NIPPON PRECISION CIRCUITS INC.

SM8131B

White LED Driver IC

OVERVIEW

The SM8131B is a charge pump DC/DC converter that switches between ×1 and ×1.5 automatically. The SM8131B switches between ×1 and ×1.5 according to detected LED drive current, so that the battery life can be prolonged to the fullest extent. Since the connected LED are all detected for the switching, the SM8131B can respond to the variation of LED forward voltage. 6-channel of LED drive current control circuit is built-in, the SM8131B can control 1 to 6 lights of white LED, which are connected in parallel. The LED drive current per channel is set up by external resistor. Besides, by setting up SEL1/SEL2 pins, 6-channel of LED drive current control circuit can be divided to 2-groups, and input signal controlling of EN1/EN2 pins allow ON/OFF and dimming per group.

FEATURES

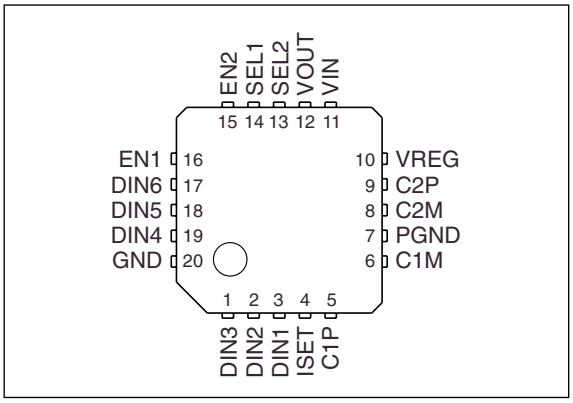
- Battery life extension by automatic charge pump switch between ×1 and ×1.5 according to the detection of the LED drive current
- Controlling 1 to 6 lights of white LED connected in parallel
- Set up LED drive current value by external resistor (5kΩ:5mA/ch, 15kΩ:15mA/ch, 20kΩ:20mA/ch)
- Dividing 6-channel to 2-groups by setting up SEL1/SEL2 pins (L/L = 6:0ch, L/H = 5:1ch, H/L = 4:2ch, H/H = 3:3ch)
- 2-wire input controlling (1-wire input controlling when SEL1/SEL2 pins are set to "LOW")
- ON/OFF and brightness control by input signal controlling of EN1/EN2 pins
- Supply voltage range
  - No-load current (I_{OUT} = 0mA): 2.7 to 4.6V
  - Load current (I_{OUT} = 120mA): 3.3 to 4.6V
- Maximum output voltage: 4.2V (typ)
- Maximum output current: 120mA (typ)
- Quiescent current
  - Not-switching (×1 mode): 0.7mA (typ)
  - Switching (×1.5 mode): 2.0mA (typ)
- Standby current (Power save mode): 0.01μA (typ)
- Operating frequency (×1.5 mode): 750kHz (typ)
- LED drive current accuracy (RSET = 20kΩ) :20mA ± 3%
- Input signal frequency for dimming (Duty = 50%) :150kHz (max)
- Package:20-pin QFN

APPLICATIONS

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

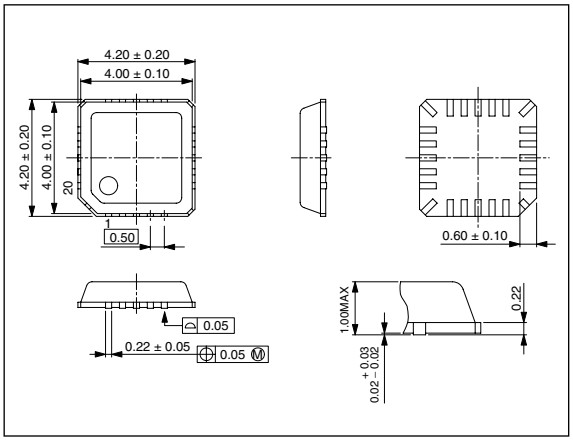
PINOUT

(Top view)



PACKAGE DIMENSIONS

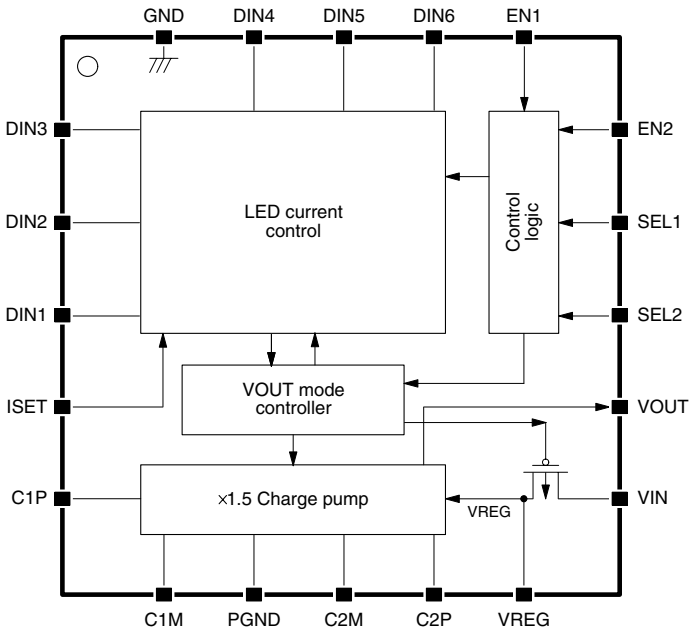
(Unit: mm)



ORDERING INFORMATION

Device	Package
SM8131B00B	20-pin QFN

BLOCK DIAGRAM



PIN DESCRIPTION

Number	Name	I/O	Description
1	DIN3	O	LED drive current control output 3 (connect to GND when not used)
2	DIN2	O	LED drive current control output 2 (connect to GND when not used)
3	DIN1	O	LED drive current control output 1 (connect to GND when not used)
4	ISET	I	LED drive current setting resistor connection
5	C1P	–	Charge pump capacitor connection 1P
6	C1M	–	Charge pump capacitor connection 1M
7	PGND	–	Charge pump ground connection
8	C2M	–	Charge pump capacitor connection 2M
9	C2P	–	Charge pump capacitor connection 2P
10	VREG	–	LED drive current control voltage monitor (Don't connect any lines)
11	VIN	–	Voltage supply
12	VOUT	O	LED driving voltage output
13	SEL2	I	Group setting data input 2
14	SEL1	I	Group setting data input 1
15	EN2	Ip*1	Group B enable data input (High active)
16	EN1	Ip*1	Group A enable data input (High active)
17	DIN6	O	LED drive current control output 6 (connect to GND when not used)
18	DIN5	O	LED drive current control output 5 (connect to GND when not used)
19	DIN4	O	LED drive current control output 4 (connect to GND when not used)
20	GND	–	Ground

