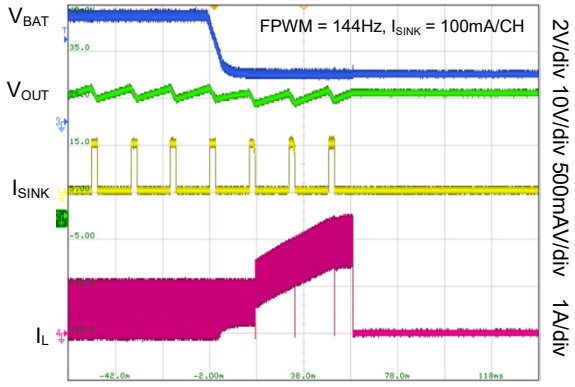
Time (200ms/div)

Boost Over-Voltage Protection



Time (10ms/div)

Boost Latched Over-Current Protection



Time (20ms/div)

FUNCTIONAL BLOCK DIAGRAM

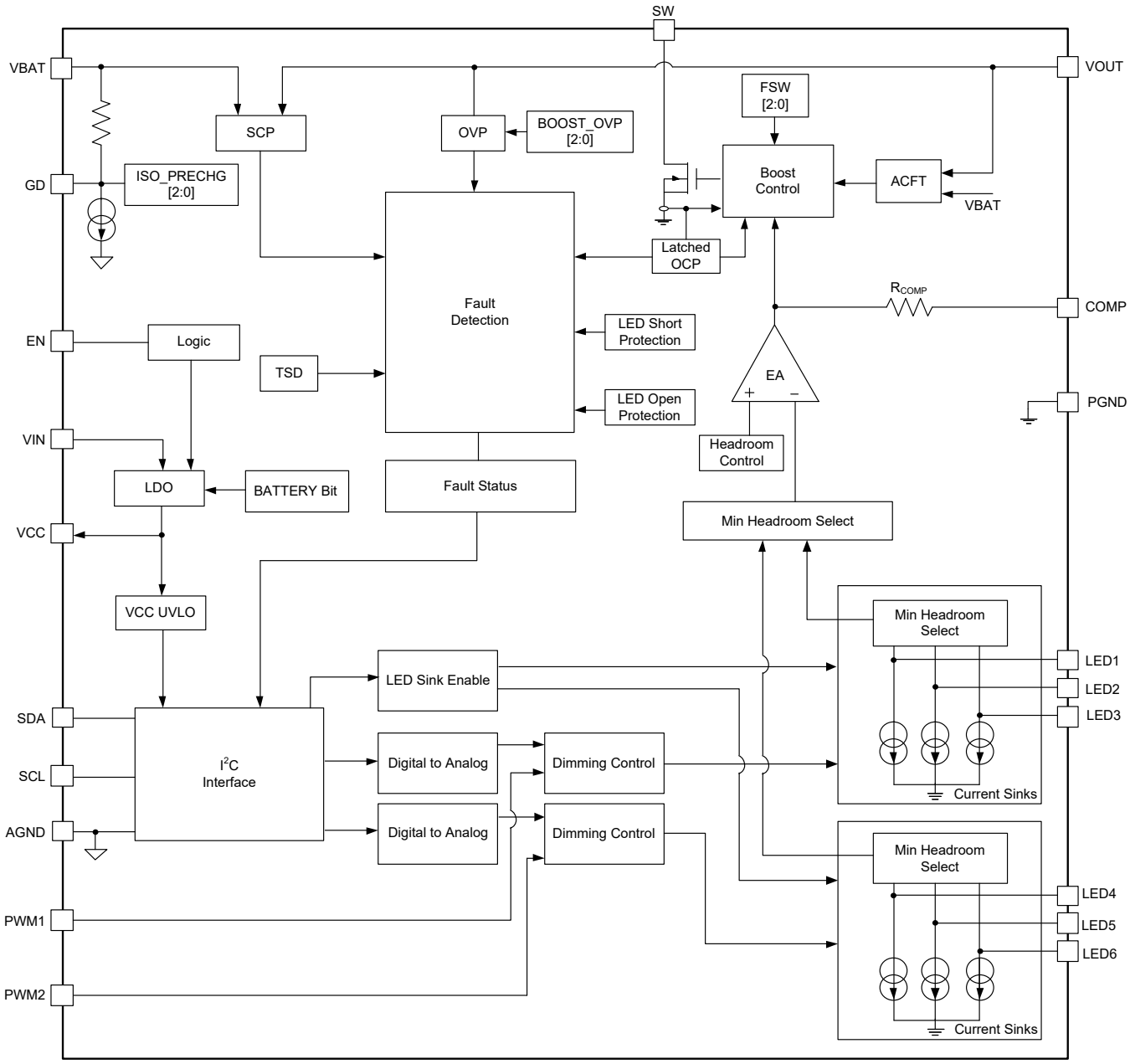


Figure 2. Block Diagram

DETAILED DESCRIPTION

The SGM3791 is an adaptive LED anode voltage Boost converter with six integrated sink channels, optimized for PWM-based dimming mode. During LED sink turn-on phase, the sink current is mainly supplied by the Boost output capacitor and inductor current. And the inductor current remains constant during this LED sink turn-off phase to minimize the input inrush current.

As any one of the LEDx pin voltages is below the pre-defined 500mV (TYP) threshold, indicating insufficient anode voltage, the regulator automatically adjusts the Boost's peak current to restore proper voltage levels.

The SGM3791 supports a wide voltage range up to 9V for 2-cell Li-Ion batteries, and the VBAT voltage can be low enough as long as the inductor current does not trigger the OCP. Once the V_{CC} UVLO requirement is met, the device registers can be configured via the I^2C interface.

The device operates its six sink channels in a PWM-based current mode, controlled via external PWM input signals. These channels can be configured into 2 independent groups, each managed by separate PWM inputs, allowing flexible sink current programming. The LED sink current is also programmable from 20mA (practical application considerations) to 100mA as small as 0.1mA increment via the I^2C interface.

The SGM3791 incorporates an I^2C interface, providing programmability to function setting and status reading.

The SGM3791 integrates various protection features such as over-current protection, programmable Boost over-voltage threshold, system fault indications, LED string open and short detection, Boost short-circuit protection and thermal shutdown.

Internal Regulator VCC

The SGM3791 implements an internal VCC regulator to support 1s or 2s Li-Ion battery configurations. The VCC pin has a UVLO rising threshold of 3.0V and a UVLO falling threshold of 2.9V. For 1s battery configuration, the battery input voltage can be tied directly to VIN and VBAT pins as shown in Figure 3.

An external power supply up to 9V can also be connected to the VIN pin and the internal LDO generates a VCC voltage up to 5V, as shown in Figure 4.

