SM8135B

White LED Driver IC

OVERVIEW

The SM8135B is a charge pump type white LED driver. It can drive 1 to 4 backlight white LED connected in parallel, making it ideal for portable devices with small LCD. The charge pump switches between ×1 bypass mode, ×1.5 and ×2 boost mode in response to LED drive current requirements. The boost switching occurs in response to the drive current of all the connected LED and thus supports variations in LED forward-bias voltage drop (VF). Besides, the detection of switching is repeated in approx. 1sec-cycle by mode reset action, the SM8135B can respond to temporary variation of supply voltage. These ingenuities on switching detection can prolong the battery life to the fullest extent. Each LED drive current is controlled by a 4-channel LED drive current control circuit. The LED drive current per channel is setup by external resistor.

FEATURES

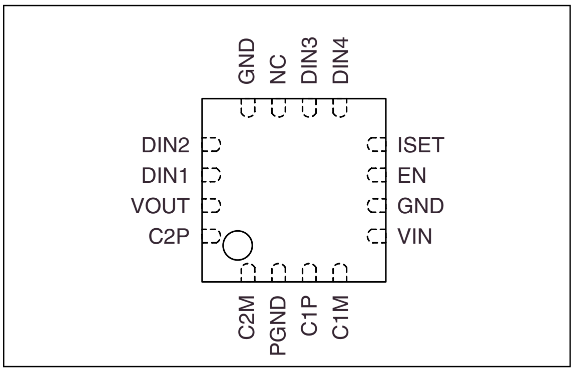
- Battery life extension by automatic charge pump switch between ×1, ×1.5 and ×2 according to the detection of the LED drive current
- Controlling 1 to 4 lights of white LED connected in parallel
- Set up LED drive current value by external resistor (120kΩ: 20mA/ch)
- 1-wire input controlling
- ON/OFF and brightness control by signal controlling of EN pin
- Soft start circuit built-in
- Thermal shut down circuit built-in
- Input voltage range
  No-load current (I_{OUT} = 0mA): 2.7 to 4.6V
  Load current (I_{OUT} = 80mA): 3.0 to 4.6V
- Maximum output voltage: 4.9V (typ)
- Maximum output current: 80mA (typ)
- Quiescent current
  Not-switching (×1 mode): 0.3mA (typ)
  Switching (×1.5 mode): 1.5mA (typ)
  Switching (×2 mode): 1.5mA (typ)
- Standby current: 0.01µA (typ)
- Operating frequency (boost mode): 1MHz (typ)
- LED drive current accuracy between channel (REST = 120kΩ): ± 5% (max)
- Package: 16-pin QFN

APPLICATIONS

- Cellular phone
- PDA
- Portable games
- Handy terminal
- Digital still camera
- Digital video camera
- LCD panel back light
- White LED driving

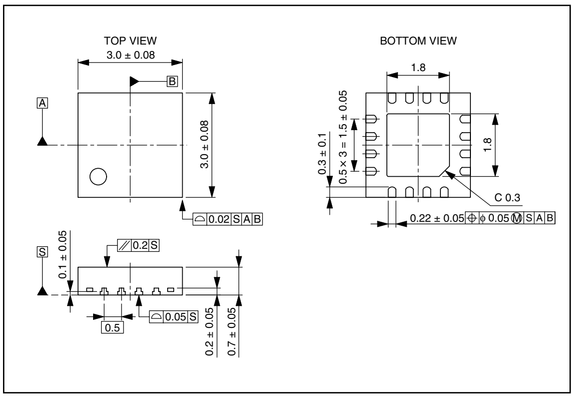
PINOUT

(Top view)



PACKAGE DIMENSIONS

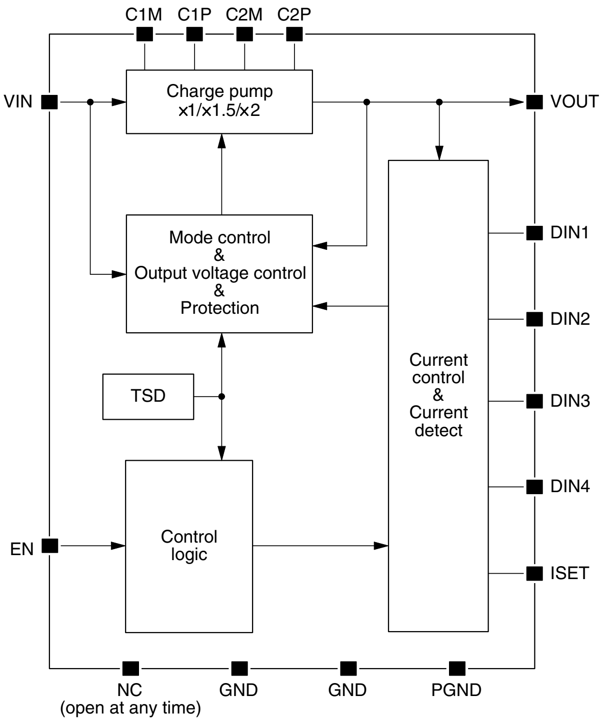
(Unit: mm)



ORDERING INFORMATION

Device	Package
SM8135BB	16-pin QFN

BLOCK DIAGRAM



PIN DESCRIPTION

Number	Name	I/O	Description
1	C2M	–	Charge pump boost capacitor connection 2M
2	PGND	–	Charge pump ground
3	C1P	–	Charge pump boost capacitor connection 1P
4	C1M	–	Charge pump boost capacitor connection 1M
5	VIN	–	Supply voltage input
6	GND	–	Ground
7	EN	I	Enable/LED drive current setting (High active)
8	ISET	I	LED drive current setting resistor connection
9	DIN4	O	LED drive current control output 4 (connect to ground when not used)
10	DIN3	O	LED drive current control output 3 (connect to ground when not used)
11	NC	–	No connection (leave open circuit for normal operation)
12	GND	–	Ground
13	DIN2	O	LED drive current control output 2 (connect to ground when not used)
14	DIN1	O	LED drive current control output 1 (connect to ground when not used)
15	VOUT	O	LED drive voltage output
16	C2P	–	Charge pump boost capacitor connection 2P