*1. Input with built-in pull-down resistor

SPECIFICATIONS

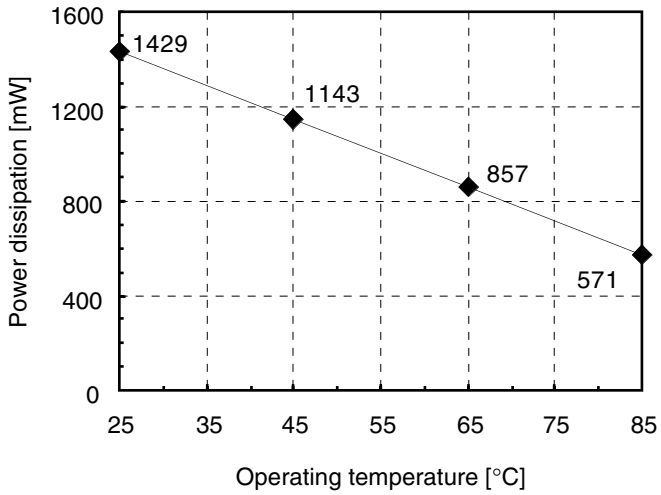
Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit
VIN voltage range	V_{IN}	–0.3 to 6.5	V
Input voltage range	V_{EN}, V_{SEL}	V_{GND} – 0.3 to V_{IN} + 0.3	V
Output voltage range	$V_{DIN1\ to\ 6}$	V_{GND} – 0.3 to V_{IN} + 0.3	V
	V_{OUT}	6.5	V
Power dissipation	P_D	1429 (Ta = 25°C)*1	mW
Operating temperature range	Ta	–30 to 85	°C
Storage temperature range	T_{stg}	–55 to 125	°C

*1. When mounted on a 34 × 40 × 1.6mm glass epoxy board, the power dissipation is related to the operating temperature by the following equation.

- Maximum junction temperature: T_{MAX} = 125°C
- Operating temperature: Ta [°C]
- Thermal resistance: θ_J = 70°C/W

$$P_D = \frac{(T_{MAX} - Ta)}{\theta_J}$$



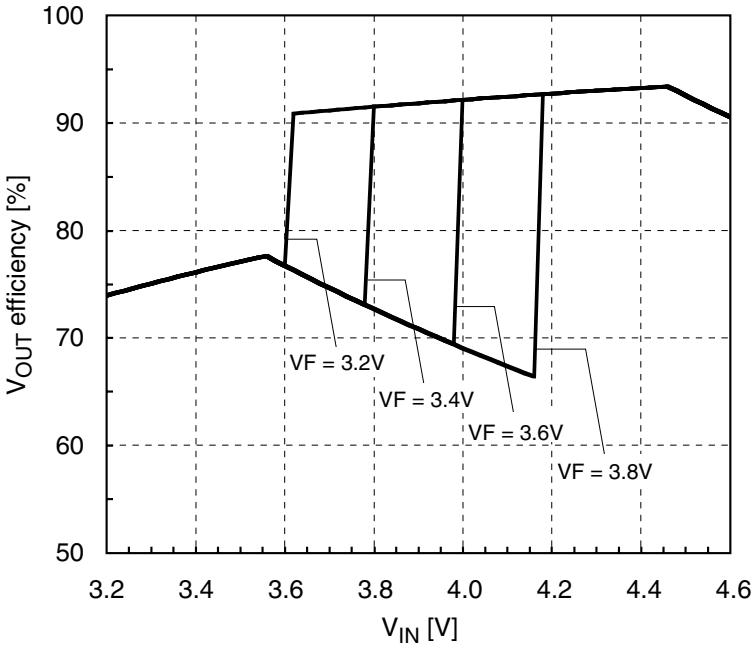
Electrical Characteristics

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

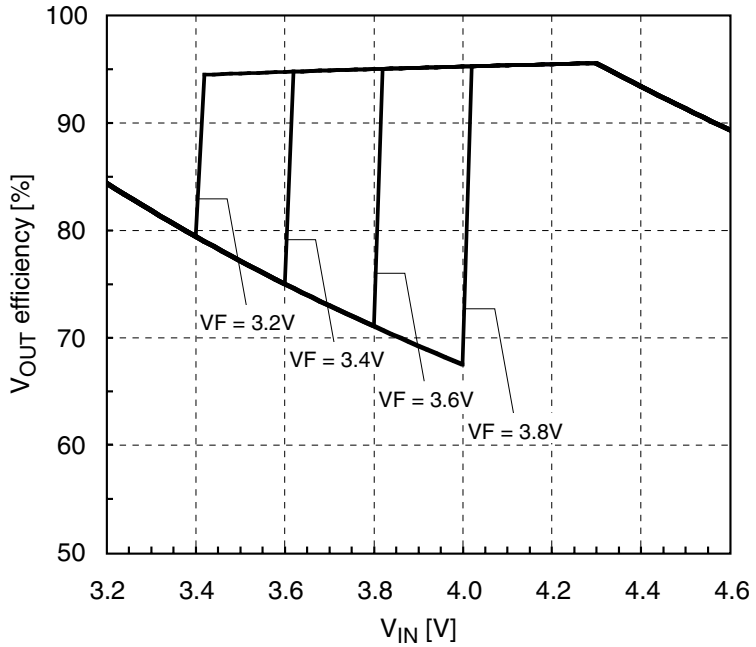
Parameter	Pin	Symbol	Condition	Rating			Unit
				min	typ	max	
Supply voltage range	VIN	V_{IN0}	×1.0 mode, I_{OUT} = 0mA	2.7	3.6	4.6	V
		V_{IN}	×1.5 mode, I_{OUT} = 120mA	3.3	3.6	4.6	V
Standby current	VIN	I_{STB}	Power-save mode	–	0.01	1.00	μA
Quiescent current	VIN	I_{DD1}	×1.0 mode, I_{OUT} = 0mA	–	0.7	1.5	mA
		I_{DD2}	×1.5 mode, I_{OUT} = 0mA	–	2.0	4.0	mA
Output voltage	VOUT	V_{OUT}	×1.5 mode, I_{OUT} = 120mA	4.0	4.2	4.4	V
Maximum output current	VOUT	I_{OUT}	×1.5 mode	–	120	–	mA
Operating frequency	C1M	f_{OSC}	×1.5 mode switching frequency	650	750	850	kHz
Internal power-ON reset time*1	EN	T_{POR}	Time from when power is applied until internal circuits reset	–	0.05	1.0	ms
Soft start time	DIN1 to 6	T_{SS}	EN startup → I_{LED} rising edge	–	1.3	5.0	ms
LED drive pin leakage current	DIN1 to 6	$I_{leak1\ to\ 6}$	Power-save mode, DIN pin = 4.2V	–	0.01	1.00	μA
LED drive current	DIN1 to 6	$I_{LED1\ to\ 6}$	×1.0 mode, RSET = 20kΩ	19.4	20.0	20.6	mA
LED drive current setting resistance*1	ISET	RSET	RSET maximum value	–	–	50	kΩ
Input signal frequency*1	EN1/2	f_{ENIN}	EN input pulse duty 50%, maximum signal input frequency	–	–	150	kHz
Input pulse width*1	EN1/2	T_{ENH}	Minimum EN pulse HIGH-level width	3.0	–	–	μs
		T_{ENL}	Minimum EN pulse LOW-level width	3.0	–	–	μs
Hold time	EN1/2	T_{CEH}	Time from when EN1 = EN2 = LOW until LED drive circuit shutdown	1.17	1.37	1.63	ms
Input voltage	EN1/2, SEL1/2	V_{IH}	HIGH-level input voltage range	1.8	–	–	V
		V_{IL}	LOW-level input voltage range	–	–	0.6	V
Input current	EN1/2	I_{IH}	Pull-down pin, EN pin = 3.6V	–	5.0	10.0	μA