If external power supply is low, it is recommended to connect the VIN pin to VCC pin as shown in Figure 5. Set the BATTERY bit to 1 to disable the LDO and use an external V_{CC}.

In Configuration 2 and Configuration 3, even if the VBAT voltage drops to 2V due to some large loads, it will not cause the system to shut down. For Configuration 1 and Configuration 3, set DRV_SPEED bit to 1 for efficiency consideration. Set BATTERY bit to 1 to disable internal LDO.

For 2s battery configuration, the battery voltage can be tied directly to the VIN pin, the device's internal regulator will regulate a fixed 5.0V VCC voltage.

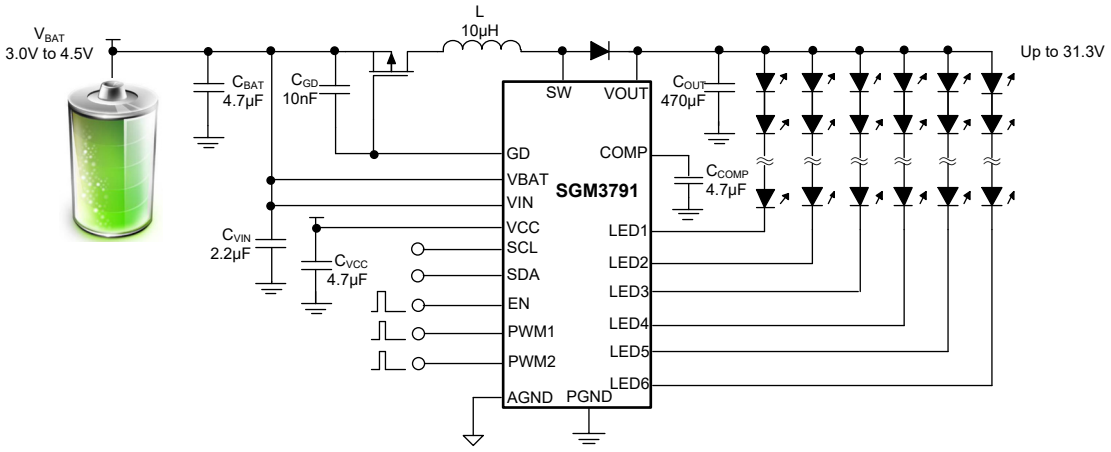


Figure 3. 1S Battery Configuration 1

DETAILED DESCRIPTION (continued)