SPECIFICATIONS

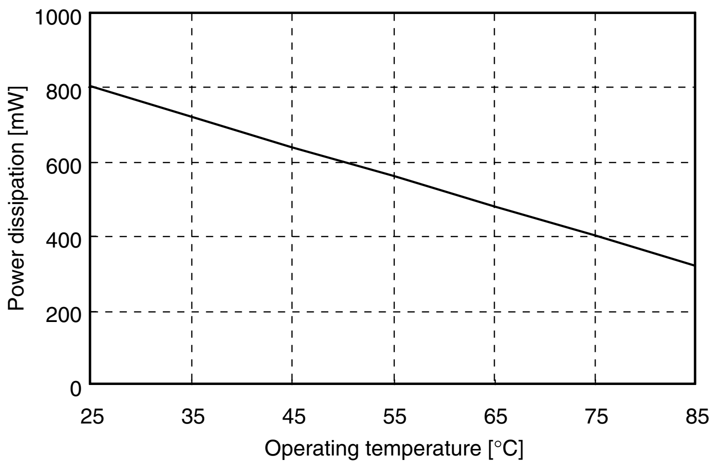
Absolute Maximum Ratings

GND = 0V

Parameter	Symbol	Rating	Unit
VIN voltage range	V_{IN}	–0.3 to 5.5	V
Input voltage range	V_{EN}	–0.3 to V_{IN} + 0.3	V
Output voltage range	$V_{DIN1\ to\ 4}$	–0.3 to V_{IN} + 0.3	V
	V_{OUT}	5.5	V
VOUT output current	I_{OUT}	500	mA
Power dissipation	P_D	800 (Ta = 25°C)*1	mW
Junction temperature	T_{JMAX}	+125	°C
Storage ambient temperature range	T_{stg}	–55 to +125	°C

*1. When mounted on a 4-layer PCB.

Note. The device may suffer breakdown if any one of these parameter ratings is exceeded.



Package power dissipation when mounted on 4-layer board

Recommended Operating Conditions

GND = 0V

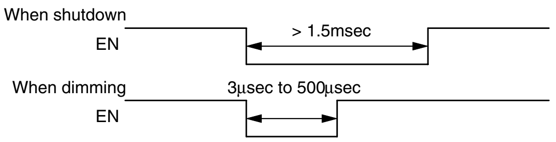
Parameter	Pin	Symbol	Conditions	Rating			Unit
				min	typ	max	
Supply voltage range	VIN	V_{IN0}	I_{OUT} = 0mA	2.7	3.6	4.6	V
		V_{IN}	I_{OUT} = 80mA	3.3	3.6	4.6	V
Input voltage range	EN	V_{ES}	Logic-level pin	0	–	V_{IN}	V
Ambient temperature range	–	Ta		–30	–	+85	°C

Electrical Characteristics

V_{IN} = 3.6V, GND = 0V, Ta = 25°C unless otherwise noted.

Parameter	Pin	Symbol	Condition	Rating			Unit
				min	typ	max	
Standby current	VIN	I_{STB}	Standby mode	–	0.01	1.00	µA
Quiescent current 1		I_{DD1}	×1.0 mode, I_{OUT} = 0mA	–	0.3	1.0	mA
Quiescent current 2[*1]	VIN	I_{DD2}	×1.5 mode, I_{OUT} = 0mA	–	1.5	4.5	mA
Quiescent current 3		I_{DD3}	×2.0 mode, I_{OUT} = 0mA	–	1.5	4.5	mA
Output voltage	VOUT	V_{OUT}		4.4	4.9	5.4	V
Maximum output current	VOUT	I_{OUT}	×1.5/×2.0 mode	80	–	–	mA
Operating frequency	C1M	f_{OSC}	×1.5/×2.0 mode switching frequency	750	1000	1250	kHz
Internal power-ON reset time[*1]	EN	T_{POR}	Rest time from when power is applied	–	0.05	1.00	ms
Soft start time	DIN1 to 4	T_{SS}	EN startup → I_{LED} rising edge	0.70	1.43	3.00	ms
LED drive pin leakage current	DIN1 to 4	$I_{Leak1\ to\ 4}$	Standby mode, DIN pin = 4.9V	–	0.01	1.00	µA
LED drive current	DIN1 to 4	$I_{LED1\ to\ 4}$	×1.0 mode	18.0	20.0	22.0	mA
LED drive current matching	DIN1 to 4	ΔI_{LED}	×1.0 mode, relative accuracy between channels at I_{LED} maximum setting	–5.0	–	+5.0	%
LED drive pin voltage	DIN1 to 4	$V_{DIN1\ to\ 4}$	×1.0 mode	–	200	–	mV
LED drive current setting resistance[*1]	ISET	RSET	RSET minimum value	60	–	–	kΩ
EN hold time[*1*2]	EN	T_{CEH}	Time from when EN = LOW until shutdown	0.50	1.00	1.50	ms
EN HIGH-level input time[*1]	EN	T_{ENH}	EN input pulse HIGH-level minimum pulsewidth	3.0	–	–	µs
EN LOW-level input time[*1*2]	EN	T_{ENL}	EN input pulse LOW-level pulsewidth range	3.0	–	500	µs
Logic input voltage	EN	V_{IH}	HIGH-level input voltage range	1.4	–	–	V
		V_{IL}	LOW-level input voltage range	–	–	0.3	V
Logic input current	EN	I_{IH}	Pull-down pin, EN pin = 3.6V	–	5.0	10.0	µA
		I_{IL}	EN pin = 0V	–1.0	–	–	µA

*1. Design guaranteed value
*2.



FUNCTIONAL DESCRIPTION

LED Drive Current Setting

The SM8135B LED drive current can be set using a combination of 2 methods: (1) current setting resistance connected to ISET, and (2) input pulse control on the EN pin.

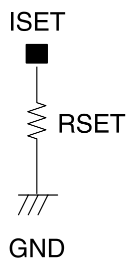
(1) Setting LED drive current using RSET

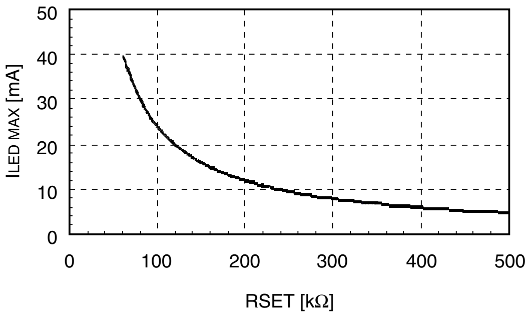
The LED drive maximum current value per LED ($I_{LED\ MAX}$) is determined by the resistor (RSET) connected to the ISET pin. The relationship between RSET and $I_{LED\ MAX}$ is given by the following equation.

$I_{LED\ MAX}$ [mA] = 2400/RSET [kΩ]

(For example, $I_{LED\ MAX}$ = 20mA when RSET = 120kΩ.)

The RSET resistance has a minimum rating of 60kΩ. At this value of resistance, the $I_{LED\ MAX}$ has a maximum rating of 40mA/LED. However, note that the total LED drive current for all LEDs must not exceed 80mA.