*1. Design guaranteed value

V_{OUT} Efficiency



Efficiency of P_{IN} vs. P_{OUT}
(LED × 6pcs, I_{LED} = 20mA, I_{OUT} = 120mA)



Efficiency of P_{IN} vs. P_{OUT}
(LED × 3pcs, I_{LED} = 15mA, I_{OUT} = 45mA)

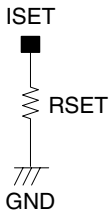
FUNCTIONAL DESCRIPTION

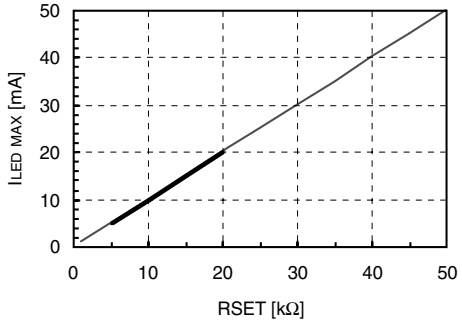
LED Drive Current Setting

The SM8131B LED drive current setting is controlled by the combination of resistance connected to ISET and the EN input signals.

(1) Setting LED Drive Current using RSET

The maximum drive current per LED (when DATA = 1) is determined by the external resistance connected to ISET. For example, if $I_{LED\ MAX}$ = 15mA, from the graph below, a resistance "RSET" of 15kΩ should be connected between ISET and GND. Note that while RSET can have a maximum resistance 50kΩ, the total LED output current must not exceed the maximum output current of 120mA.

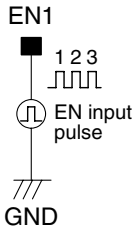


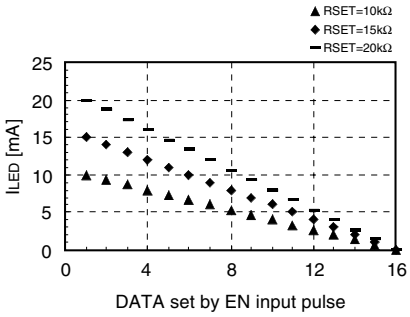


LED drive current maximum setting using RSET

(2) Setting LED Drive Current using EN Input Signals

The EN input ENABLE/DISABLE circuit, also simultaneously counts the number of input pulses using an internal counter and adjusts the LED drive current setting in response. The internal 4-bit counter provides 16-step (DATA = 1 to 16) adjustment, where each step is 1/15th of the maximum current ($I_{LED\ MAX}$) set by RSET. On the 16th pulse (DATA = 16), the LED drive current control circuit shuts down. On the 17th pulse (DATA = 1), the LED drive current is reset to the maximum current value. As the current is set to the maximum value on the first pulse, applications without pulse input can also be employed (by controlling brightness using RSET).





LED drive current setting variation using EN input pulse modulation

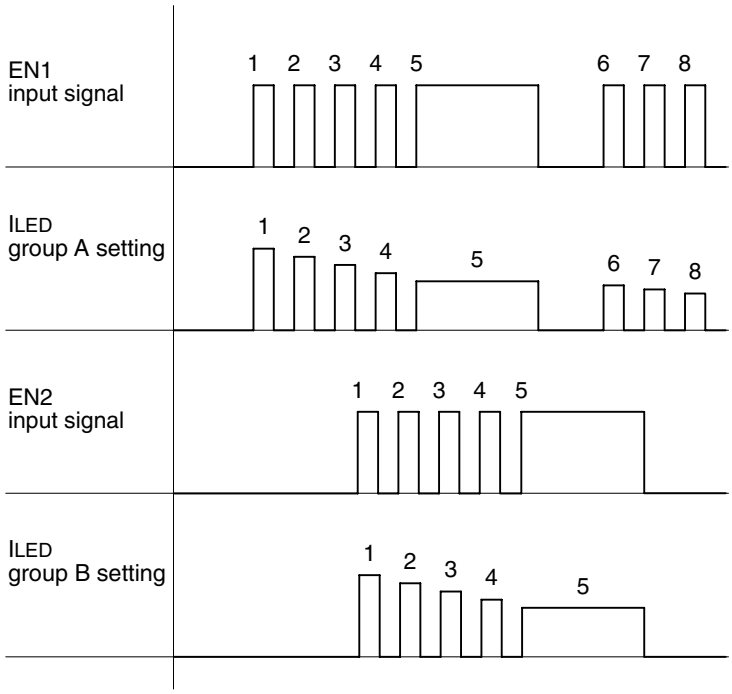
Table. LED drive current setting and EN input pulse count

DATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
EN pulse count	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	51													
I_{LED}	15/15	14/15	13/15	12/15	11/15	10/15	9/15	8/15	7/15	6/15	5/15	4/15	3/15	2/15	1/15	0

EN input signal and LED drive current setting (startup)

An internal startup signal goes HIGH on the first rising edge of either EN1 or EN2, and LED drive current starts after the soft-start time expires. The LED drive current control circuit sets the current by counting the input pulses on EN, hence the EN input voltage must be switched HIGH → LOW → HIGH the required number of data steps to reduce the current setting. When the desired setting is reached, the EN input voltage should be tied HIGH to maintain the setting. Note that the LED drive current does not flow when EN is LOW between pulses, momentarily switching the group of LEDs OFF.

The EN data input circuit operates during the soft-start time when no LED drive current flows, hence the current setting can be adjusted during the soft-start time and the LED drive circuit will then start at the desired current setting. However, setting the current using EN signal pulses is possible only when the power-ON reset ends after a rising edge on the VIN supply. Consequently, a delay of 1ms or greater should be allowed after VIN is applied before starting the EN input signals.

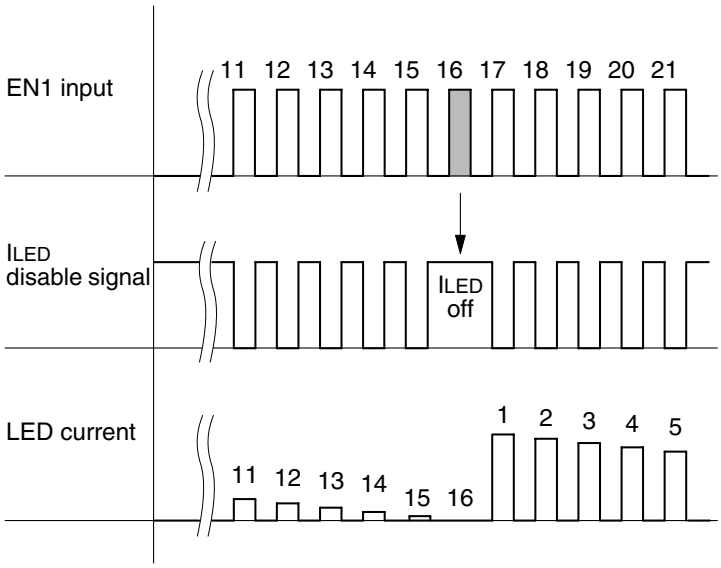


EN input signal and LED drive current setting

- The LED drive current in group A (group B) is set by the number of EN1 (EN2) input signal rising-edge. When either EN1 or EN2 input signal first rises, the internal enable signal CE goes HIGH, and the IC is enabled. The LED drive current control circuit is disabled, and the LED drive current does not flow during EN input signal LOW interval or at startup until after the soft-start time expires.

EN input signal and LED drive current setting (disable interval)

The LED drive current setting due to EN input is set by the 4-bit counter (16 steps). On the 17th pulse, the counter DATA = 1 and the current is reset to the maximum current value. When the counter DATA = 16, I_{LED} = 0mA and the LED drive circuit shuts down.



LED drive current setting disable interval

When both EN1 and EN2 are held LOW for an extended interval, the internal enable signal "CE" goes LOW and the device enters power-save mode. In this mode, the EN input internal counter is reset and subsequent rising-edge pulses on EN restart the counter from DATA = 1.

SEL inputs and LED control groups

The DIN1 to DIN6 6-channel LED drive pins can be divided into two groups of drive pins (EN1 control and EN2 control drive pins) by the state of select inputs SEL1 and SEL2. Two groups with separate LED drive current control using EN1 and EN2 allows a single device to independently adjust the backlight brightness of 2 screens. With a MODE 6:0 setting, EN2 is not used and should be connected to GND. Also, any unused DIN LED drive pins should be connected to GND.

Table. SEL setting and LED drive pin grouping

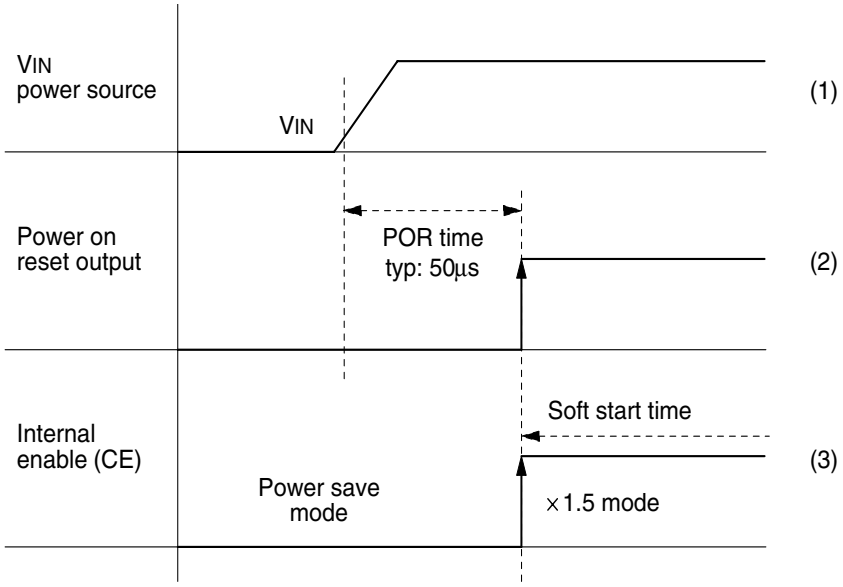
	SEL input		LED control signal					
MODE	SEL1	SEL2	DIN1	DIN2	DIN3	DIN4	DIN5	DIN6
6:0 setting	L	L	EN1	EN1	EN1	EN1	EN1	EN1
5:1 setting	L	H	EN1	EN1	EN1	EN1	EN1	EN2
4:2 setting	H	L	EN1	EN1	EN1	EN1	EN2	EN2
3:3 setting	H	H	EN1	EN1	EN1	EN2	EN2	EN2

V_{OUT} Output Circuit Mode Switching

The SM8131B switches between 3 output states: power-save mode (standby state), ×1.0 mode (VIN through mode), and ×1.5 mode (×1.5 charge pump boost). This automatically adjusts the VOUT output to match the drive LED characteristics and reduces the total power dissipation. Switching to and from ×1.0 and ×1.5 mode occurs automatically in an internal circuit, and cannot be controlled using an external input.