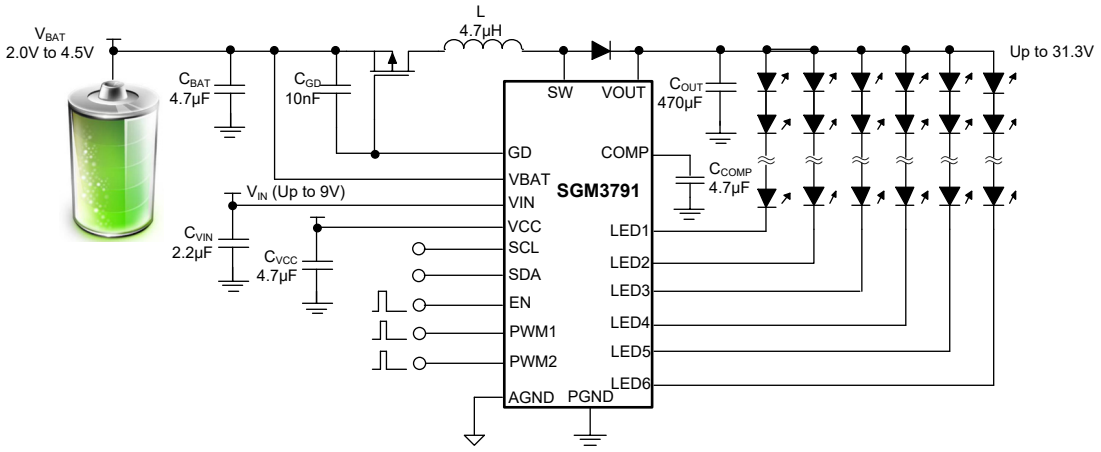


Figure 4. 1S Battery Configuration 2

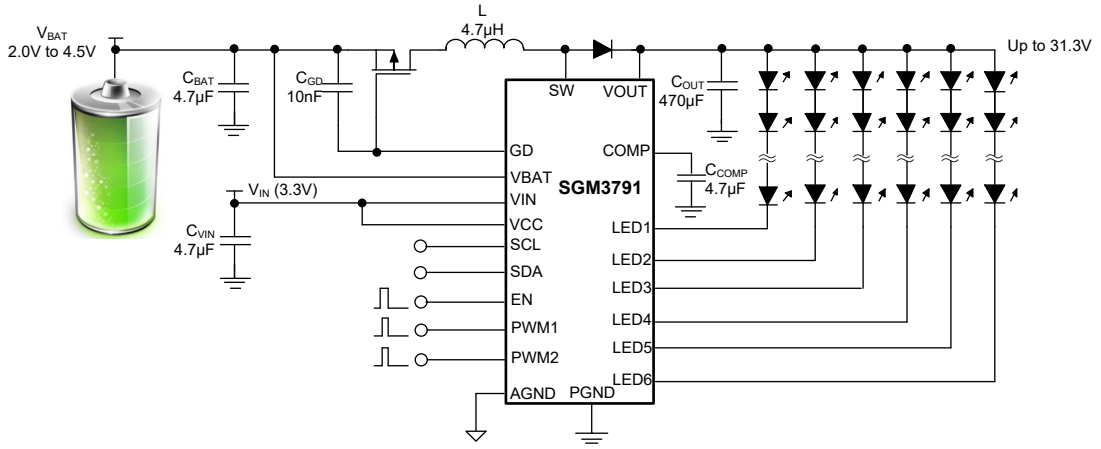


Figure 5. 1S Battery Configuration 3

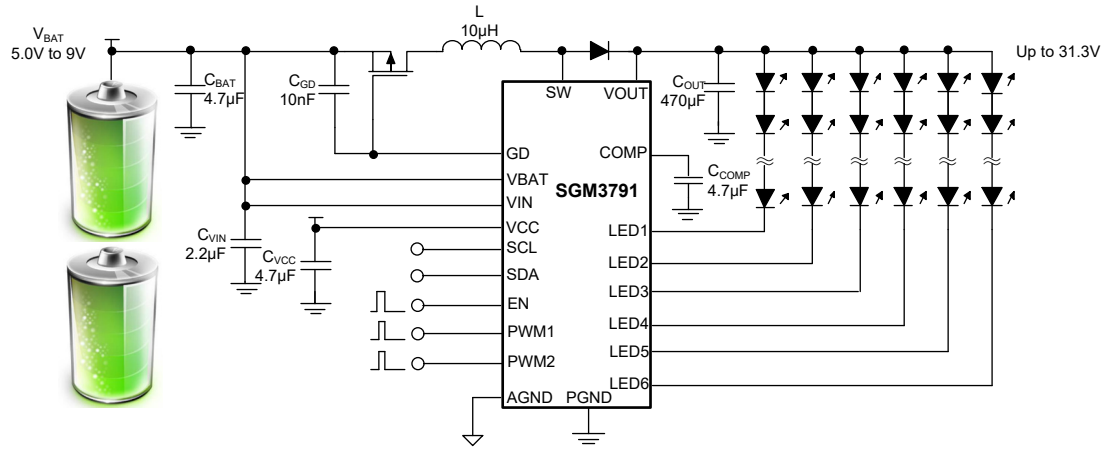


Figure 6. 2S Battery Configuration

DETAILED DESCRIPTION (continued)

Start-up

Upon sufficient input voltage and an enable signal (EN pin), the SGM3791 initiates its start-up sequence, ramping up VCC voltage. Once V_{CC} exceeds the UVLO rising threshold, the I^2C interface becomes active, allowing register configurations. It is recommended to enable the I^2C functionality after completing other register configurations.

After the I2C_EN bit is set to logic high, the device enters the pre-charge sequence.

During pre-charge, the gate driver (GD pin) applies a controlled VSG voltage (set by ISO_PRECHG[2:0] bits) to the external PFET, gradually ramping up the output voltage (V_{OUT}) without inrush current. Once V_{OUT} approaches the input voltage (V_{BAT} - 1.2), the PFET fully turns on. The SGM3791 starts switching to boost the V_{OUT} to initial output voltage (set by VOUT_INI[2:0] bits) with initial inductor peak current (set by IPK_INI[2:0] bits). Only when the output voltage reaches the initial output voltage, the sink current is allowed, which ensures the system stabilization. Initial peak current is only valid during the soft-start phase, after which the peak current is automatically limited to 2.45A (TYP).

Figure 7 is a typical start-up time sequence for SGM3791 when VIN pin and VBAT pin are connected together.

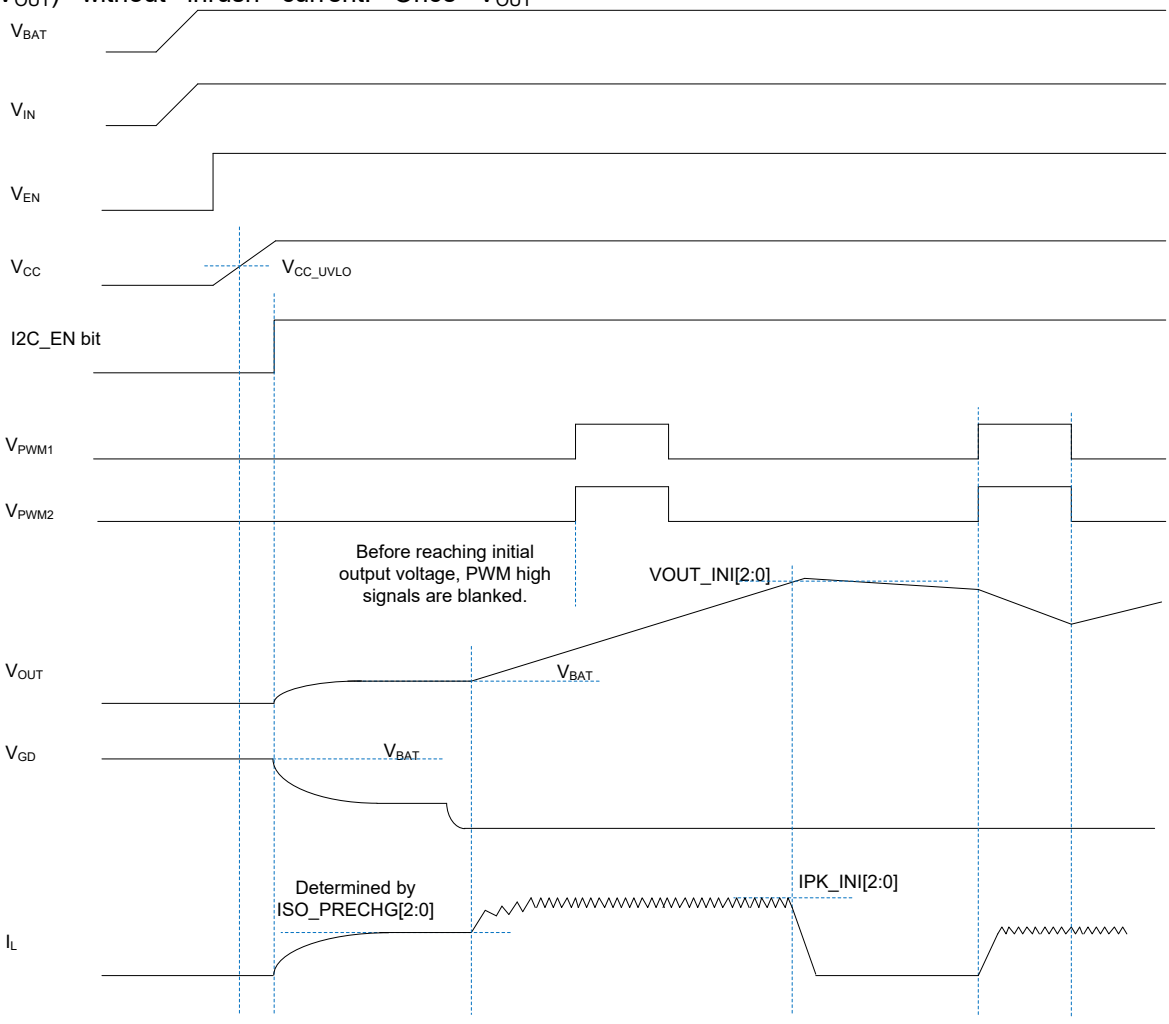


Figure 7. Typical Start-up Waveform for VIN Pin Connected to VBAT Pin

DETAILED DESCRIPTION (continued)

Input Disconnect Control

The SGM3791 integrates external PFET gate driver to control the external input high-side PFET for input disconnection. The external PFET is turned off to isolate the VBAT pin and VOUT pin unless the V_{CC_UVLO} and I2C_EN bit are logic high. During start-up sequence, the device controls a V_{SG} across the PFET to limit the start-up inrush current to charge the VOUT voltage near the VBAT voltage, and the V_{SG} is programmable via ISO_PRECHG[2:0] bits. Once the output voltage reaches the input voltage, the gate drive pulls the gate voltage to ground to fully turn on the PFET. Care should be taken when selecting external PFET, the V_{SG} rating of the selected FET should be higher than the maximal VBAT voltage. The recommended V_{SG} should be higher than the selected PFET's turn-on threshold voltage.