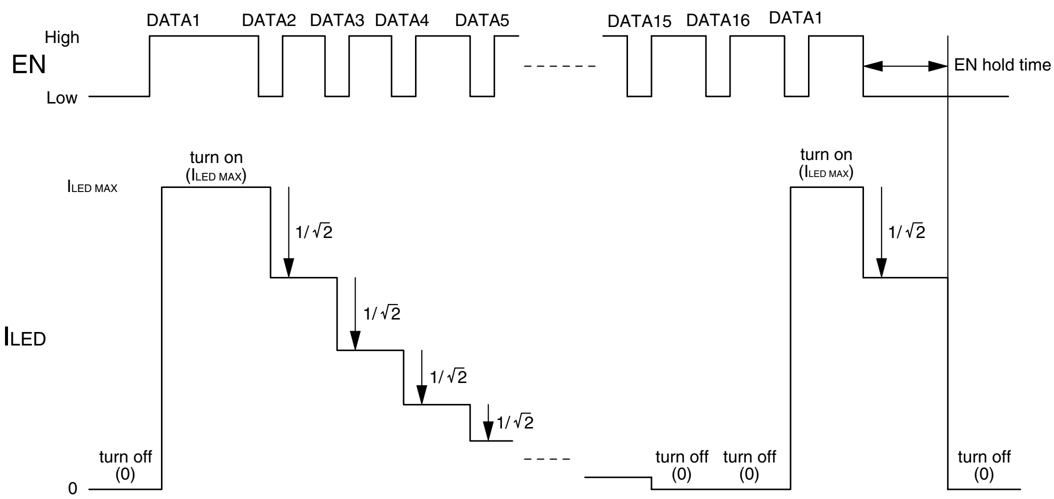
RSET vs. $I_{LED\ MAX}$

(2) Setting LED current using pulse input on EN

The EN pin has a built-in counter that can be used to set the LED current to one of 14 levels (DATA1 to DATA14) determined by the number of input pulses on EN. The LED current I_{LED} begins to flow when EN is first set to HIGH. The built-in counter is set to DATA1 (maximum setting), and the current is the maximum LED current ($I_{LED\ MAX}$) determined by resistor RSET. When an pulse input is applied on EN, the counter is incremented and the current changes from $I_{LED\ MAX}$ by a factor of approximately $1/\sqrt{2}$ for each pulse. The current change is triggered by the falling edge of the input pulse, and each pulse should have a minimum 3.0μs pulsewidth.

$I_{LED} = I_{LED\ MAX}/(\sqrt{2})^N$ N: number of pulses = 0 to 13

On the 14th and 15th pulse (DATA15 and 16), the current drive circuit is shutdown and no LED drive current flows, turning the LEDs OFF. On the 16th pulse, the current returns to the DATA1 maximum value. When the EN input is held LOW for an interval longer than the EN hold time (1ms), the whole IC returns to standby mode, and the LED current is set to 0. Note that the counter is also reset to value DATA1. Since the current is set to the maximum value $I_{LED\ MAX}$ for 0 pulses (DATA1), applications that do not generate a pulse input can still use the device to drive LEDs. In this case, the LED current setting is determined exclusively by RSET (refer to section "(1) Setting LED drive current using RSET").



Dimming control by EN pin

Table 1. EN input pulse count and I_{LED} relationship ($I_{LED\ MAX}$ = 20mA)

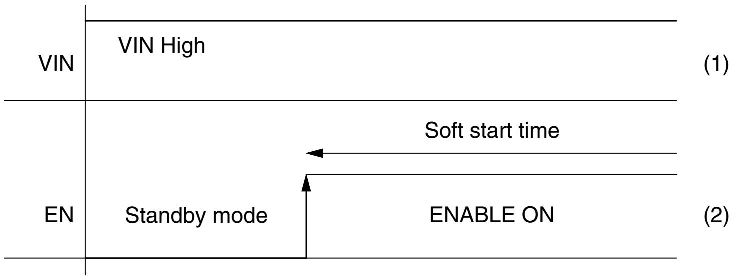
DATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DIM pulse count	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
	48	49	50													
I_{LED} [mA]	20.00	14.00	10.00	7.00	5.00	3.50	2.50	1.80	1.27	0.91	0.64	0.45	0.32	0.23	0	0
Ratio	1	$1/(\sqrt{2})^1$	$1/(\sqrt{2})^2$	$1/(\sqrt{2})^3$	$1/(\sqrt{2})^4$	$1/(\sqrt{2})^5$	$1/(\sqrt{2})^6$	$1/(\sqrt{2})^7$	$1/(\sqrt{2})^8$	$1/(\sqrt{2})^9$	$1/(\sqrt{2})^{10}$	$1/(\sqrt{2})^{11}$	$1/(\sqrt{2})^{12}$	$1/(\sqrt{2})^{13}$	(OFF)	(OFF)

V_{OUT} Output Circuit Mode Switching

The SM8135B output mode switches between 4 operating modes in response to the operating conditions. The modes are: standby mode, ×1.0 mode (VIN through mode), ×1.5 mode (1.5-times charge pump boost), and ×2.0 mode (2.0-times charge pump boost). Specifically, the use of ×1.0 mode, ×1.5 mode, and ×2.0 mode allows the VOUT output to be adjusted automatically to match drive LED characteristics. Switching between ×1.0 mode, ×1.5 mode, and ×2.0 mode is controlled automatically by an internal circuit. The operating mode cannot be specified by an external control signal.

Startup: Internal Reset Time and Soft Start Time

The SM8135B normal startup procedure (after VIN has been applied previously) is to switch from standby mode to the ×1.0/×1.5/×2.0 operating modes when the EN enable input goes HIGH. The soft start time (described on the following page) begins after switching to the operating mode using EN.

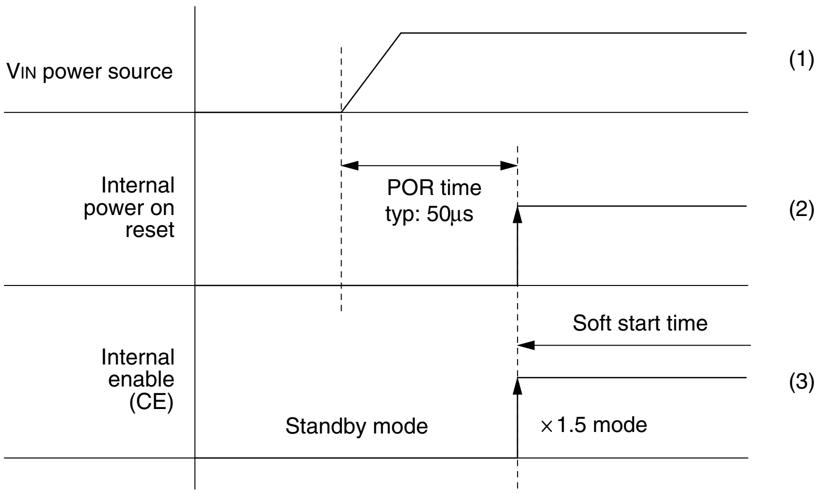


Normal startup

(1) VIN is HIGH, EN is LOW (standby mode)

(2) Switches to an operating mode when EN goes HIGH (soft start time begins)

If the VIN supply voltage is applied when EN is HIGH level, startup commences after the power-ON reset (POR) time (approximately 50µs) has elapsed.