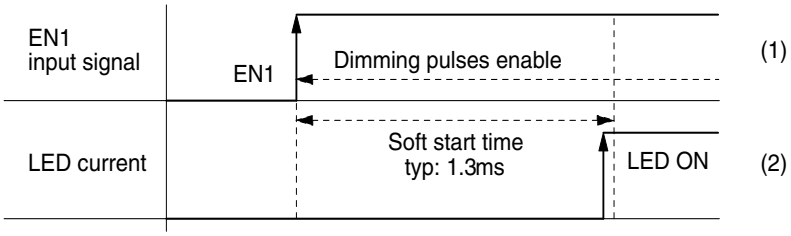
Power-ON internal reset time

The SM8131B switches from standby condition (power-save mode) to normal operating condition (×1.0/×1.5 mode) on the first rising edge of either EN1 or EN2. Note that if the VIN supply voltage is applied when EN1 or EN2 is HIGH, startup occurs after the internal power-ON reset time (approximately 50µs) expires. At start-up, operation commences in ×1.5 mode for a fixed interval during the soft-start time in order to determine whether a LED is connected to each DIN pin.



Power-ON reset operation

(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 EN1 or EN2 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 EN1 and EN2 are LOW when power is applied, the "CE" rising edge occurs simultaneously with the first rising edge.

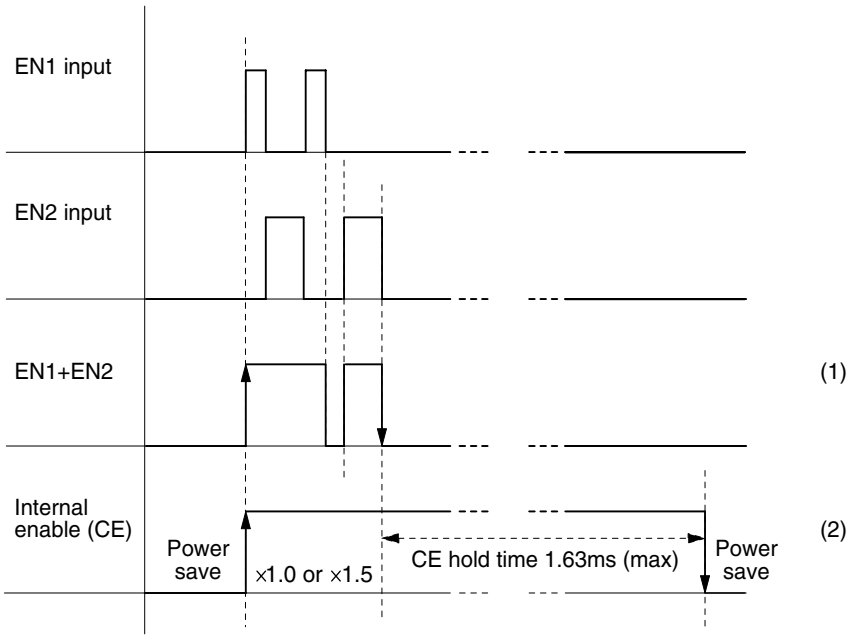


Soft start time and LED current

(1) If the EN signals are input after POR time is expired, the soft start time begin from the first EN input rising edge. The current setting can be adjusted during the soft-start time.
(2) LED current starts flow immediately before the soft start time expires.

Switching to power-save mode

The internal circuit operating mode switches from ×1.0/×1.5 mode to power-save mode when both EN1 and EN2 go LOW and do not switch HIGH for an interval of 1.63ms (max). This function turns the LEDs OFF and automatically transfers internal circuit control to power-save mode, suppressing current consumption.



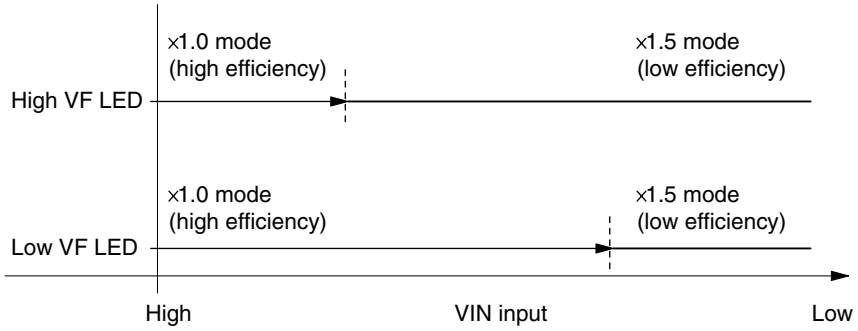
EN input signal and internal enable signal “CE”

(1) If the EN signals are input after power is applied and the POR time has expired, the internal enable signal “CE” switches with the EN1 + EN2 signal.

(2) If the internal enable signal “CE” goes from HIGH to LOW and are held for an interval greater than the “CE” hold time 1.63ms (max), the SM8131B switches to power-save mode. The internal circuits are reset on the “CE” falling edge, and the current setting must be re-established before restart.