Due to the variation of external PFET specifications from different vendors and external PFET's turn-on threshold variation, it is recommended to add a capacitor (C_{GD}) in the range of 10nF between the gate and source of the PFET, and the capacitance value of C_{GD} can be freely adjusted to control the PFET turn-on slew rate during pre-charge.

PWM Dimming Mode

The LED sink channel's turn-on and off can be controlled via a PWM signal applied on the PWMx pins. The rising edge of the PWM signal will trigger the channel start sinking current after $t_{PWM\_LED\_ON}$. The falling edge of the PWM signal will trigger the channel stop sinking current after $t_{PWM\_LED\_OFF}$ as shown in Figure 8.

The two PWM pins control two groups of LED sink channels, where PWM1 controls sink Channel 1 to 3, and PWM2 controls sink Channel 4 to 6.

The SGM3791 integrates PWM timeout function and can be enabled via PWM_TIMEOUT_EN bit. The maximum PWM on-time is programmable via PWM_TIMEOUT[2:0] bits. When the programmed PWM on-timer expires, the sink channels are forced to turn off regardless of the PWMx signals. The device waits for the arrival of the next PWM rising edge to sink current.

Boost Operation

The SGM3791 is capable of automatically replenishing the energy of the output capacitor to ensure enough headroom voltage for the next discharge cycle (LED on-pulse). The SGM3791 switches with constant inductor current throughout the replenish phase as shown in Figure 8 below. During LED sink turn-on phase, the sink current mainly supplied by the Boost output capacitor and inductor current. And the inductor current remains constant during this LED sink turn-off phase. This constant input current regulation behavior effectively controls the inrush current drawn from the input source.

The SGM3791 adaptively adjusts the Boost's peak current level based on the LED sink's PWM frequency and sink current, the peak current is adjusted to ensure enough LEDx headroom voltage.

As Figure 8 shown, the minimal of the LEDx voltage is sensed to compare with an internal 500mV reference voltage via an error amplifier, and the error amplifier's output signal is EA output. The inductor peak current is sensed via the Boost low-side power FET, and the sensed signal is compared with the EA output. When the sensed signal of inductor peak current reaches the EA output, the Boost low-side FET is turned off to cease charging of the inductor. The Boost low-side FET turns on again when an ACFT Pseudo fixed frequency rising edge is detected. The error amplifier ensures the headroom voltage is always around 500mV to ensure proper operation.

When there is no PWM on signal to discharge the output for a long duration, the Boost's output voltage continues to rise until a programmable OVP voltage set by BOOST_OVP[2:0] bits is reached which will cease switching of the Boost to protect the device from damage.

DETAILED DESCRIPTION (continued)

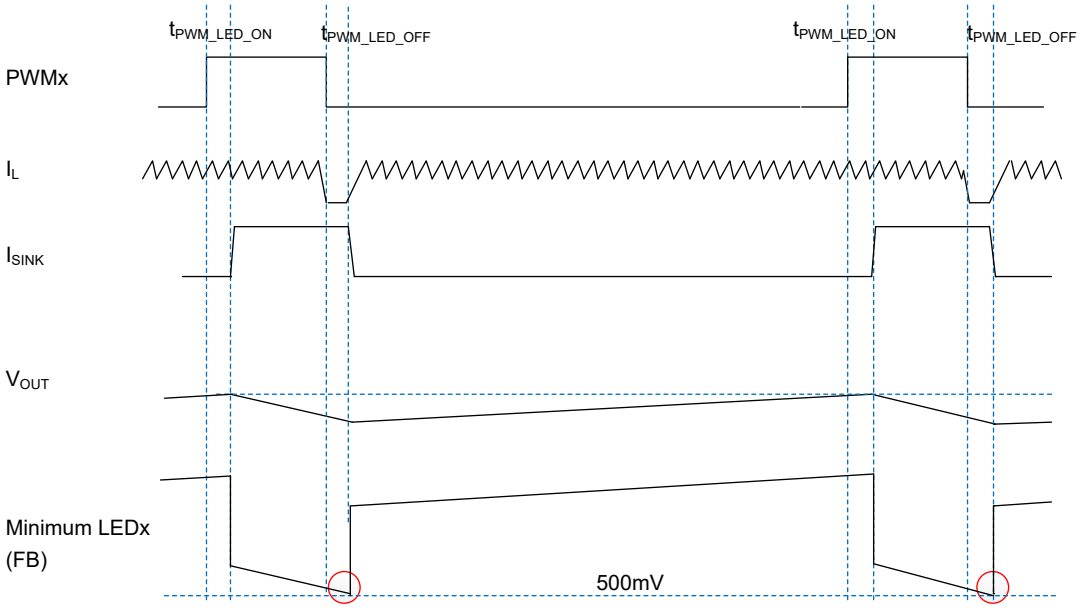


Figure 8. Steady State Adaptive Boost Operation

Boost Over-Voltage Protection

The SGM3791 integrates programmable OVP set by BOOST_OVP[2:0] bits via I^2C programming. When OVP occurs, the device will stop switching. The channel current will be remained, and it will not affect the brightness. The Boost status register (**REG0x09**) will flag this event by setting BOOST_OVP_STAT bit = 1. When the output voltage decreases by the hysteresis value, the device can start switching again and the BOOST_OVP_STAT bit will be reset to 0. .

See detail waveform in **Boost Over-Voltage Protection**.

LED Short and Open Protections

The SGM3791 integrates comprehensive protection mechanisms to handle short and open scenarios in LED strings, ensuring reliable and safe operation under various fault conditions.

An LED short-circuit condition is detected if the voltage at any LEDx pin exceeds 4V continuously for 128 PWM cycles. See detail waveform in **LED Short-Circuit Protection.**

An open-circuit condition is identified when the adaptive Boost output reaches the programmed OVP threshold, and the voltage at any LEDx pin falls below 100mV (TYP). See detail waveform in **LED OPEN Protection.**

When FAULT_SHUTDOWN bit = 0 and LED protection is triggered, the fault channel SINKx_EN bit will be reset to 0, but I2C_EN bit is remain 1, and the LED status register (**REG0x10**) will flag this event by LED_SC_FLAG bit or LED_OPEN_FLAG bit and relevant SINKx_FLAG bit.

When FAULT_SHUTDOWN bit = 1 and LED protection is triggered, the fault channel SINKx_EN bit will be reset to 0, and I2C_EN bit will be set to 0 too.