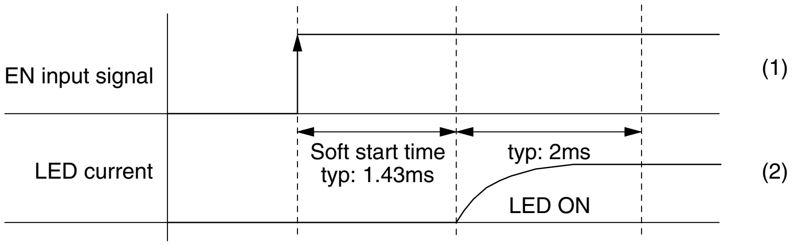
Internal reset operation when power is applied (power-ON reset)

(1) VIN voltage rises when power is applied.

(2) Power-ON reset (POR) circuit resets internal circuits approximately 50µs after the power is applied.

(3) If EN is HIGH when power is applied, the internal circuits start operating when the internal "CE" signal rising edge occurs after the power-ON reset time. If EN is LOW when power is applied, the "CE" rising edge occurs simultaneously with the first rising edge.

Immediately after startup, the device operates in ×1.5 mode for a fixed interval (soft start time: approximately 1.43ms) to set the current for LEDs connected to the DIN pins. After the soft start time has elapsed, the LEDs are turned ON. Approximately 2ms is required for the LED drive current to reach the set drive value.



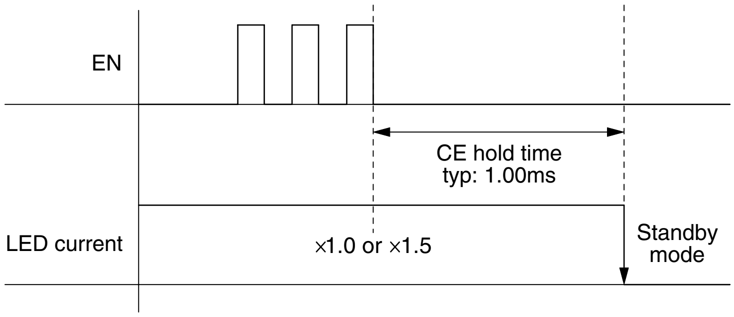
Soft start time and LED current

(1) If the EN signal is input after power is applied, the soft start time begins on the EN rising edge. The DIM pulse input for dimming is active during the soft start time.

(2) After the soft start time (1.43ms) has elapsed, the LEDs are turned ON. Approximately 2ms is required for LED drive current to reach set values.

Switching to Standby Mode

The SM8135B switches from ×1.0/×1.5/×2.0 mode to standby mode if EN goes LOW and stays LOW for an interval of 1.00ms (typ). This function is used to switch the internal circuits to standby mode automatically when the LEDs turn OFF in order to reduce current consumption.

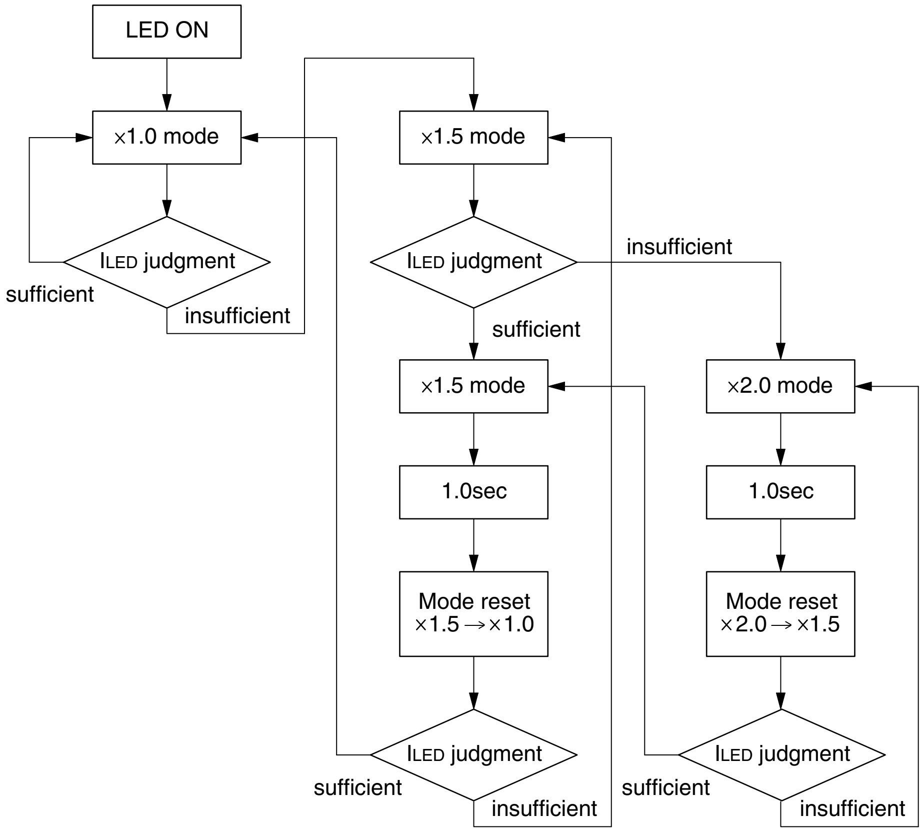


Switching to standby mode, and EN hold time

■ If EN is LOW for longer than the enable hold time of 1.00ms (typ), the SM8135B switches to standby mode. In standby mode, the internal circuits are reset, hence the drive current settings must be re-entered to restart the device.

