MP3331

2A, Synchronous Boost Flash LED Driver with I²C Interface

The Future of Analog IC Technology

DESCRIPTION

The MP3331 is a highly-efficient, 2A, single flash LED driver in a very compact package for high-resolution camera phones that improves image and video quality in low-light environments. The device operates in a 1/2/3/4MHz synchronous DC/DC boost converter to provide an optimized solution for smaller PCB spaces with higher efficiency.

The MP3331 features a standard I²C interface, single LED channel, rich protection modes, and high power density and performances. It supports flash/assist/torch/indicator/5V DC modes.

The cathode of the flash LED is referenced to GND, which improves thermal performance. It is available in a WLCSP9-1.7mm x 1.7mm package.

FEATURES

- 2.7V to 5.5V Input Voltage
- 1/2/3/4MHz Selectable Switching Frequency
- Switching Frequency Foldback Function
- 400kHz I²C Compatible Interface
- Standby/Flash/Assist/Torch/Indicator/5V DC Mode

FLASH MODE:

- Up to 2A Programmable Current with +/-7% Accuracy

ASSIST/TORCH MODE:

- Up to 508mA Programmable Current with +/-7% Accuracy

INDICATOR MODE:

- Works in 31.5kHz PWM Dimming Mode with 2/16, 3/16, 4/16, 5/16 Duty Cycle

5V DC MODE:

- Fixed 5V Output Voltage
- External Torch/Strobe Pin
- Low-Battery Voltage Protection
- Pre-Flash for Auto Detect Load Condition
- LED Short/Open Protection
- VOUT-GND Short Protection
- Over-Voltage Protection
- Over-Temperature Protection
- Input Under-Voltage Lockout Protection
- Thermal Protection
- Input to Output Disconnection Function
- Available in a WLCSP9-1.7mm x 1.7mm Package

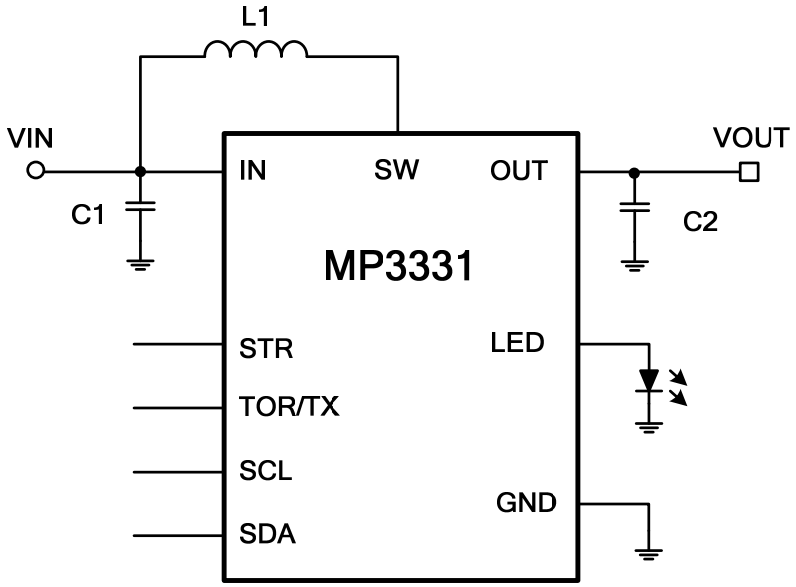
APPLICATIONS

- Camera Phone LED Flash
- Tablets
- Digital Still Camera

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TYPICAL APPLICATION



Typical Application Circuit

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ORDERING INFORMATION

Part Number*	Package	Top Marking
MP3331GC	WLCSP-9 (1.7mm x 1.7mm)	*See Below*

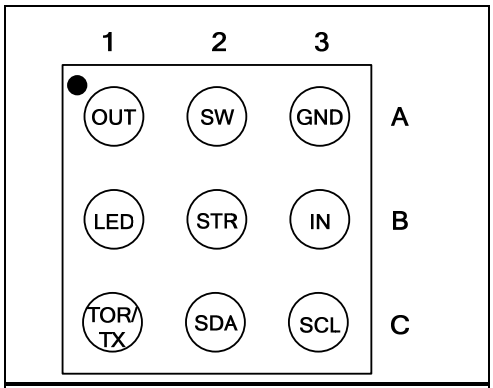
***** For Tape & Reel, add suffix –Z (e.g. MP3331GC)

TOP MARKING

CMY
LLL

CM: Product code of MP3331GC
Y: Year code
LLL: Lot number

PACKAGE REFERENCE



WLCSP-9 (1.7mm x 1.7mm)

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ABSOLUTE MAXIMUM RATINGS (1)

All the pins.....-0.3V to +6V
Junction temperature ..... 150°C
Lead temperature..... 260°C
Continuous power dissipation (T_A = 25°C) **(2)**
WLCSP-9 (1.7mm x 1.7mm) 1.14W

Recommended Operating Conditions (3)

Supply voltage (V_{IN}) ..... 2.7V to 5.5V
Operating junction temp.....-40°C to +125°C

Thermal Resistance (4) θ_{JA} θ_{JC}

WLCSP-9 (1.7mm x 1.7mm)….110….0.5..°C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation will produce an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

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ELECTRICAL CHARACTERISTICS

V_{IN} = 3.6V, T_A = 25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply						
Operating input voltage	V_{IN}		2.7		5.5	V
Input UVLO threshold	V_{IN_UVLO}	Rising edge		2.5		V
Input UVLO hysteresis				150		mV
Standby current	$I_{Q_STANDBY}$	V_{IN} = 2.7V to 5.5V, I²C active			10	µA
Operating quiescent current	I_Q	V_{IN} = 3.6V, No switching, pass mode		0.95		mA
Switching Regulator						
Switching frequency	fs	Fs = 4MHz	3.6	4	4.4	MHz
Minimum on time	t_{ON_MIN}			50		ns
NMOS on resistance	R_{DSON_N}	V_{IN} = 3.6V		80		mΩ
PMOS on resistance	R_{DSON_P}	V_{IN} = 3.6V		120		mΩ
Constant DC output voltage	V_{OUT_5V}	5V DC mode		5		V
Inductor current limit	I_{LIMIT}	Code setting = 00, max duty cycle(5)		1.9		A
		Code setting = 11, max duty cycle(5)		4.2		A
LED Driver						
Flash current setting	I_{LED_FLASH}	Flash mode, value setting = 000000		0		mA
		Flash mode, value setting = 001010	295	317	339	mA
Torch current setting	I_{LED_TORCH}	Assist light/torch mode, value setting = 000000		0		mA
		Assist light /torch mode, value setting = 001010	295	317	339	mA
Current source headroom voltage	V_{HD}	Current = 200mA		150		mV
		Current = 1500mA(5)		250		mV
Current ramp-up step time	t_{RAMP_UP}	TUP_I = 000		8		µs
Current ramp-down step time	t_{RAMP_DOWN}			2		µs
Flash to TX current settling time	t_{SETTLE}	TX from low to high, ILED from 1500mA to 31.7mA			5	µs
Digital Input						
Input logic-low voltage					0.4	V
Input logic-high Voltage			1.2			V