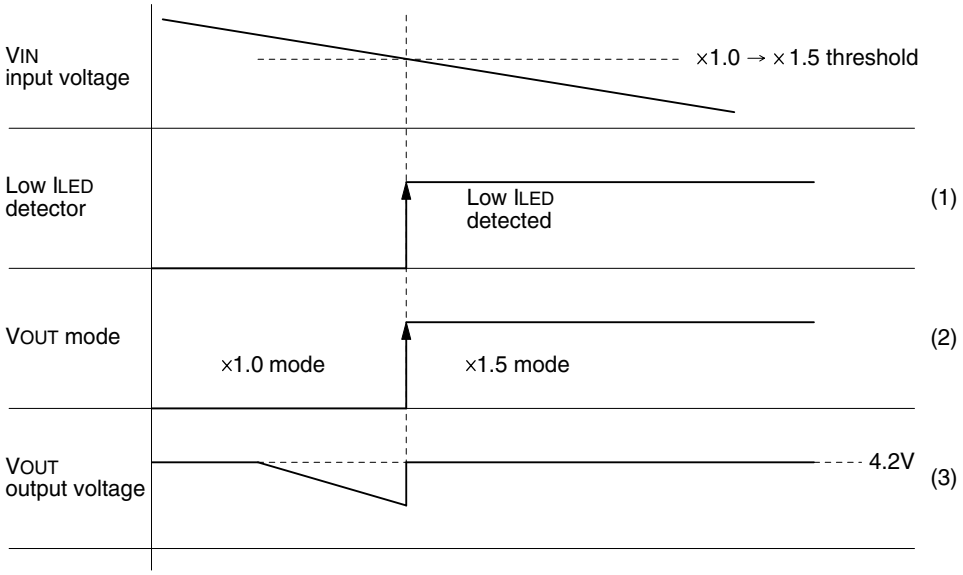
Switching from ×1.0 mode to ×1.5 mode

If the LEDs can be driven solely by the current determined by RSET and EN pulse input without boosting the V_{IN} input voltage, the V_{OUT} output operates in ×1.0 mode. In other words, if sufficient current flows even with the LED forward-direction voltage drop "VF", then V_{OUT} is less than 4.2V. Operation in the more efficient ×1.0 mode reduces the total power dissipation and extends the battery drive time. And if low "VF" LEDs are used or the LED drive current setting is LOW, the operating time in ×1.0 mode is also extended.



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

If the V_{IN} voltage falls or RSET increases such that the LED drive current is too low in ×1.0 mode, then the LED drive circuit low-current detector operates, the V_{OUT} output is automatically switched to ×1.5 mode, and the charge pump boosts the output voltage. This occurs even if only one LED low-current condition is detected among the 6-channel LED drive circuits, thus it is recommended that LEDs have small "VF" variation to optimize the total efficiency.



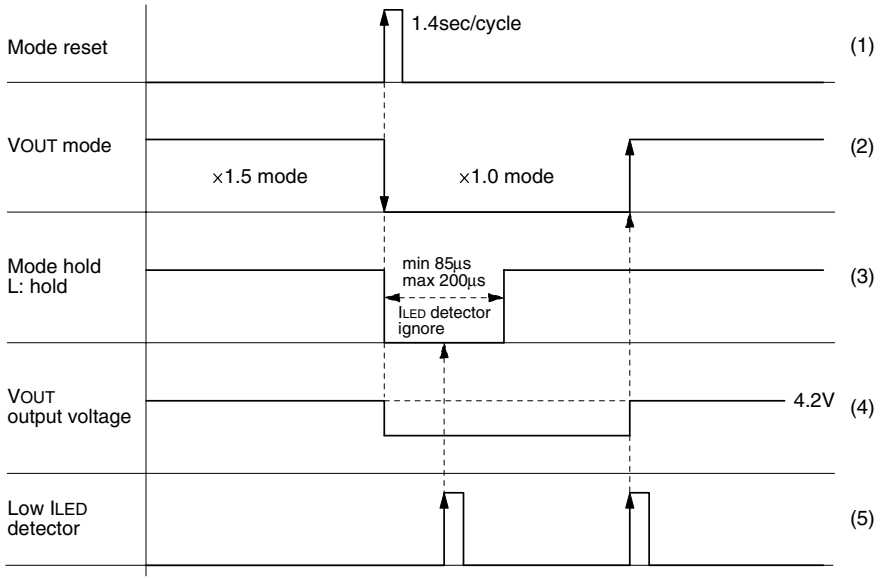
V_{IN} voltage drop and V_{OUT} output voltage

(1) When V_{IN} falls, V_{OUT} cannot overcome the LED "VF" rating, causing insufficient current flows and the I_{LED} low-current signal becomes active.
(2) When the I_{LED} low-current condition is detected, the V_{OUT} output circuit switches to ×1.5 mode (charge pump mode).
(3) Prior to switching to ×1.5 mode, the V_{OUT} voltage may be lower than 4.2V but sufficient current is supplied to the LED.

If after startup, the LED connected to a DIN pin is switched, the LED connection detector circuit flags an error, and correct mode switching may not occur. If the DIN pin does not control the LED drive current, the low-current detector does not operate and the device cannot switch to ×1.5 mode.

Switching from ×1.5 mode to ×1.0 mode

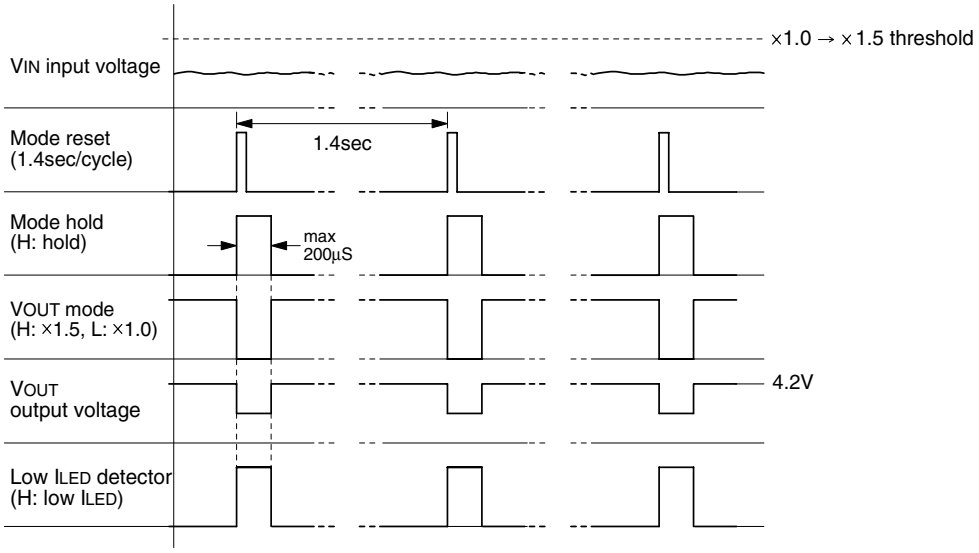
VF increases immediately after the LED current starts to flow, and then decreases as the LED temperature increases due to the heating effect of the current flow. It can take about 10 seconds for the LED temperature to stabilize and for VF to reach equilibrium, and VF may fluctuate more than 200mV. The 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 SM8131B outputs a mode reset signal once every 1.4 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 to ×1.0 mode due to the mode reset signal

(1) Mode reset signal is output once every 1.4 seconds.
(2) Switching from ×1.5 to ×1.0 mode due to the mode reset signal pulse.
(3) The mode hold time of 200µs (max) starts when output switches to ×1.0 mode. During this interval, the mode is not switched even if an I_{LED} undercurrent condition is detected.
(4) If V_{IN} is low, the V_{OUT} voltage momentarily drops because the boost function stops as a result of switching to ×1.0 mode.
(5) The I_{LED} undercurrent signal is ignored during the mode hold time, and the mode only switches in response to the detector output after the mode hold time expires.