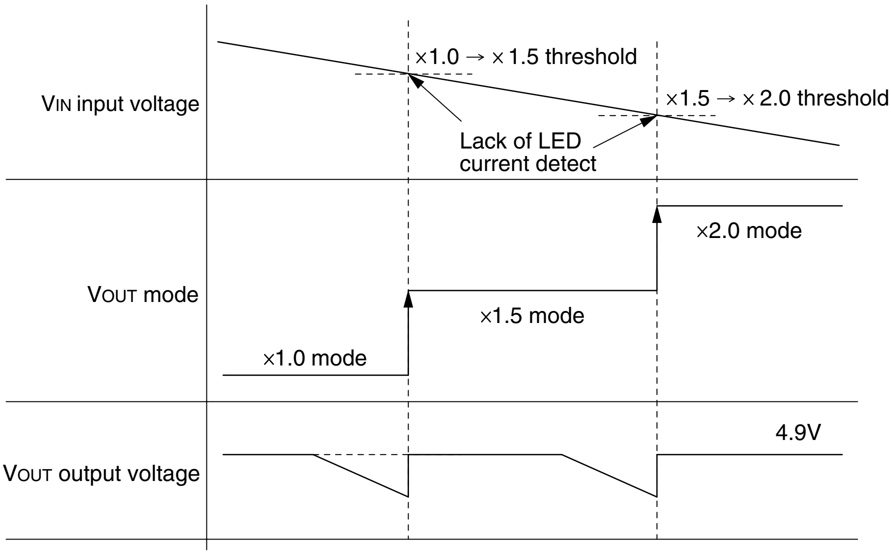
Boost Mode Auto-switching

The SM8135B switches between ×1.0 mode (VIN through mode), ×1.5 mode (1.5-times charge pump boost), and ×2.0 mode (2.0-times charge pump boost) automatically in response to the operating state to reduce current consumption. The switching transition flow chart is shown in the following figure.



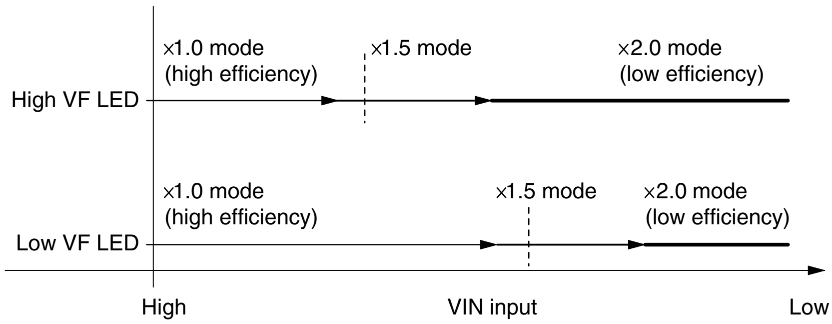
Boost mode switching flow chart

This section describes the boost mode switching in response to insufficient LED drive current level detection. The next section describes the mode reset functions. Initially, when the LED drive current begins to flow, operation begins in ×1.0 mode at the set current value if possible, without boosting the input voltage VIN. If the set current value cannot be attained in ×1.0 mode due to a VIN voltage drop or an increase in the set current value, a low-current detector circuit connected to each LED drive circuit is activated that switches the VOUT output to ×1.5 mode automatically, and the charge pump circuit starts boosting the voltage by 1.5 times. If the set current value still cannot be attained, the LED drive circuits are switched to ×2.0 mode, and the charge pump starts boosting the voltage by 2 times.



V_{IN} voltage drop and V_{OUT} output voltage

In ×1.0 mode, $V_{IN} = V_{OUT}$. However, the V_{OUT} output does not always reach the electrical characteristics typical rating of 4.9V. However, as long as an insufficient current condition is not detected, ×1.0 mode operation continues. In other words, V_{OUT} may drop below 4.9V if sufficient LED drive current is flowing to counter the LED forward-bias voltage drop VF. The longer the device can operate in the high output efficiency ×1.0 mode, the lower the total current consumption and the longer the battery drive time can be extended. Furthermore, the more that low VF LEDs and lower LED drive current are used, the longer the device can operate automatically in ×1.0 mode.

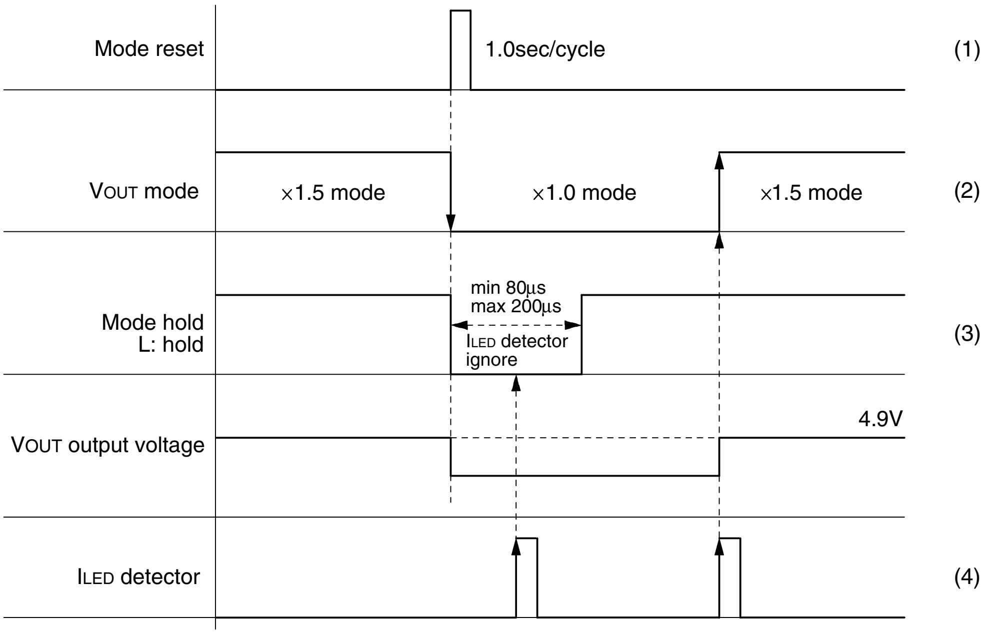


V_{OUT} mode switching time comparison due to drive LED “VF” variation

The LED low-current detector circuit switches the output boost mode whenever a single insufficient current condition is detected among the 4 channel LED drive currents, hence drive LEDs with small VF variation should be used to increase overall efficiency. If, after startup, a LED connection to the DIN pins is switched ON/OFF, the LED current detection circuit will operate incorrectly and normal boost mode switching does not occur. Also, if LED drive current control using a DIM pin is not used, the low-current detector circuit does not operate and the boost mode does not switch to either ×1.5 or ×2.0 mode.