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ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 3.6V, T_A = 25°C, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Strobe/Torch/TX pull-down resistor				250		kΩ
Protection						
Time-out time	$t_{TIMEOUT}$	Time setting code = 0011	190	200	210	ms
Over-voltage threshold	V_{OVP}		5.2	5.5	5.8	V
LED short detection voltage	V_{LED_ST}			1		V
V_{OUT} short blanking time	T_{OUT_ST}	VOUT<VIN-1V and when enable bit is on.		5		ms
LED open detection voltage	V_{LED_OP}			90		mV
Thermal shutdown threshold(5)	T_{j_SD}			150		℃
Adaptive thermal threshold(5)				130		℃
Low-battery threshold	V_{BAT_LOW}	Code Setting = 000		3.0		V
		Code Setting =110		3.6		V
I²C Interface						
Input logic low	V_{IL}		0		0.4	V
Input logic high	V_{IH}		1.3V			V
Output logic low	V_{OL}	I_{LOAD} = 3mA			0.4	V
SCL clock frequency	F_{SCL}				400	kHz
SCL high time	T_{HIGH}		0.6			µs
SCL low time	T_{LOW}		1.3			µs
Data setup time	$T_{SU,DAT}$		100			ns
Data hold time	$T_{HD,DAT}$		0		0.9	µs
Setup time for repeated start	$T_{SU,STA}$		0.6			µs
Hold time for start	$T_{HD,STA}$		0.6			µs
Bus free time between a start and a stop condition	T_{BUF}		1.3			µs
Setup time for stop condition	$T_{SU,STO}$		0.6			µs
Rise time of SCL and SDA	T_R		20+0.1*C_B		300	ns
Fall time of SCL and SDA	T_F		20+0.1*C_B		300	ns
Pulse width of suppressed spike	T_{SP}		0		50	ns
Capacitance bus for each bus line	C_B				400	pF

NOTES:

5) Guaranteed by design.

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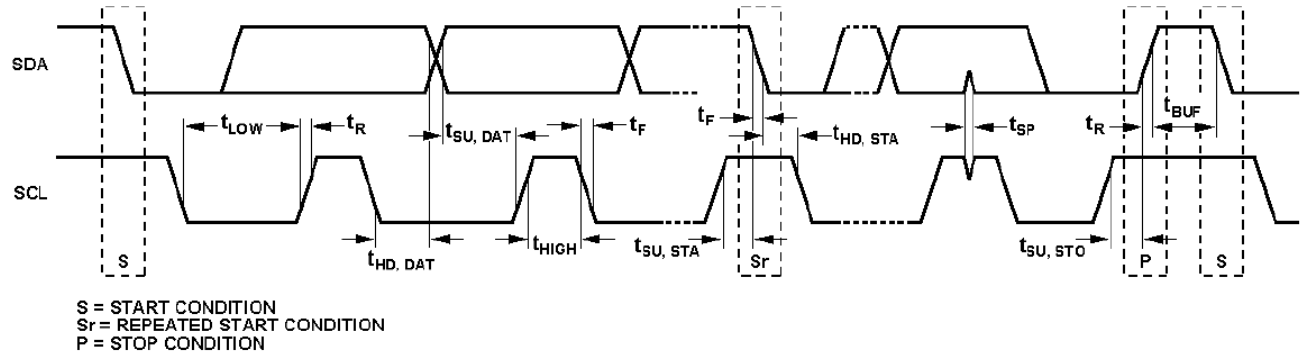


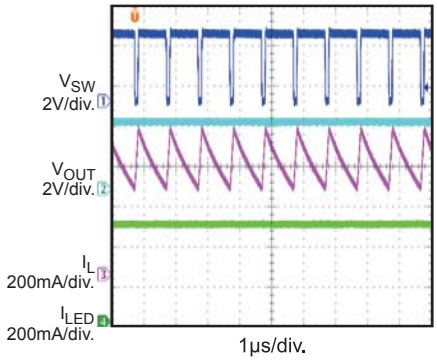
Figure 1: I²C Compatible Interface Timing Diagram

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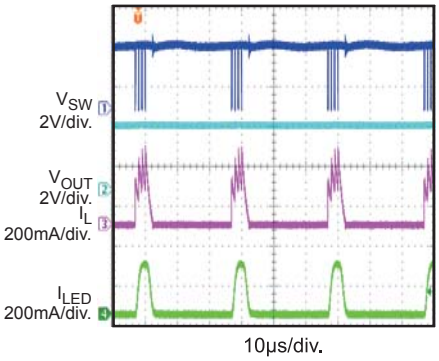
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 3.3V, 1LED, FL_TIM = 100ms, L = 1µH, T_A = 25°C, unless otherwise noted.

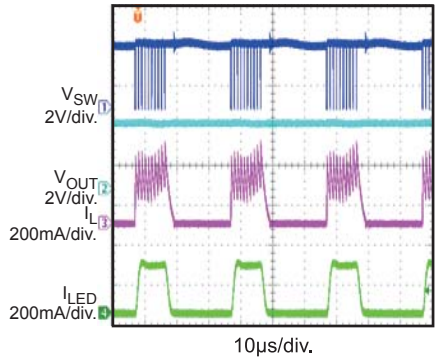
Torch/Assist Mode
I_{LED} = 500mA



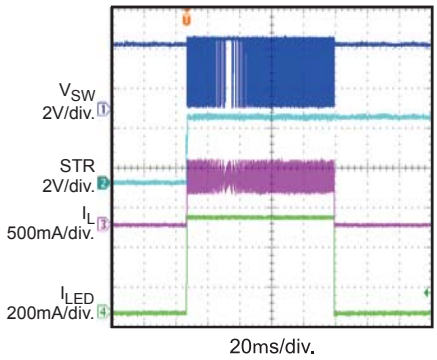
Indicator Mode
Duty=2/16



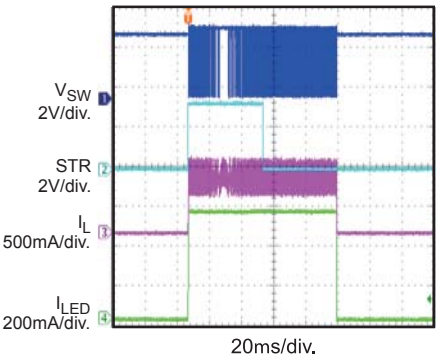
Indicator Mode
Duty=5/16



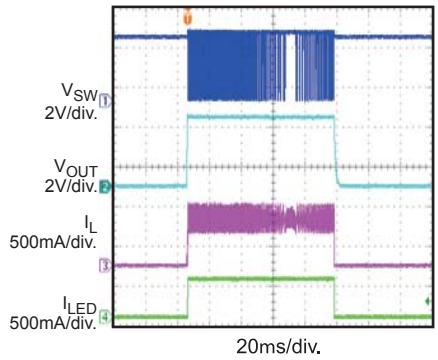
Flash Mode
Hardware and Level Sensitive Mode