For example, if the V_{IN} voltage is low and the V_{OUT} output voltage in ×1.0 mode does not provide sufficient drive current, then the mode reset will cause a LED undercurrent condition. The LED undercurrent detector circuit will output an LED undercurrent signal immediately after the switch to ×1.0 mode, but the output will stay in ×1.0 mode and not return to ×1.5 mode for the duration of the mode hold time. Consequently, the V_{OUT} output is not boosted during the 85µs (min) to 200µs (max) mode hold time and the voltage drops and the LED brightness is reduced. However, the LEDs are OFF for a maximum of 200µs only, and this is not discernible to the naked eye and thus is not a problem.



V_{OUT} drop due to the mode reset single

VIN Input Voltage Range

The V_{IN} minimum input voltage value to ensure rated drive current flows in each LED is determined by the I_{LED} setting (largest setting if divided into 2 groups), the total load current I_{OUT} on pin VOUT, and the LED forward-direction voltage drop "VF", as given in the following equations:

(1) $VF \leq 1.5 \times VIN - 10 \times I_{OUT} - 8 \times I_{LED}$

(2) $VIN \geq (VF + 10 \times I_{OUT} + 8 \times I_{LED})/1.5$

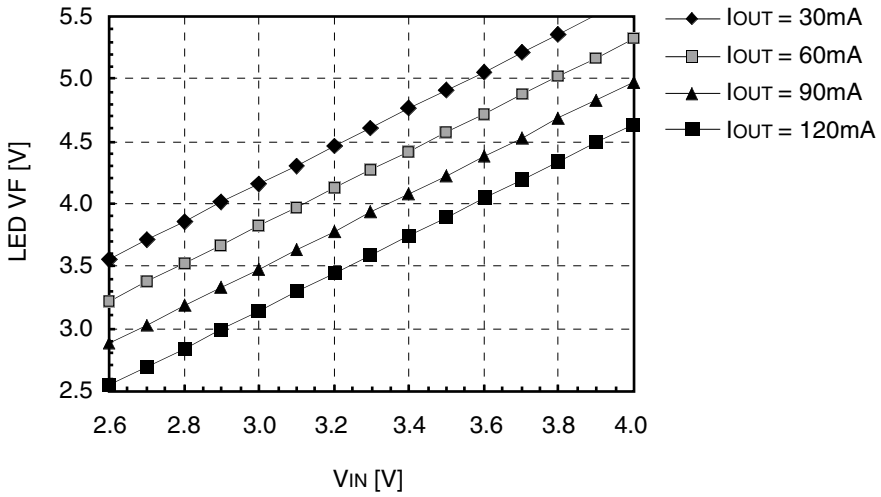
where 1.5 is the charge pump boost factor, 10 is the VOUT output impedance, and 8 is the LED drive circuit internal resistance.

For example, if V_{IN} = 3.5V, I_{LED} = 20mA, and I_{OUT} = 120mA, then VF is given by equation as follows:

$1.5 \times 3.5 - 10 \times 0.12 - 8 \times 0.02 = 3.89$ [V]

Thus if LEDs with VF of 3.89V or lower rating at I_{LED} = 20mA are used, the device will provide sufficient drive current. If V_{IN} falls and the drive LED VF exceeds the calculated value, V_{IN} will take I_{LED} down with it below the required setting.

The relationship in equation is shown graphically for values of I_{OUT} = 30/60/90/120mA.



V_{IN} voltage and LED forward-direction voltage drop limit value

PERIPHERAL PARTS

About the External Capacitors

The best capacitors for use with the SM8131B 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.

About the LED Current Setting Resistor "RSET"

The LED drive current variation depends on the LED drive current setting resistor "RSET" variation. Therefore, a precise resistor is recommended for RSET. The ISET output current value is about 20μA, so a 1/10 watt class resistor is acceptable as the RSET.

TYPICAL APPLICATION CIRCUITS

MODE 6:0 setting

SEL1 = SEL2 = LOW

EN1 = LED control input for group A (ON/OFF and dimmer)