Mode Reset Function

VF increases immediately after the LED current starts to flow, and then decreases as the LED temperature increases due to the heating effect of the current flow. It can take about 10 seconds for the LED temperature to stabilize and for VF to reach equilibrium, and VF may fluctuate more than 200mV. The VF fluctuation is affected by the ambient temperature and LED current setting, and has a large affect on the automatic mode switching voltage tolerances. To counter the effects of VF fluctuation, the SM8135B outputs a mode reset signal once every 1.0 seconds which automatically switches the output mode to ×1.0, and then a determination is made whether to make the ×1.0 → ×1.5 mode switch.



Switching from ×1.5 mode to ×1.0 mode due to mode reset signal

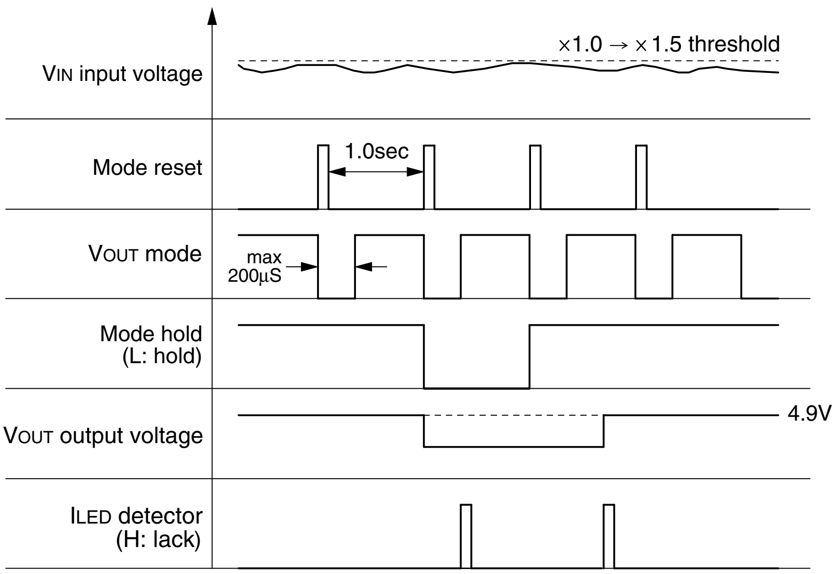
(1) Mode reset signal is output once every 1.0 seconds.

(2) Mode switches from ×1.5 to ×1.0 mode on the rising edge of the mode reset signal.

(3) A 200µs (max) mode hold time begins after switching to ×1.0 mode. LED drive current insufficient state is detected but the mode is not switched during this interval.

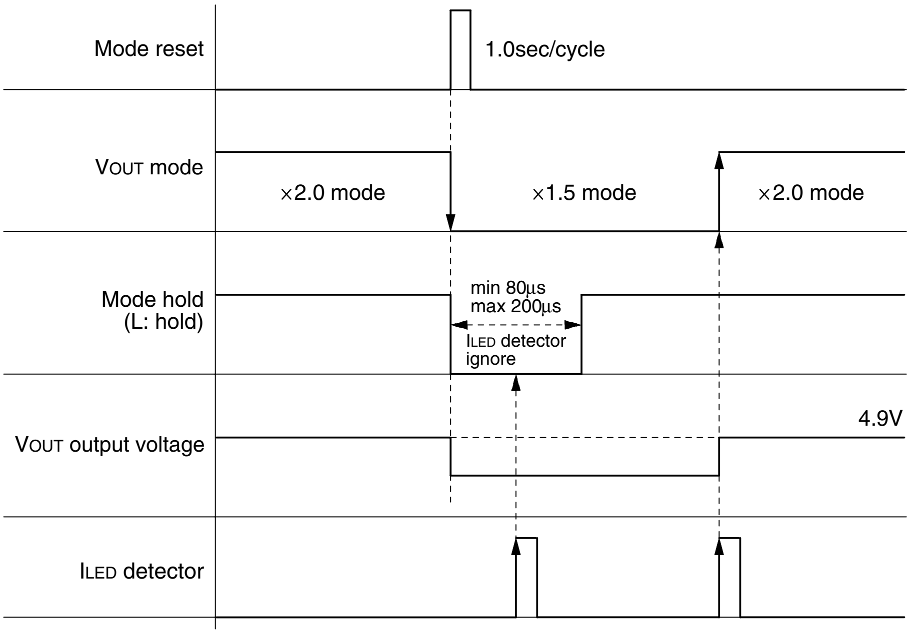
(4) LED drive current insufficient signal is ignored during the mode hold time, but normal mode switching operation resumes when the mode hold time elapses.

A mode hold signal of 200µs (max) duration is output immediately after switching to ×1.0 mode. The V_{OUT} output is held in ×1.0 mode and any LED drive current insufficient detection signal is ignored during the mode hold signal output. For example, if the V_{IN} voltage drops and the V_{OUT} output voltage in ×1.0 mode cannot provide sufficient current to drive the LEDs, a LED drive current insufficient condition occurs momentarily due to the mode reset. The LED low-current detector circuit outputs a LED drive current insufficient signal immediately after switching modes, but during the mode hold time the device stays in ×1.0 mode and does not switch to ×1.5 mode. Consequently, the V_{OUT} voltage drops and the LED brightness decreases during the 85µs (min) to 200µs (max) mode hold time. However, a 200µs decrease in the brightness is not a problem as it is not perceptible to the human eye.



V_{OUT} drop due to mode reset signal (between ×1.5 and ×1.0 mode)

The mode reset operation when in ×2.0 mode performs boost mode switching between ×2.0 mode and ×1.5 mode. Mode switching directly from ×2.0 mode to ×1.0 mode does not occur.



Switching from ×2.0 mode to ×1.5 mode due to mode reset signal

(1) Mode switches from ×2.0 to ×1.5 mode on the rising edge of the mode reset signal.

(2) A 200µs (max) mode hold time begins after switching to ×1.5 mode. LED drive current insufficient state is detected but the mode is not switched during this interval.

(3) LED drive current insufficient signal is ignored during the mode hold time, but normal mode switching operation resumes when the mode hold time elapses.

The mode reset function periodically tests the boost mode to try to maximize the duration of operation in the higher efficiency ×1.0 and ×1.5 modes in order to extend battery drive time.

Thermal Shutdown Circuit (Overtemperature Protection Circuit)

The SM8135B features a thermal shutdown circuit that operates whenever the IC temperature exceeds approximately 170°C for whatever reason, stopping the V_{OUT} output. V_{OUT} output recommences when the IC temperature falls below approximately 150°C. At output shutdown, the LED drive current DATA settings are stored.

PERIPHERAL PARTS

About the External Capacitors

The best capacitors for use with the SM8135B are multi-layer ceramic capacitors. When selecting a multi-layer ceramic capacitor, only X5R and X7R dielectric types are strongly recommended, since the loss of capacitance in various conditions is less than other types such as Z5U and Y5V. The much loss of capacitance in various conditions may cause the output voltage unstable.