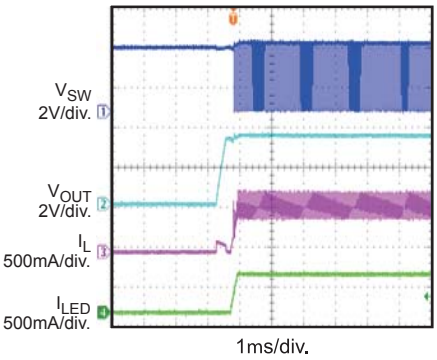
Flash Mode
Hardware and Edge Sensitive Mode



Flash Mode
Software and Edge Sensitive Mode



LED Enable

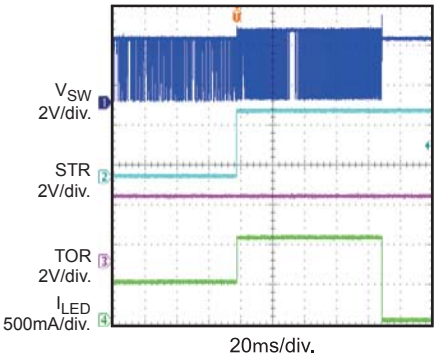


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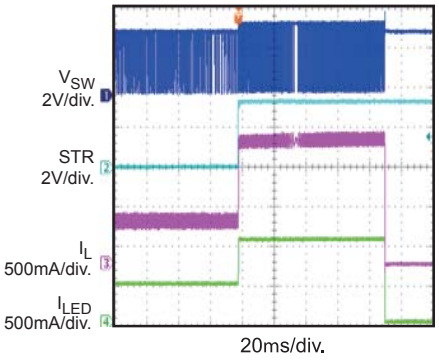
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 3.3V, 1LED, FL_TIM = 100ms, L = 1μH, T_A = 25°C, unless otherwise noted.

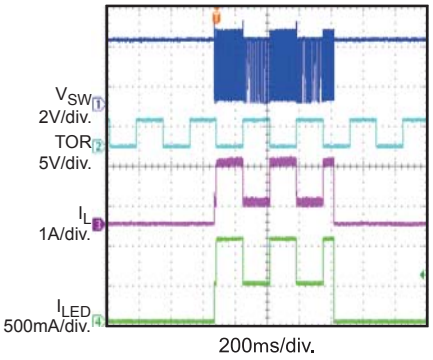
Torch to Flash Mode
I_{TOR}=500mA, I_{FL}=1A



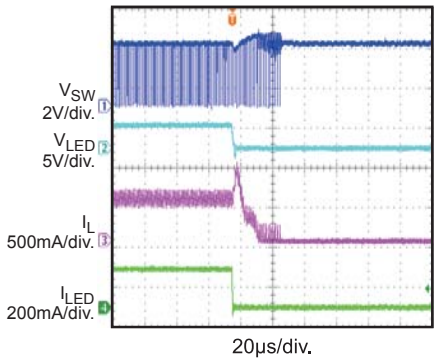
Assist to Flash Mode
I_{TOR}=500mA, I_{FL}=1A



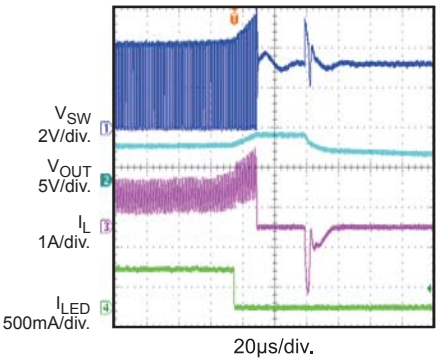
Flash Mode
TX Pin with 3Hz PWM Input



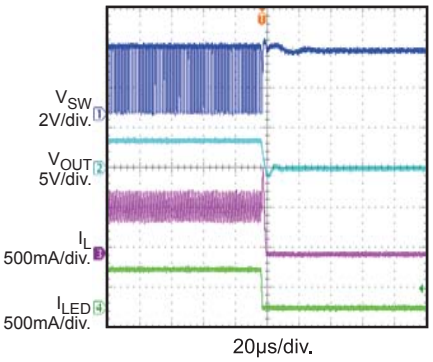
LED-GND Short Protection



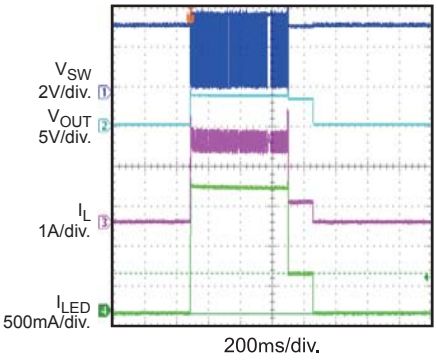
LED Open Protection



V_{OUT}-GND Pin Short Protection



Junction Over-Temperature Protection
In Flash Mode, T_J>130□C



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PIN FUNCTIONS

Pin #	Name	Description
A1	OUT	**Boost converter output.**
A2	SW	**Boost converter switching node.**
A3	GND	**Ground.**
B1	LED	**Current source for LED.** Connect the anode of LED to LED.
B2	STR	**Strobe signal input** STR synchronizes the flash pulse to the image capture. If STR is floated, internally pull STR to low weakly.
B3	IN	**Input supply.** IN provides the power for the internal power and logic circuit. IN must be bypassed locally.
C1	TOR/TX	**Torch signal input or synchronization input signal for RF transmission signal.** If TOR/TX is floated, internally pull TOR/TX to low weakly.
C2	SDA	**I²C interface clock data input.**
C3	SCL	**I²C interface clock signal.**