When a fault event is detected, the corresponding SINKx_EN bit will toggle to logic low and the chip stops to detect the fault channel. Three situations need to be considered:

(1) When the fault event is removed and the SINKx_EN bit is toggled to logic high by the host, the channel will resume operation.

(2) When the fault event is removed and the SINKx_EN bit remains low, the channel remains off.

(3) When the fault event is not removed and the SINKx_EN bit is toggled to logic high, the channel will operate until the fault event is detected again.

DETAILED DESCRIPTION (continued)

Boost Short-Circuit Protection

During start-up, if the output voltage (V_{OUT}) is not able to reach Boost input voltage (V_{BAT} - 1.2) after the pre-charge time of near 32ms (TYP), it is considered that the Boost output is in short-circuit condition, and the PFET's gate is directly pulled to VBAT, completely turning off the PFET. The Boost status register (**REG0x09**) will flag this event by setting BOOST_SC_STAT bit = 1. The device will operate in hiccup mode and repeatedly attempt to charge V_{OUT} to V_{BAT} - 1.2. The hiccup time is 224ms (TYP). See detail in **Boost Short-Circuit Protection.**

When the short-circuit status is removed, the device will operate in normal mode automatically and the BOOST_SC_STAT bit will be reset to 0. See detail in **Boost Short-Circuit Recovery.**

Boost Over-Current Protection

If the inductor current reaches the current limit continuously for 4ms (TYP), the OCP will be triggered and the Boost status register (**REG0x09**) will flag this event by setting OCP_FLAG bit = 1, the device will be latched and stop switching. Reset I2C_EN bit or EN to exit latched status. See detail in **Boost Latched Over-Current Protection.**

Thermal Shutdown

The SGM3791 implements the thermal shutdown feature to prevent the device from excessive thermal dissipation. When the die temperature reaches above 150℃ (TYP), the device turns off, and the Boost status register (**REG0x09**) will flag this event by setting TSD_STAT bit = 1. After the die temperature drops 20℃ (TYP) below the T_{SD} temperature, the device resumes operation with a normal start-up sequence. And the TSD_STAT bit will be reset to 0.

Light Load Operation

When the PWM duty cycle is small, it means that the average load current is small, and the EA output is reduced, thus reducing the peak inductor current. The SGM3791 will enter into DCM light load mode.

If the average load decreases further and the EA output is less than 0.56V and the minimum LEDx voltage is higher than 1V, the SGM3791 will enter into power-save mode. The peak current is fixed at the value slightly higher than I_{NTRIP} due to delay and the headroom control voltage is changed to 1V to ensure sufficient ability to adjust brightness from extremely low to high.

REGISTER MAPS

All registers are 8-bit and individual bits are named from D[0] (LSB) to D[7] (MSB).

I²C Slave Address of SGM3791: 0x28 or 0x29 (0b00101000 or 0b101001 + R/W)

ADDRESS	REGISTER NAME	D[7]	D[6]	D[5]	D[4]	D[3]	D[2]	D[1]	D[0]
0x00	ISO_PRECHARGE	Reserved		FSW[1:0]		FAULT_SHUTDOWN	ISO_PRECHG[2:0]		
0x01	VOUT_INI	Reserved	PWM_TIMEOUT_EN	PWM_TIMEOUT[2:0]			VOUT_INI[2:0]		
0x02	IPK_INI	Reserved					IPK_INI[2:0]		
0x03	I_SINK1_1	Reserved						I_SINK1[1:0]	
0x04	I_SINK1_2	I_SINK1[9:2]							
0x05	I_SINK2_1	Reserved						I_SINK2[1:0]	
0x06	I_SINK2_2	I_SINK2[9:2]							
0x07	EN_SINK	Reserved		SINK6_EN	SINK5_EN	SINK4_EN	SINK3_EN	SINK2_EN	SINK1_EN
0x08	MODE	DRV_SPEED	I2C_EN	RCOMP[2:0]			LOOPSPEED[2:0]		
0x09	BOOST_STATUS	BATTERY	OCP_FLAG	BOOST_OVP_STAT	BOOST_SC_STAT	TSD_STAT	BOOST_OVP[2:0]		
0x10	LED_STATUS	LED_SC_FLAG	LED_OPEN_FLAG	LED6_FLAG	LED5_FLAG	LED4_FLAG	LED3_FLAG	LED2_FLAG	LED1_FLAG

Bit Types:
R: Read only
R/W: Read/Write

REGISTER MAPS (continued)

REG0x00: Isolation Gate Drive Pre-Charge Register [Reset = 0x2B]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:6]	Reserved	00	R/W	Reserved
D[5:4]	FSW[1:0]	10	R/W	Switching Frequency Adjustment 00 = pseudo 200kHz 01 = pseudo 500kHz 10 = pseudo 800kHz (default) 11 = pseudo 1.1MHz
D[3]	FAULT_SHUTDOWN	1	R/W	LED_FLAG whether to turn DEV_EN low 0 = No 1 = Yes (default)
D[2:0]	ISO_PRECHG[2:0]	011	R/W	Isolation Gate Drive Adjustment 000 = 600mV V_{SG} 001 = 780mV V_{SG} 010 = 0.96V V_{SG} 011 = 1.14V V_{SG} (default) 100 = 1.32V V_{SG} 101 = 1.5V V_{SG} 110 = 1.68V V_{SG} 111 = 1.86V V_{SG}

REG0x01: Initial Output Voltage Register [Reset = 0x5E]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	Reserved	0	R/W	Reserved
D[6]	PWM_TIMEOUT_EN	1	R/W	PWM Time Out Enable 0 = Disable 1 = Enable (default)
D[5:3]	PWM_TIMEOUT[2:0]	011	R/W	PWM Time Out Setting (Numbers of 500kHz internal digital clock) 000 = 700 001 = 900 010 = 1100 011 = 1300(default) 100 = 1500 101 = 1700 110 = 1900 111 = 2100
D[2:0]	VOUT_INI[2:0]	110	R/W	Initial Output Voltage Adjustment 000 = 11V 001 = 14V 010 = 17V 011 = 20V 100 = 22V 101 = 24V 110 = 26V (default) 111 = 28V

REG0x02: Initial Peak Inductor Current Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:3]	Reserved	00000	R/W	Reserved
D[2:0]	IPK_INI[2:0]	000	R/W	Initial Peak Inductor Current Adjustment 000 = 1.4A (default) 001 = 1.55A 010 = 1.7A 011 = 1.85A 100 = 2A 101 = 2.15A 110 = 2.3A 111 = 2.45A

REGISTER MAPS (continued)