Table. The EIA three digit "TC" code

Lower temperature limit	High temperature limit	Maximum allowable capacitance change from +25°C (0V DC)
X = –55°C	5 = +85°C	F = ± 7.5%
Y = –30°C	6 = +105°C	P = ± 10%
Z = +10°C	7 = +125°C	R = ± 15%
	8 = +150°C	S = ± 22%
		T = +22%/–33%
		U = +22%/–56%
		V = +22%/–82%

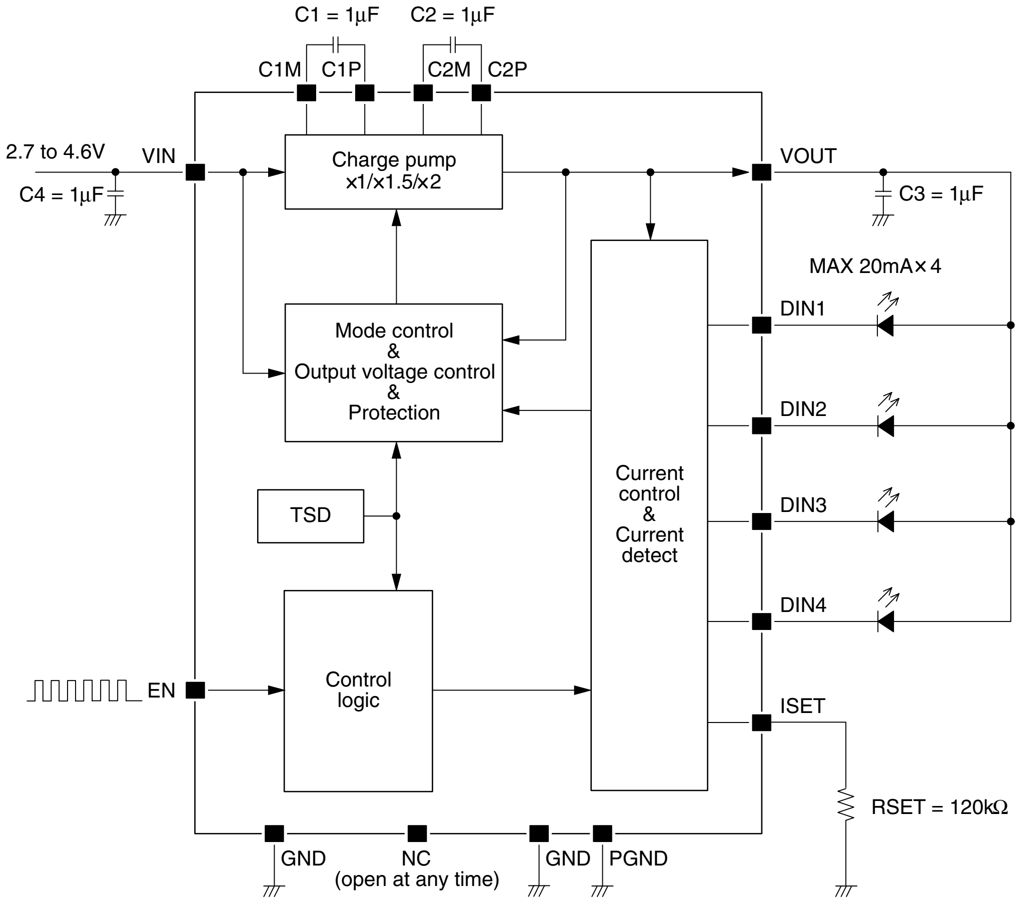
For example : X5R

About the Input Capacitor "C4"

The parts layout of PCB may merely cause the “V_{OUT}” output voltage unstable. In this case, increasing the “C4” input capacitance value or adding another capacitor on the VIN input line is effective to solve the unstable output voltage.