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FUNCTIONAL BLOCK DIAGRAM

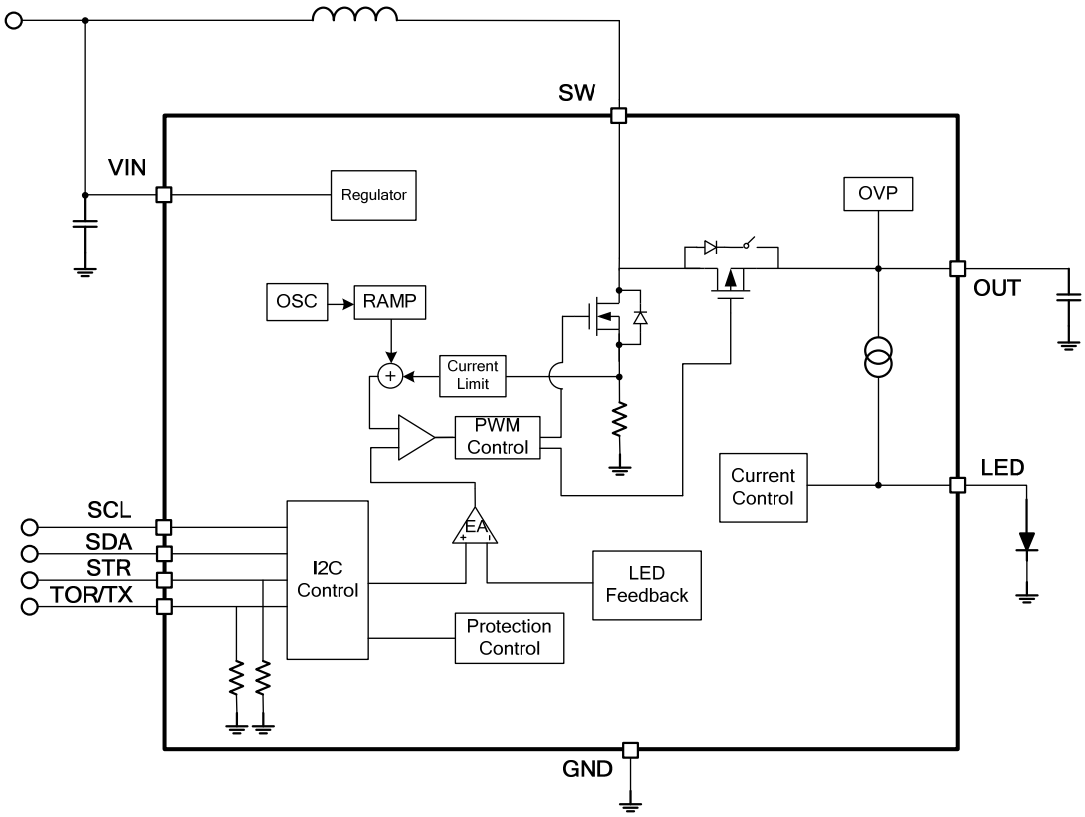


Figure 2: MP3331 Functional Block Diagram

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OPERATION

The MP3331 is a single-channel flash LED driver with an I²C interface for a camera flash that supports good image capture. It works in flash mode, assist mode, torch mode, indicator mode, and fixed 5V DC output mode.

LED Driver Operation

The MP3331 uses PWM mode with peak current control to regulate the LED current. It works in a selectable 1M/2M/3M/4MHz switching frequency with a synchronous rectifier PMOS. When enabled, the synchronous PMOS works as a 350mA current source to charge the output capacitor until V_{OUT} rises above the 2.3V. The device will change to boost switching mode if the voltage across the current source is less than the target reference. If V_{IN} is very close to V_{OUT}, the IC works in boost switching mode and pass mode automatically to minimize the power loss. In pass mode, the synchronous PMOS is turned on completely. During the current start-up, the current ramps up smoothly step by step until the target setting current is reached.

Table 1: Mode Configuration

Configuration						Mode
TX/TOR	STR	LED_EN	STR_MOD	5V_MOD	LED_MOD	
High	X	1	0	X	00	Torch
X	X	1	X	X	10	Assist light
X	X	1	X	X	01	Indicator
X	High	1	1	X	11	Flash
X	X	1	0	X	11	Flash
High	High	1	1	X	00	Torch to flash
X	High	1	1	X	10	Assist to flash
X	X	X	X	1	X	5V

Standby Mode

In default, if V_{IN} is higher than UVLO, the device changes to standby mode. The I²C is active and is ready to communicate with the host. Table 1 shows all work modes for MP3331.

Torch Mode

In standby mode, if TOR goes from low to high (TX/TOR = 1), the device switches to torch mode, and the current ramps up step by step after setting LED_EN to 1. The current for LED is set through register I_TOR. The ramping up slew rate is set by register TUP_I. The current is disabled by pulling TOR to low or by setting LED_EN bits to 0. By pulling TOR to low, LED_EN and LED_MOD bits will reset automatically to default if LED_SD is 0 (see Figure 3).

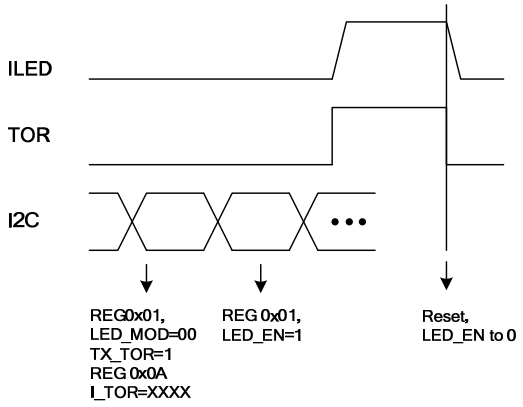


Figure 3: Torch Mode

Assist Mode

To enter assist mode, set LED_MOD register to 10 and LED_EN to 1. The current ramps up to the target value, which is set by I_TOR. The ramping up slew rate is set by register TUP_I. The current is disabled by switching to standby mode or by setting LED_EN bits to 0 (see Figure 4).

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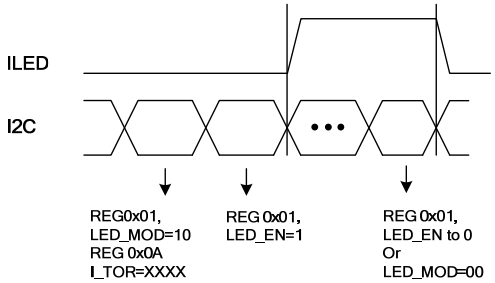


Figure 4: Assist Mode

Indicator Mode

The device enters indicator mode, which provides a low current output when LED_MOD is set to 01, and LED_EN is set to 1. In this mode, the driver current sources the output current in 31.5kHz PWM mode. The current amplitude is set by I_TOR while the duty cycle is set by the INDI_PWM register. When disabled, switch to standby mode or set LED _EN bits to 0 (see Figure 5).

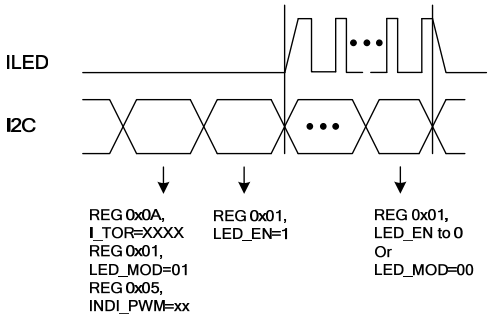


Figure 5: Indicator Mode

Flash Mode

The device works in flash mode in the following ways:

1. **Hardware and level sensitive mode**.

In this mode, STR_MOD = 1, STR_LV = 1, LED_EN = 1, and LED_MOD = 11. The flash current starts ramping up after STR goes high. The current is set by I_FL, and the ramping up time is set by TUP_I. The flash current ends when STR is pulled to low. If LED_SD = 0, the LED_MOD is reset to standby mode, and LED_EN is set to 0 after the flash. If LED_SD = 1, the LED_MOD, and LED_EN are not reset. If the flash timer set by FL_TIM ends before STR goes low, the flash current terminates immediately. LED_MOD and LED_EN are reset to the default value, and the time-out fault bit FT_TO is set to 1 and is not cleared until read back or input power reset (see Figure 6).