REG0x03: Group 1 Sink Current 1 Register [Reset = 0x02]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:2]	Reserved	000000	R/W	Reserved
D[1:0]	I_SINK1[1:0]	10	R/W	Higher 2 Bits of Sink Channel 1 to 3 Sink Current Adjustment 00 01 10 (default) 11

REG0x04: Group 1 Sink Current 2 Register [Reset = 0xBC]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:0]	I_SINK1[9:2]	1011 1100	R/W	Low Byte of Sink Channel 1 to 3 Sink Current Adjustment (00)0000000 = 0mA (00)00000001 = 0.1mA ……=…… (00)11001101 = 20mA ……=…… (10)10111100 = 70mA (default) ……=…… (11)11101000 = 100mA

REG0x05: Group 2 Sink Current 1 Register [Reset = 0x02]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:2]	Reserved	000000	R/W	Reserved
D[1:0]	I_SINK2[1:0]	10	R/W	Higher 2 Bits of Sink Channel 4 to 6 Sink Current Adjustment 00 01 10 (default) 11

REG0x06: Group 2 Sink Current 2 Register [Reset = 0xBC]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:0]	I_SINK2[9:2]	1011 1100	R/W	Low Byte of Sink Channel 4 to 6 Sink Current Adjustment (00)0000000 = 0mA (00)00000001 = 0.1mA ……=…… (00)11001101 = 20mA ……=…… (10)10111100 = 70mA (default) ……=…… (11)11101000 = 100mA

REGISTER MAPS (continued)

REG0x07: Sink Channel Enable Control Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7:6]	Reserved	00	R/W	Reserved
D[5]	SINK6_EN	0	R/W	Sink Channel 6 Enable 0 = Disable (default) 1 = Enable
D[4]	SINK5_EN	0	R/W	Sink Channel 5 Enable 0 = Disable (default) 1 = Enable
D[3]	SINK4_EN	0	R/W	Sink Channel 4 Enable 0 = Disable (default) 1 = Enable
D[2]	SINK3_EN	0	R/W	Sink Channel 3 Enable 0 = Disable (default) 1 = Enable
D[1]	SINK2_EN	0	R/W	Sink Channel 2 Enable 0 = Disable (default) 1 = Enable
D[0]	SINK1_EN	0	R/W	Sink Channel 1 Enable 0 = Disable (default) 1 = Enable

REG0x08: Mode Control Register [Reset = 0x13]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	DRV_SPEED	0	R/W	Driver Speed 0 = slow (default) 1 = fast For V_{CC} ≤ 3.3V, it is recommended to set this bit to 1.
D[6]	I2C_EN	0	R/W	Device Enable 0 = Disable (default) 1 = Enable
D[5:3]	RCOMP[2:0]	010	R/W	COMP Resistor Adjustment 000 = 13kΩ 001 = 19kΩ 010 = 28kΩ (default) 011 = 40kΩ 100 = 6.5kΩ 101 = 9.5kΩ 110 = 14kΩ 111 = 20kΩ
D[2:0]	LOOPSPEED[2:0]	011	R/W	Loop Speed Adjustment (gm of EA) 000 = 76μS 001 = 153μS 010 = 229μS 011 = 306μS (default) 100 = 382μS 101 = 458μS 110 = 535μS 111 = 595μS

REGISTER MAPS (continued)

REG0x09: Boost Status Register [Reset = 0x06]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	BATTERY	0	R/W	VIN_UVLO Threshold 0 = LDO is enabled (default) 1 = External VCC
D[6]	OCP_FLAG	0	R	Boost OCP Status 0 = No OCP (default) 1 = Boost OCP
D[5]	BOOST_OVP_STAT	0	R	Boost OVP Status 0 = No OVP (default) 1 = Boost OVP
D[4]	BOOST_SC_STAT	0	R	Short-Circuit Status 0 = No SCP (default) 1 = Boost SCP
D[3]	TSD_STAT	0	R	Thermal Shutdown Fault Status 0 = No TSD (default) 1 = TSD Fault
D[2:0]	BOOST_OVP[2:0]	110	R/W	Boost OVP 000 = 15.5V 001 = 18.5V 010 = 21.5V 011 = 23.5V 100 = 25.5V 101 = 27.5V 110 = 29.5V (default) 111 = 31.3V

REG0x10: LED Status Register [Reset = 0x00]

BITS	BIT NAME	DEFAULT	TYPE	DESCRIPTION
D[7]	LED_SC_FLAG	0	R	LED Short 0 = No Short (default) 1 = LED Short
D[6]	LED_OPEN_FLAG	0	R	LED Open 0 = No Open (default) 1 = LED Open
D[5]	LED6_FLAG	0	R	LED6 Status 0 = No Fault (default) 1 = Fault
D[4]	LED5_FLAG	0	R	LED5 Status 0 = No Fault (default) 1 = Fault
D[3]	LED4_FLAG	0	R	LED4 Status 0 = No Fault (default) 1 = Fault
D[2]	LED3_FLAG	0	R	LED3 Status 0 = No Fault (default) 1 = Fault
D[1]	LED2_FLAG	0	R	LED2 Status 0 = No Fault (default) 1 = Fault
D[0]	LED1_FLAG	0	R	LED1 Status 0 = No Fault (default) 1 = Fault

APPLICATION INFORMATION

Typical Application

Figure 9 below shows a typical schematic.

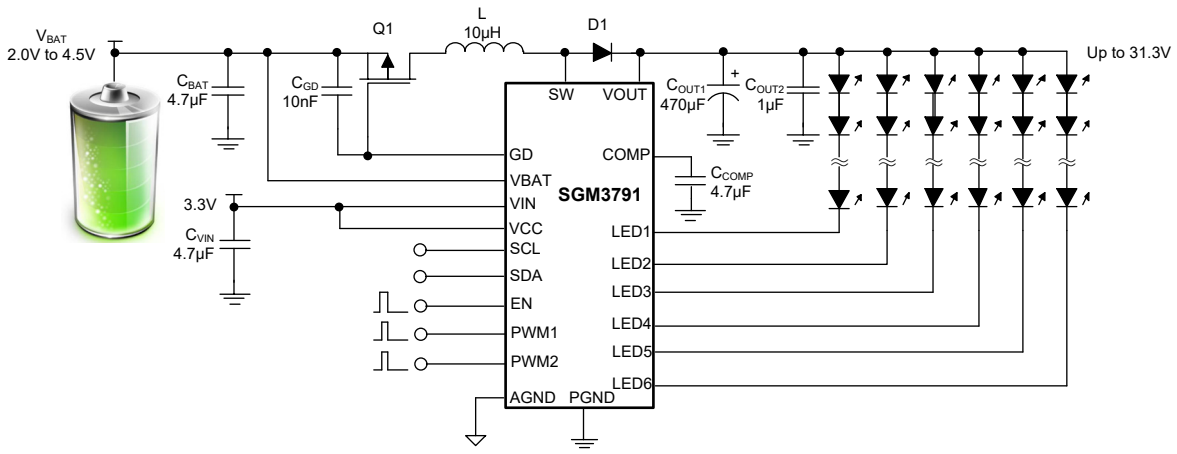


Figure 9. Typical Application

Inductor Selection

Inductance is an important power device for Boost converter design. Selecting appropriate inductor parameters can ensure that the system has high efficiency and stable steady-state performance. At the same time, it will also affect the system transient response and loop stability. Inductor's DC resistance, saturation current and inductance are important specifications for DC/DC design.