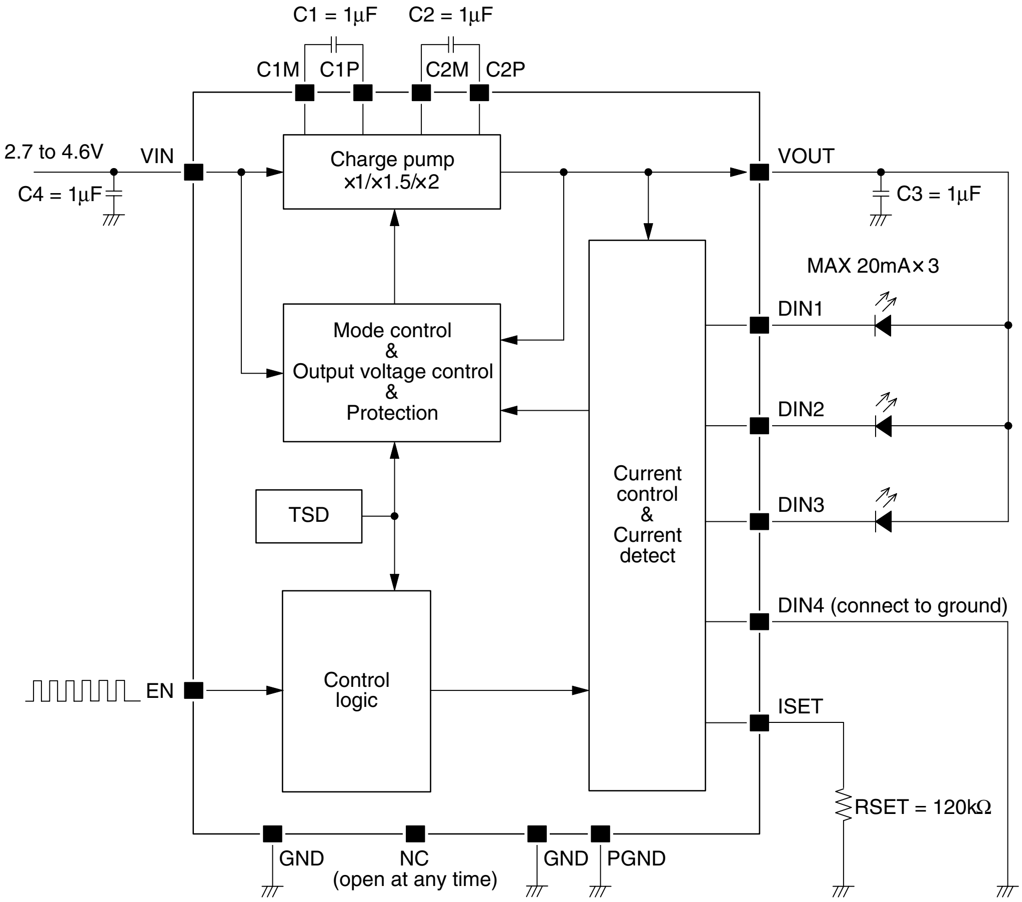
TYPICAL APPLICATION CIRCUITS

LED × 4, $I_{LED\ MAX}$ = 20mA



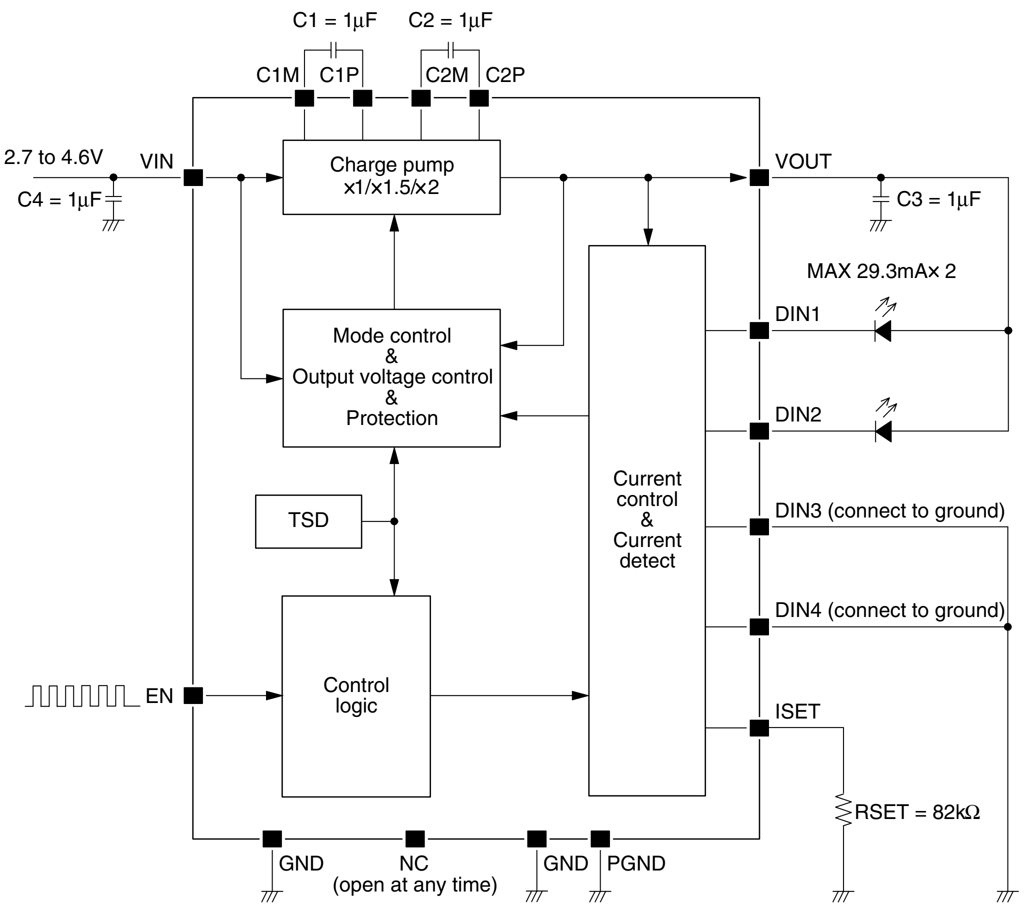
Note. If the driving LED is less than 4 pcs, unused DIN pins should be connect to GND.
Dimming and ON/OFF control is performed using pulse input on EN with a maximum LED current determined by resistor RSET (see P.6 “Setting LED current using pulse input on EN”).
The HIGH-level and LOW-level pulsewidths for the pulse input on EN must be 3.0µs or longer (see “Electrical Characteristics”).

LED × 3, $I_{LED\ MAX}$ = 20mA



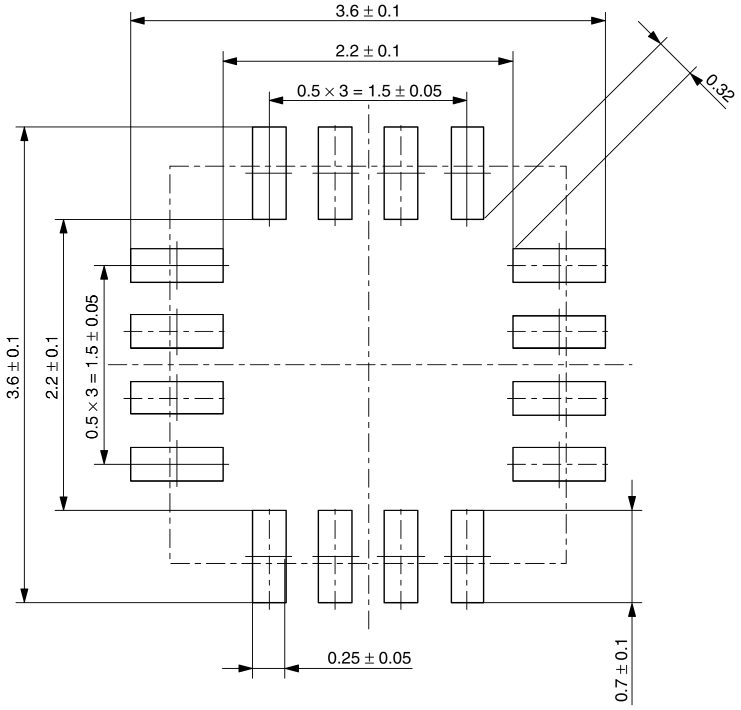
Note. If the driving LED is less than 4 pcs, unused DIN pins should be connect to GND.
Dimming and ON/OFF control is performed using pulse input on EN with a maximum LED current determined by resistor RSET (see P.6 "Setting LED current using pulse input on EN").
The HIGH-level and LOW-level pulsewidths for the pulse input on EN must be 3.0µs or longer (see "Electrical Characteristics").

LED × 2, $I_{LED\ MAX}$ = 29.3mA



Note. If the driving LED is less than 4 pcs, unused DIN pins should be connect to GND.
Dimming and ON/OFF control is performed using pulse input on EN with a maximum LED current determined by resistor RSET (see P.6 “Setting LED current using pulse input on EN”).
The HIGH-level and LOW-level pulsewidths for the pulse input on EN must be 3.0μs or longer (see “Electrical Characteristics”).

FOOTPRINT PATTERN



Please pay your attention to the following points at time of using the products shown in this document.

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NC0707AE 2007.11