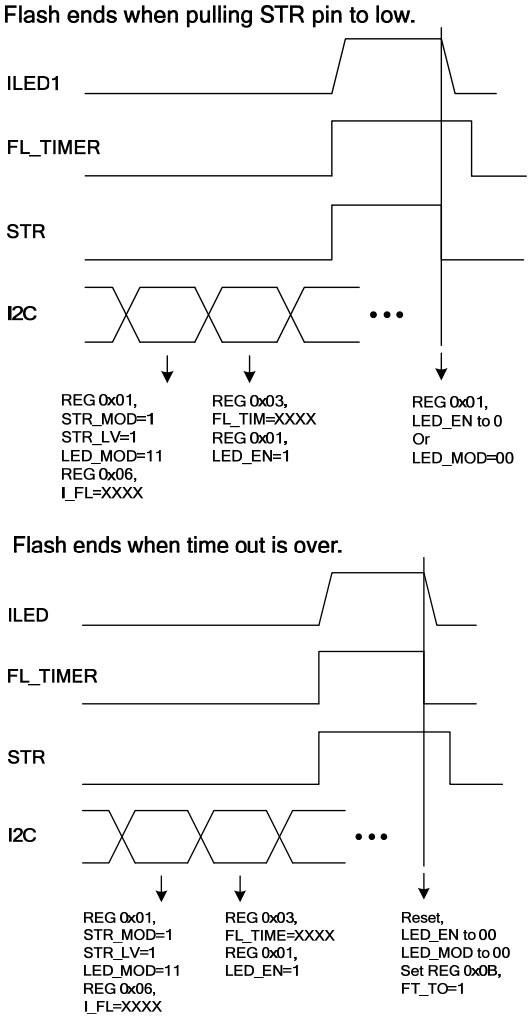


Figure 6: Hardware and Level Sensitive Mode

2. **Hardware and edge sensitive mode**.

In this mode, STR_MOD = 1, STR_LV = 0, LED_EN = 1, and LED_MOD = 11. The flash current starts ramping up after STR goes high. The current is set by I_FL, and the ramping up time is set by TUP_I. The flash current ends when the flash timer set by FL_TIM ends. If LED_SD = 0, the LED_MOD is reset to standby mode, and LED_EN is set to 0 after the flash. If LED_SD = 1, the LED_MOD, and LED_EN are not reset (see Figure 7).

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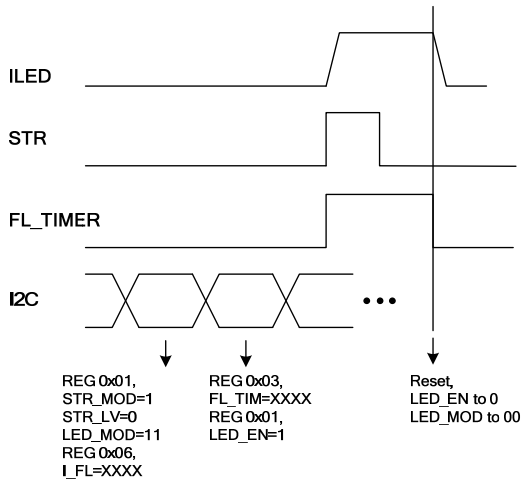


Figure 7: Hardware and Edge Sensitive Mode

3. Software and edge sensitive mode

In this mode, STR_MOD = 0, LED_EN = 1, and LED_MOD = 11. The current is set by I_FL, and the ramping up time is set by TUP_I. The flash current ends when the flash timer set by FL_TIM ends. If LED_SD = 0, the LED_MOD is reset to standby mode, and LED_EN is set to 0 after the flash. If LED_SD = 1, the LED_MOD, and LED_EN are not reset (see Figure 8).

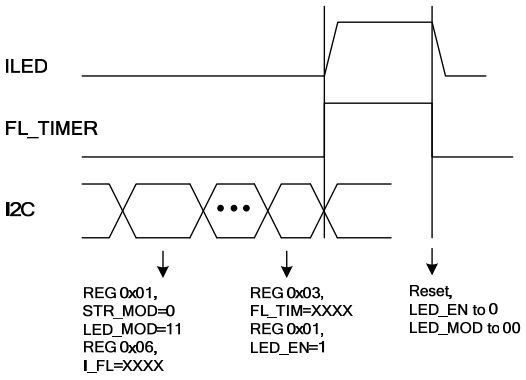


Figure 8: Software and Edge Sensitive Mode

Torch Mode to Flash Mode

During torch mode, the device can change to flash mode from torch mode directly when STR goes from low to high (if STR_MOD = 1). After the flash, the operation is the same as described in the “Flash Mode” section (see Figure 9).

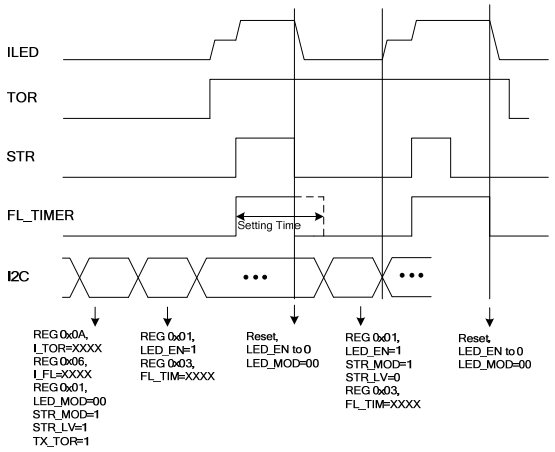


Figure 9: Torch Mode to Flash Mode

Assist Mode to Flash Mode

During assist-light mode, the device can change to flash mode from assist-light mode directly when STR goes from low to high (if STR_MOD = 1). After the flash, the operation is the same as described in the “Flash Mode” section (see Figure 10).

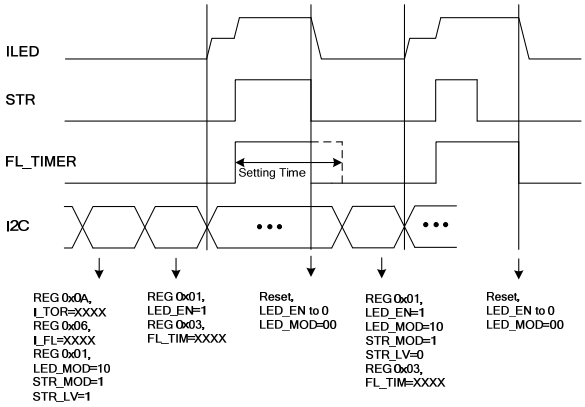


Figure 10: Assist Mode to Flash Mode

5V DC Output Mode

If 5V_MOD is set to 1, the device works in a fixed 5V DC output mode, and the control loop is taken over by the voltage loop. Note that the LED current sources can still output current if the mode conditions are met (as described above). Care must be taken to ensure thermal temperatures are ok because the 5V powers the LED directly. To avoid this, it is recommended to set LED_EN to 0 during the 5V DC mode (see Figure 11).

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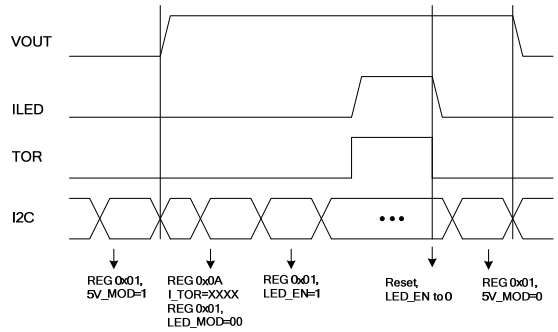


Figure 11: 5V DC Mode

Switching Frequency Setting

The switching frequency is selected by SW_FS bits. 1M/2M/3M/4MHz are available to optimize efficiency.