The saturation current value of inductor will affect the operation of Boost converter. When the inductor current is close to or higher than the saturation current, the inductance will drop rapidly, which causes the peak inductor current to rise and reach the peak current limit of the IC. The selected inductor's saturation current should maintain a 20% margin.

Table 1 below provides some common inductance recommendations for different switching frequency with different VBAT voltage, where the number of series connections for the SGM3791 LEDs is 6 to 8.

Table 1. Recommended Inductor for Different Combination of VBAT and FSW[2:0] Bits

V_{BAT} Configuration	FSW[1:0] Bits Setting	Recommended Inductor
Dual-Cell Li-Ion	00 or 01 or 10 or 11	10μH
Single Cell Li-Ion	00 or 01	10μH
Single Cell Li-Ion	10 or 11	4.7μH

Output Capacitor Selection

The proprietary architecture of the SGM3791 does not place stringent requirement on output capacitor selection compared with traditional DC/DC converters. The output capacitor mainly serves as the energy storage element for the pulsating LED sink current. For short LED sink-on duration, the voltage drop is mainly determined by the amount of output capacitance, larger capacitance results in smaller voltage drop. Smaller output capacitance results in larger voltage drop for the same amount of on-pulse duration, which also results in longer replenish time. To ensure sufficient headroom, the output capacitance should be designed accordingly based on the peak current of 2.45A (TYP) capability of the Boost DC/DC. A 470μF electrolytic capacitor is recommended for the SGM3791 to cover up to 2.5ms on-pulse duration and up to 100mA sinking current per channel. In addition, a 4.7μF ceramic capacitor is recommended to place at the output of the SGM3791.

Input Capacitor Selection

A minimal of 1μF ceramic capacitor on the VIN pin is recommended, a 47μF or higher electrolytic capacitor is recommended if the input of SGM3791 is far away from the power supply.

V_{CC} Capacitor Selection

V_{CC} capacitor requires an effective capacitance value of at least 1μF to ensure stability, and it is recommended to use 4.7μF ceramic capacitors.

APPLICATION INFORMATION (continued)

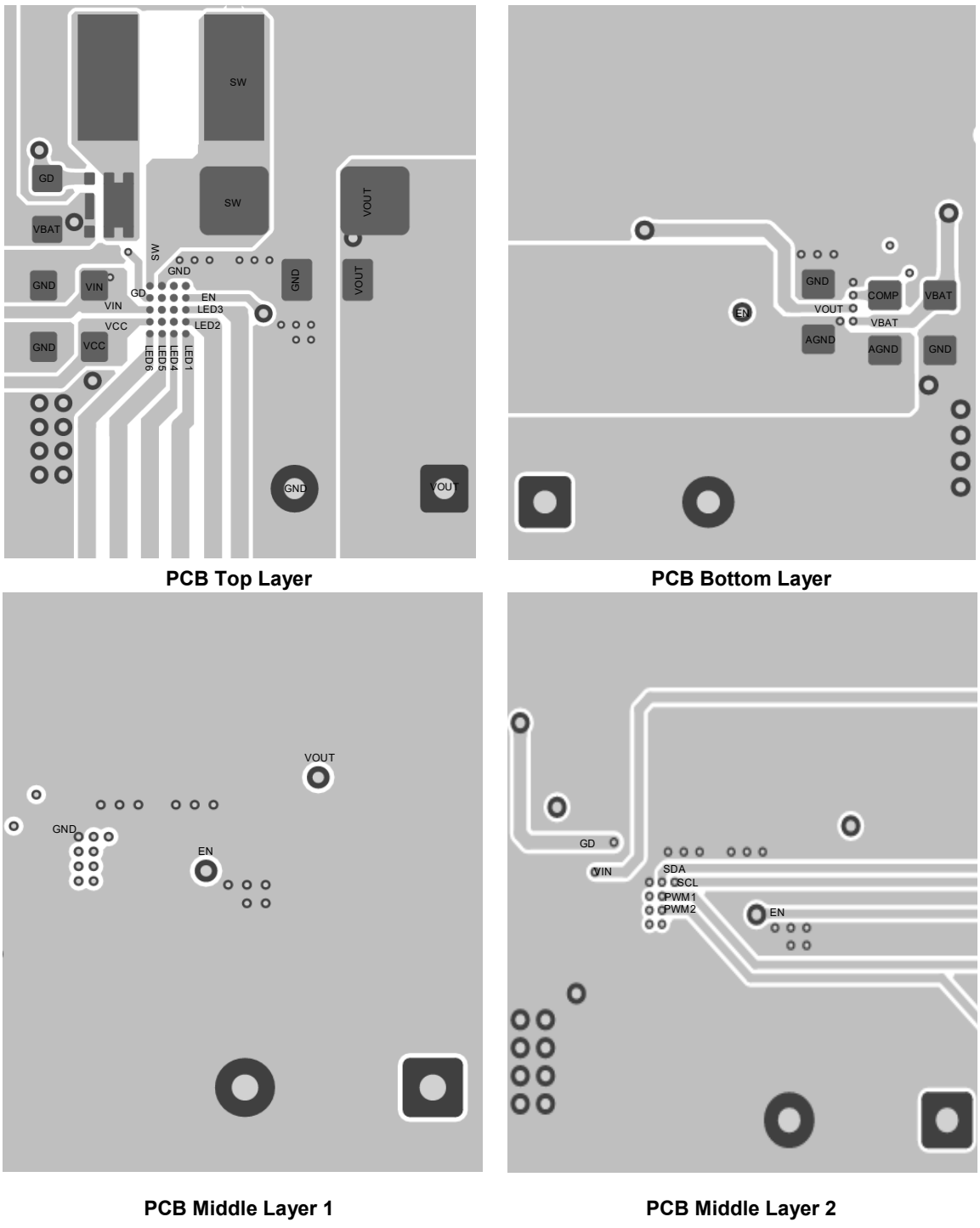
COMP Capacitor Selection

The COMP capacitor and internal register controlled resistance form a zero to adjust the loop bandwidth and phase margin. The internal resistance is adjusted through RCOMP[2:0] bits. The following table shows the recommended combination of resistor and capacitor.