Switching Frequency Foldback

In default 4MHz switching mode, if the voltage across the current source is larger than the value set by the register bits VTH_PAS, the IC switches to 1MHz mode to improve efficiency and EMI. In 1MHz mode, the switching frequency can be stretched down according to the load condition with FS_SD =0. The IC goes into pass mode (which turns on the synchronous PMOS fully) if the input voltage is high enough.

Current Reduction

When the MP3331 works in flash mode, output current reduction may occur due to the following conditions:

1. **TX is high**.

During flash mode, if TOR/TX goes from low to high, the flash current drops to the current set by I_TX in less than 5μs and sets the FT_TX bit to 1. If TX goes low, the current ramps up to the flash current again (see Figure 12).

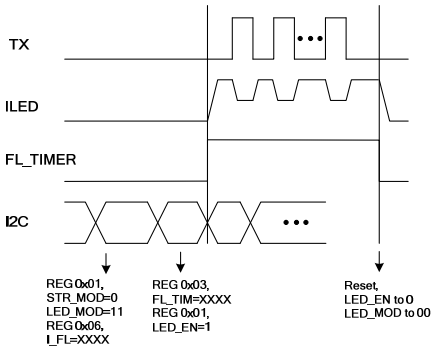


Figure 12: Flash Mode when TX is Active

2. **Low battery voltage threshold is triggered**.

During a flash pulse, if the battery voltage drops below the threshold set by VBL_RUN, the current reduces step-by-step with a 2μs/step until the battery voltage rises up to the specific low battery voltage threshold. Actual current in the IFL_ACT register can be read back. The minimum current caused by the current reduction in IFL_MIN can be read back after the flash.

Low Battery Voltage Protection

The device provides low battery voltage protection in flash mode in the following ways:

1. Before the flash, if the input voltage is lower than the threshold set by VBL_RUN, the device remains disabled (if VBL_SD = 1 and sets the fault bit FT_VBATL to 1). If VBL_SD = 0, the device ramps to the current set by I_TX and sets the fault bit FT_VBATL to 1. The fault bit is cleared after read back or the input power resets.

2. During flash start-up, if the input voltage is lower than the threshold set by VBL_RUN, the current stops ramping. The fault bit FT_VBATL is set. During the flash pulse, if the input voltage is lower than the threshold set by VBL_RUN, the current ramps down step-by-step. The fault bit is set until read back or the input power resets. After the flash, the minimum current caused by the current reduction is read back through the IFL_MIN register. The IFL_MIN value holds until the next flash occurs or the power resets. The actual current is read back through IFL_ACT during flash time. This

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function tells the device how much flash current can be drawn from the battery for the next flash. Thus, it is possible to do a pre-flash function and provide continuous stable flash current according to IFL_MIN information (see Figure 13).

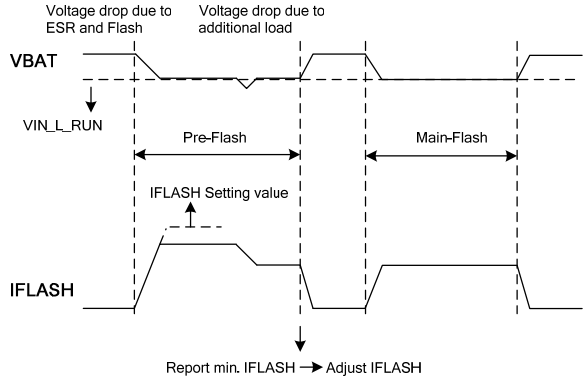


Figure 13: Pre-Flash Operation

VOUT-GND Short Protection

If VOUT<VIN-1V, the device stops switching and disconnects the synchronous PMOS to avoid drawing a very large current from the battery. Once the device stops switching, set the FT_VOSC bit to 1 and reset the mode setting. The fault bit remains until read back or power reset.

LED-GND Short Protection

If VLED < 1V & ILED > 25mA, the IC marks off the current source and resets the mode setting bits. Then the fault bit FT_LEDSC is set. The fault bit FT_LEDSC is 1 until read back or power reset.

LED Open Protection

If VOUT - VLED < 90mV & VOUT > 5.5V, the IC stops switching and resets the mode setting bits. Then the fault bits FT_OVP and FT_LEDOP are set. The fault bits FT_OVP and FT_LEDOP are 1 until read back or power reset.

Output Over-Voltage Protection

If VOUT > 5.5V, the device stops switching and resumes normal operation until VOUT drops below 5.2V. The fault bit FT_OVP is 1 until read back or power reset.

Junction Over-Temperature Protection

If Tj > 130℃, the flash current drops to the current set by I_TX (if LED_OTAD = 1). The fault bit FT_OTP is set. If Tj > 150℃, the device stops switching and resets the mode setting. The fault bit FT_OTP has to be cleared to 0 by read back or power reset before the IC will re-start.

Time-Out Protection

If the device works in flash mode with hardware and level sensitive enabled, the time-out protection triggers when the STR high-level pulse is longer than the timer set by FL_TIM. The device stops switching and resets the mode setting. The fault bit is 1 until read back or power reset before the IC re-starts.

UVLO Protection

If the VIN drops below the UVLO threshold, the device stops, and all the registers are reset to default.

I²C Interface Register Description

I²C Chip Address

After the start condition, the I²C compatible master sends a 7-bit address followed by an eighth read (read: 1) or write (write: 0) bit. The following bit indicates the register address to/from which the data will be written/read (see Figure 14 and the Tables below).

							LSB
1	1	0	0	1	1	1	R/W

Figure 14: I²C Compatible Device Address

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Register Mapping:

Add	D7	D6	D5	D4	D3	D2	D1	D0
00H	DEV_ID4	DEV_ID3	DEV_ID2	DEV_ID1	DEV_ID0	REV_ID2	REV_ID1	REV_ID0
01H	STR_LV	STR_MOD	STR_POL	LED_EN	TX_TOR	LED_MOD1	LED_MOD0	5V_MOD
02H	NA	NA	NA	IL_PEAK1	IL_PEAK0	FS_SD	NA	NA
03H	FL_TIM3	FL_TIM2	FL_TIM1	FL_TIM0	LED_SD	NA	SW_FS1	SW_FS0
04H	VBL_RUN2	VBL_RUN1	VBL_RUN0	VBL_SD	NA	NA	NA	NA
05H	LED_OTAD	TUP_I2	TUP_I1	TUP_I0	VTH_PAS1	VTH_PAS0	INDI_PWM1	INDI_PWM0
06H	NA	NA	I_FL5	I_FL4	I_FL3	I_FL2	I_FL1	I_FL0
07H	NA	NA	I_TX5	I_TX4	I_TX3	I_TX2	I_TX1	I_TX0
08H	NA	NA	IFL_ACT5	IFL_ACT4	IFL_ACT3	IFL_ACT2	IFL_ACT1	IFL_ACT0
09H	NA	NA	IFL_MIN5	IFL_MIN4	IFL_MIN3	IFL_MIN2	IFL_MIN1	IFL_MIN0
0AH	NA	NA	I_TOR5	I_TOR4	I_TOR3	I_TOR2	I_TOR1	I_TOR0
0BH	FT_VBATL	FT_OVP	FT_VOSC	FT_LEDSC	FT_OTP	FT_TO	FT_TX	NA
0CH	NA	NA	NA	NA	NA	NA	NA	FT_LEDOP

Table 1: Chip ID Register

Addr: 0x00				
Bit	**Bit Name**	**Access**	**Default**	**Description**
2:0	REV_ID	R	000	Revision ID
7:3	DEV_ID	R	00011	Device ID

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Table 2: Mode Setting Register

Addr: 0x01				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7	STR_LV	RW	1	Flash mode trigger mode with STR signal. 0 = edge sensitive; 1 = level sensitive.
6	STR_MOD	RW	1	STR enable bit. 0 = software enable; 1 = hardware enable.
5	STR_POL	RW	1	STR signal input active polarity. 0 = active low; 1 = active high.
4	LED_EN	RW	0	LED current source enable bit. 0 = LED current sink disable; 1 = enable
3	TX_TOR	RW	0	TX mode or torch mode selection bit; 0 indicates TX/TOR used for TX signal; 1 indicates TX/TOR used for torch signal. In flash mode, TX/TOR is forced to be used as a TX signal pin regardless of what this bit is.
2:1	LED_MOD	RW	00	Device mode setting bits. 00 = standby/torch mode; 01 = indicator mode; 10 = assist light mode; 11 = flash mode.
0	5V_MOD	RW	0	5V DC output enable bit. 0 = disable; 1 = enable.

Table 3: Peak Current Setting Register

Addr: 0x02				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:5	NA	RW	000	Reserved.
4:3	IL_PEAK	RW	01	Inductor current limit setting bits. 00 = 1.9A, 01 = 2.8A,10 = 3.6A,11 = 4.2A
2	FS_SD	RW	0	Disable switching frequency stretching down from 1MHz if VIN voltage is close to VOUT voltage. 0 = Enable Fs stretching down function. 1 = Disable Fs stretching down function.
0:1	NA	RW	NA	Reserved.

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Table 4: Flash Timer Setting Register

Addr: 0x03				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:4	FL_TIM	RW	0001	Flash timer setting bits. 50ms to 800ms, 50ms/step. 0000 = 50ms; 0001 = 100ms; …; 1111 = 800ms.
3	LED_SD	RW	0	LED_MOD and LED_EN resetting control bit. 0 = reset LED_MOD and LED_EN to default value after flash or torch. 1 = no reset.
2	NA	RW	0	Reserved.
1:0	SW_FS	RW	00	Switching frequency setting bits. 00 = 4MHz; 01 = 3MHz; 10 = 2MHz;11 = 1MHz.

Table 5: Low Battery Voltage Setting Register

Addr: 0x04				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:5	VBL_RUN	RW	111	Low battery voltage setting bits. If VIN drops below this voltage during start-up, the current ramping stops. If VIN drops below this voltage during the flash current pulse, the current is decreased until VIN is higher than its threshold. It works only in flash mode. 000 = 3V; 001 = 3.1V; ...110 = 3.6V; 111 = disabled; 0.1V per step.
4	VBL_SD	RW	1	Device disabled or reduce the flash current selection bit when VIN is less than the threshold set by VBL_RUN before the flash. 1 = device disabled; 0 = Enable and the current ramps up to the current set by I_TX.
3:0	NA	RW	NA	NA

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Table 6: Indicator Register

Addr: 0x05				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7	LED_OTAD	RW	0	Adaptive thermal flash current control bit. 1 = current reduced to the current set by I_TX when Tj >130℃; 0 = disable when Tj >150℃.
6:4	TUP_I	RW	001	Current ramp-up time per step. 000 = 8μs; 001 = 16μs; …111 = 64μs/step. 111 reserved.
3:2	VTH_PAS	RW	01	Defines the threshold when Fs drops to 1MHz or switches to pass mode from boost mode. 00 = 300mV, 01 = 450mV, 10 = 600mV, 11 = 750mV.
1:0	INDI_PWM	RW	00	PWM duty cycle of 31.5kHz in indicator mode. 00 = 2/16; 01 = 3/16; 10 = 4/16; 11 = 5/16.

Table 7: LED Flash Current Setting Register

Addr: 0x06				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:6	NA	RW	NA	Reserved.
5:0	I_FL	RW	010000	LED flash current setting bits. 0 to 2000mA, 31.7mA/step. 000000 = 0mA; 000001= 31.7mA…111111 = 2000mA. (Default 010101 = 508mA)

Table 8: TX Current Setting Register

Addr: 0x07				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:6	NA	RW	NA	Reserved.
5:0	I_TX	RW	010000	Defines the flash current in flash mode if TX is high. 0 to 2000mA, 31.7mA/step. 000000 = 0mA; 000001= 31.7mA…111111 = 2000mA. (Default 010000 = 508mA).

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Table 9: Actual Flash LED Current Register

Addr: 0x08				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:6	NA	R	NA	Reserved.
5:0	IFL_ACT	R	000000	The actual flash current in flash mode. It can be read only during flash. 0 to 2000mA, 31.7mA/step. 000000 = 0mA; 000001= 31.7mA …111111 = 2000mA.

Table 10: Minimum Flash LED Current Register

Addr: 0x09				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:6	NA	R	NA	Reserved.
5:0	IFL_MIN	R	000000	The minimum flash current caused by low battery voltage current reduction in flash mode. 0 to 2000mA, 31.7mA/step. 000000 = 0mA; 000001= 31.7mA … 111111 = 2000mA.

Table 11: LED Torch Current Setting Register

Addr: 0x0A				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:6	NA	R	NA	Reserved.
5:0	I_TOR	RW	001000	LED torch current setting bits. 0 to 508mA, 31.7mA/step. 000000 = 0mA, 000001= 31.7mA …010000 = 508mA. (Default 001000 = 254mA)

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Table 12: Fault Indication Register

Addr: 0x0B				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7	FT_VBATL	R	0	Low battery voltage fault bit. 0 = no fault. 1 = fault.
6	FT_OVP	R	0	Output over voltage fault bit. 0 = no fault. 1 = fault.
5	FT_VOSC	R	0	VOUT-GND short fault bit. 0 = no fault. 1 = fault.
4	FT_LEDSC	R	0	LED short fault bit. 0 = no fault 1 = fault.
3	FT_OTP	R	0	Junction over-temperature fault bit. 0 = no fault 1 = fault.
2	FT_TO	R	0	Flash time out fault bit. 0 = no fault. 1 = fault.
1	FT_TX	R	0	TX fault bit. 0 = no fault. 1 = fault.
0	NA	R	NA	NA

Table 13: Fault Indication Register

Addr: 0x0C				
Bit	**Bit Name**	**Access**	**Default**	**Description**
7:2	NA	R	NA	Reserved.
1	NA	R	NA	Reserved.
0	FT_LEDOP	R	0	LED open fault bit. 0 = no fault; 1 = fault.