Table 2. Recommended Combination of Resistor and Capacitor

C_{OUT} (μF)	C_{COMP} (μF)	R_{COMP} (kΩ)
470	3.3	40
470	4.7	28
470	6.8	19
470	10	13
220	3.3	20
220	4.7	14
220	6.8	9.5
220	10	6.5

LAYOUT GUIDELINES



PCB Top Layer **PCB Bottom Layer**

PCB Middle Layer 1 **PCB Middle Layer 2**

Figure 10. PCB Layout Example

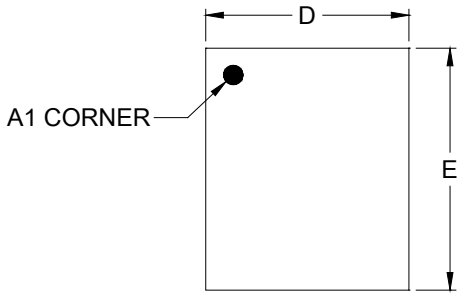
REVISION HISTORY

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

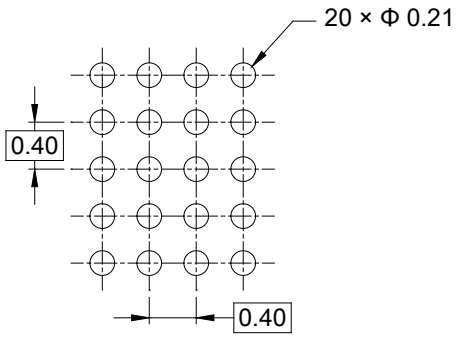
Changes from Original (DECEMBER 2024) to REV.A	**Page**
Changed from product preview to production data	All

PACKAGE OUTLINE DIMENSIONS

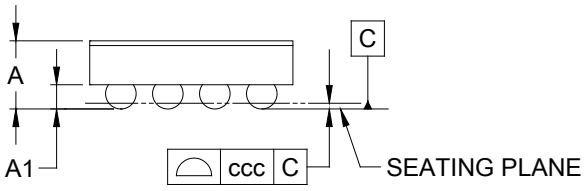
WLCSP-1.73×2.06-20B



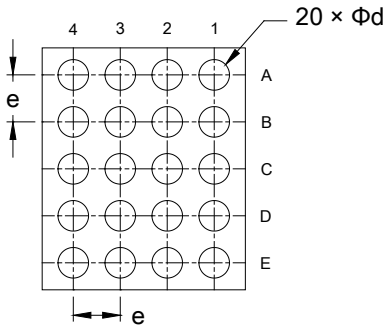
TOP VIEW



RECOMMENDED LAND PATTERN (Unit: mm)



SIDE VIEW



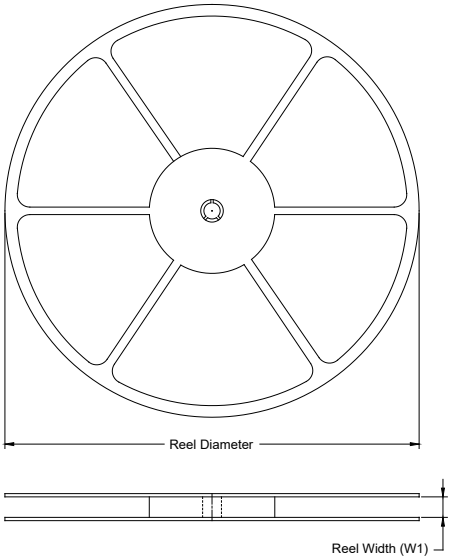
BOTTOM VIEW

Symbol	Dimensions In Millimeters		
	MIN	NOM	MAX
A	-	-	0.618
A1	0.186	-	0.226
D	1.700	-	1.760
E	2.030	-	2.090
d	0.230	-	0.290
e	0.400 BSC		
ccc	0.050		

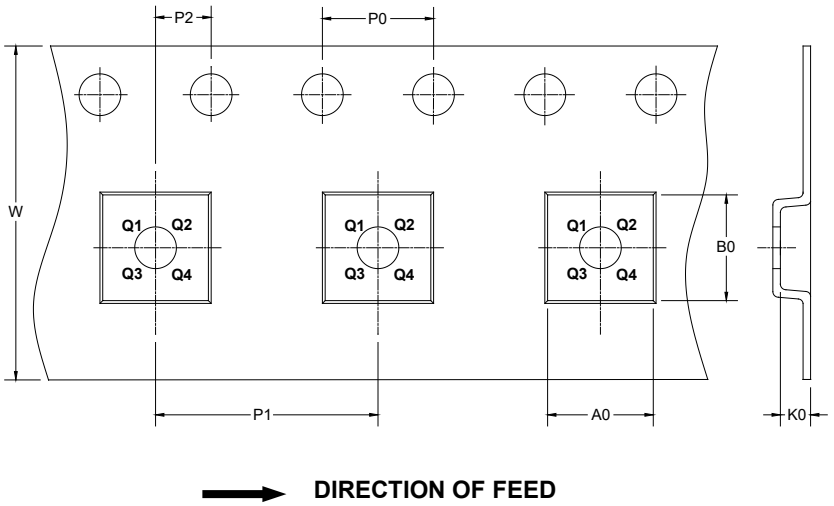
NOTE: This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

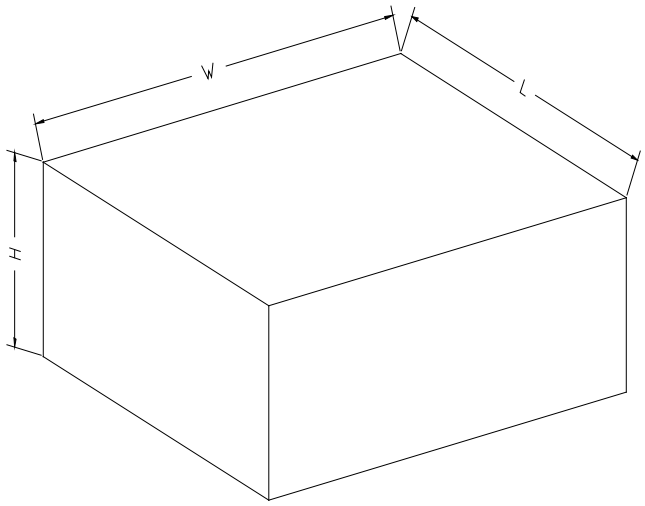
NOTE: The picture is only for reference. Please make the object as the standard.

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
WLCSP-1.73×2.06-20B	7"	9.5	1.87	2.31	0.74	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