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APPLICATION INFORMATION

Selecting the Input Capacitor

The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent the high-frequency switching current from passing through to the input. Use ceramic capacitors with X5R or X7R dielectrics for their low ESR and small temperature coefficients. A higher value capacitor helps reduce the input voltage ripple and noise. For most applications, a 10μF ceramic capacitor will suffice.

Selecting the Inductor

The converter requires an inductor to supply a higher output voltage while being driven by the input voltage. A larger value inductor results in less ripple current, resulting in lower peak inductor current and reducing stress on the internal N-channel MOSFET. However, the larger value inductor has a larger physical size, a higher series resistance, and a lower saturation current.

Choose an inductor that does not saturate under the worst-case load conditions. Select the minimum inductor value to ensure that the boost converter works in continuous conduction mode (CCM) with high efficiency and good EMI performance.

Calculate the required inductance value using Equation (1) and Equation (2):

$$L \geq \frac{\eta \times V_{OUT} \times D \times (1-D)^2}{2 \times f_{SW} \times I_{LOAD}} \quad (1)$$

$$D = 1 - \frac{V_{IN}}{V_{OUT}} \quad (2)$$

Where V_{IN} and V_{OUT} are the input and output voltages, f_{SW} is the switching frequency; I_{LOAD} is the LED load current, and η is the efficiency.

The switching current is used for the peak current mode control. In order to avoid reaching the current limit, the worst-case inductor peak current should be less than 80% of the current-limit (I_{LIM}). For most applications, 0.47uH~2uH inductor will suffice.

Selecting the Output Capacitor

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. The output capacitor impedance must be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. Please note that ceramic capacitance is dependent on the voltage rating; a DC bias voltage and the value can lose as much as 50% of its capacitance at its rated voltage rating. Please leave a large enough voltage rating margin when selecting the component. In addition, too low a capacitance value will cause loop instability. For most applications, a 10μF ceramic capacitor will suffice.

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TYPICAL APPLICATION CIRCUITS

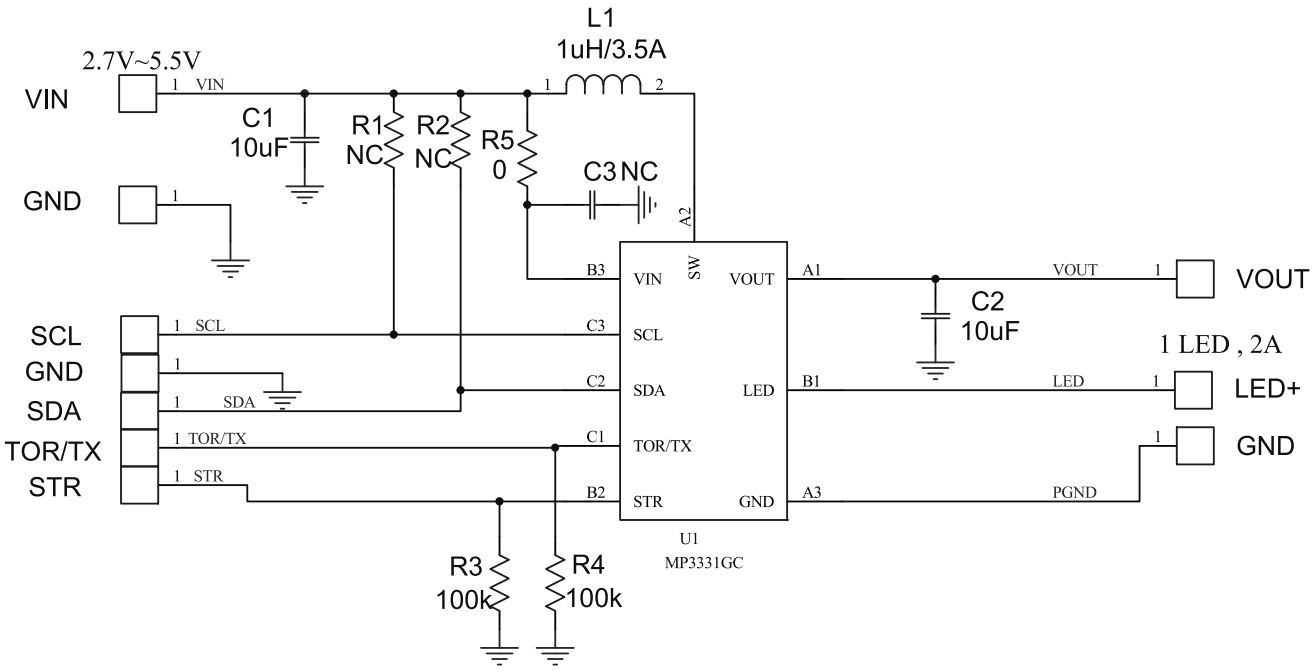
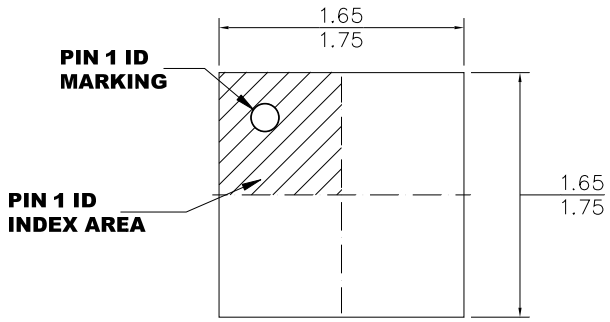


Figure 15: Typical Application Circuit

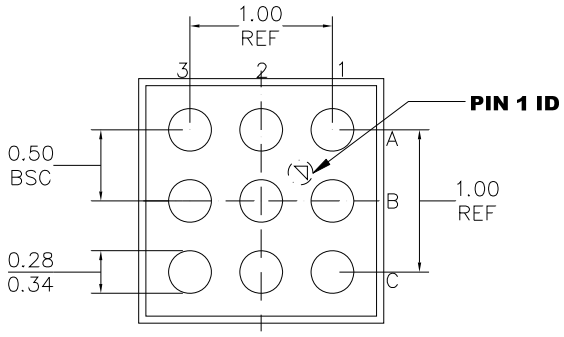
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PACKAGE INFORMATION

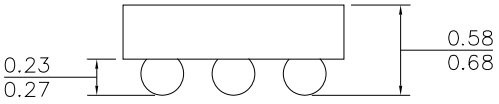
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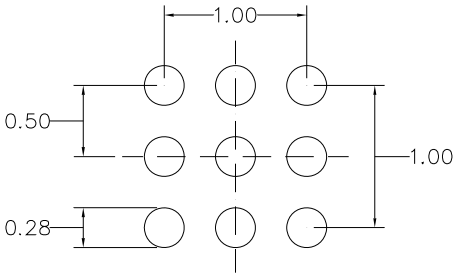
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN

NOTE:

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2) BALL COPLANARITY SHALL BE 0.05 MILLIMETER MAX.
3) JEDEC REFERENCE IS MO-211.
4) DRAWING IS NOT TO SCALE.

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