EN2 = LOW

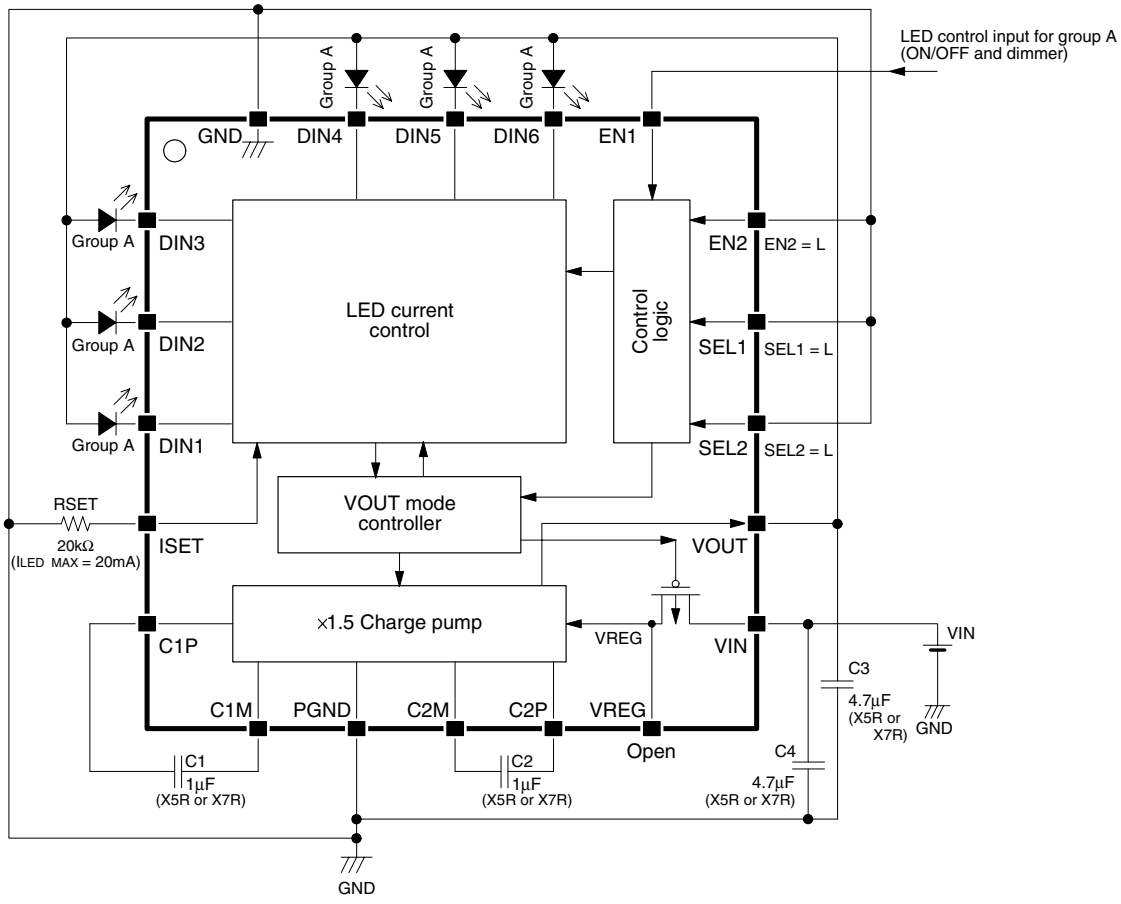
Group A = 6pcs (DIN1, DIN2, DIN3, DIN4, DIN5, DIN6)

Group B = 0pcs

RSET = 20kΩ ($I_{LED\ MAX}$ = 20mA)

C1 = C2 = 1µF (X5R or X7R)

C3 = C4 = 4.7µF (X5R or X7R)



MODE 6:0 setting, $I_{LED\ MAX}$ = 20mA circuit example

MODE 5:1 setting

SEL1 = LOW

SEL2 = HIGH

EN1 = LED control input for group A (ON/OFF and dimmer)

EN2 = LED control input for group B (ON/OFF and dimmer)

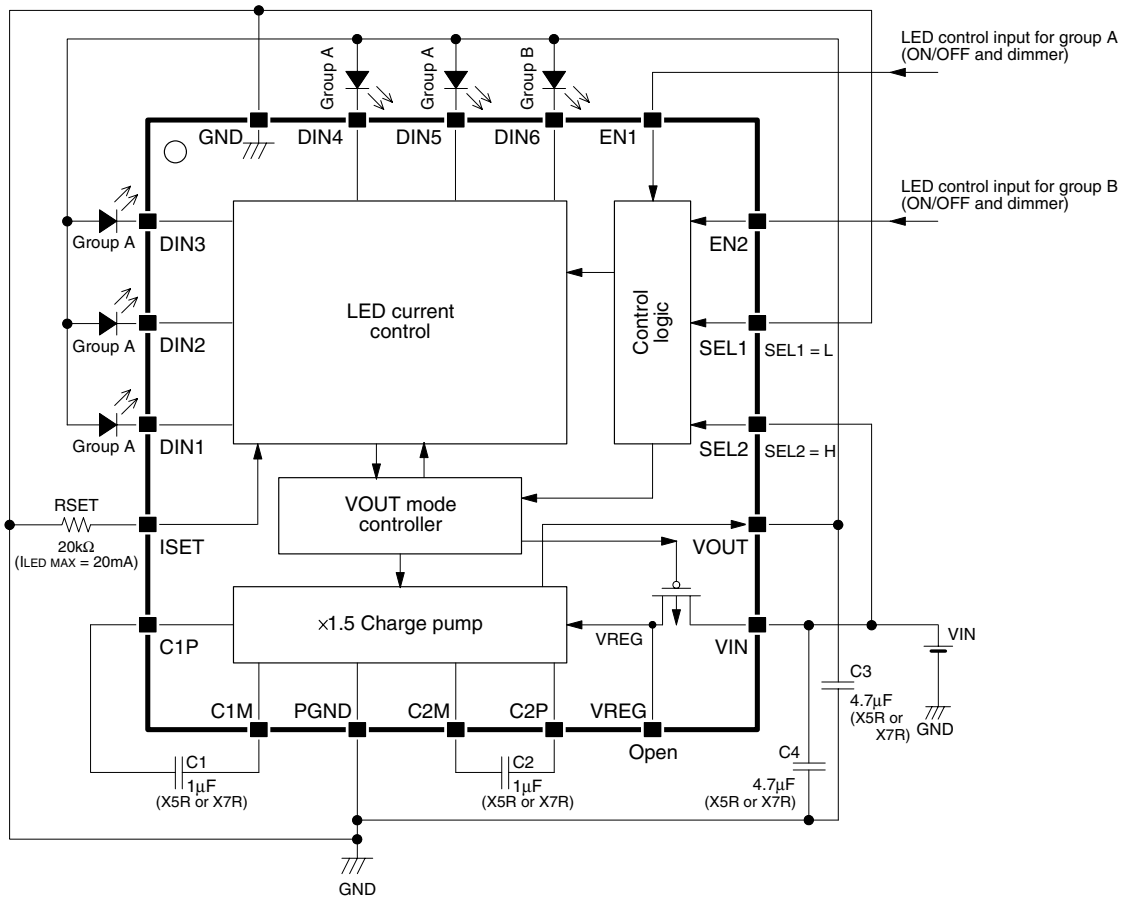
Group A = 5pcs (DIN1, DIN2, DIN3, DIN4, DIN5)

Group B = 1pcs (DIN6)

RSET = 20kΩ ($I_{LED\ MAX}$ = 20mA)

C1 = C2 = 1µF (X5R or X7R)

C3 = C4 = 4.7µF (X5R or X7R)



MODE 5:1 setting, $I_{LED\ MAX}$ = 20mA circuit example

MODE 4:2 setting

SEL1 = HIGH

SEL2 = LOW

EN1 = LED control input for group A (ON/OFF and dimmer)

EN2 = LED control input for group B (ON/OFF and dimmer)

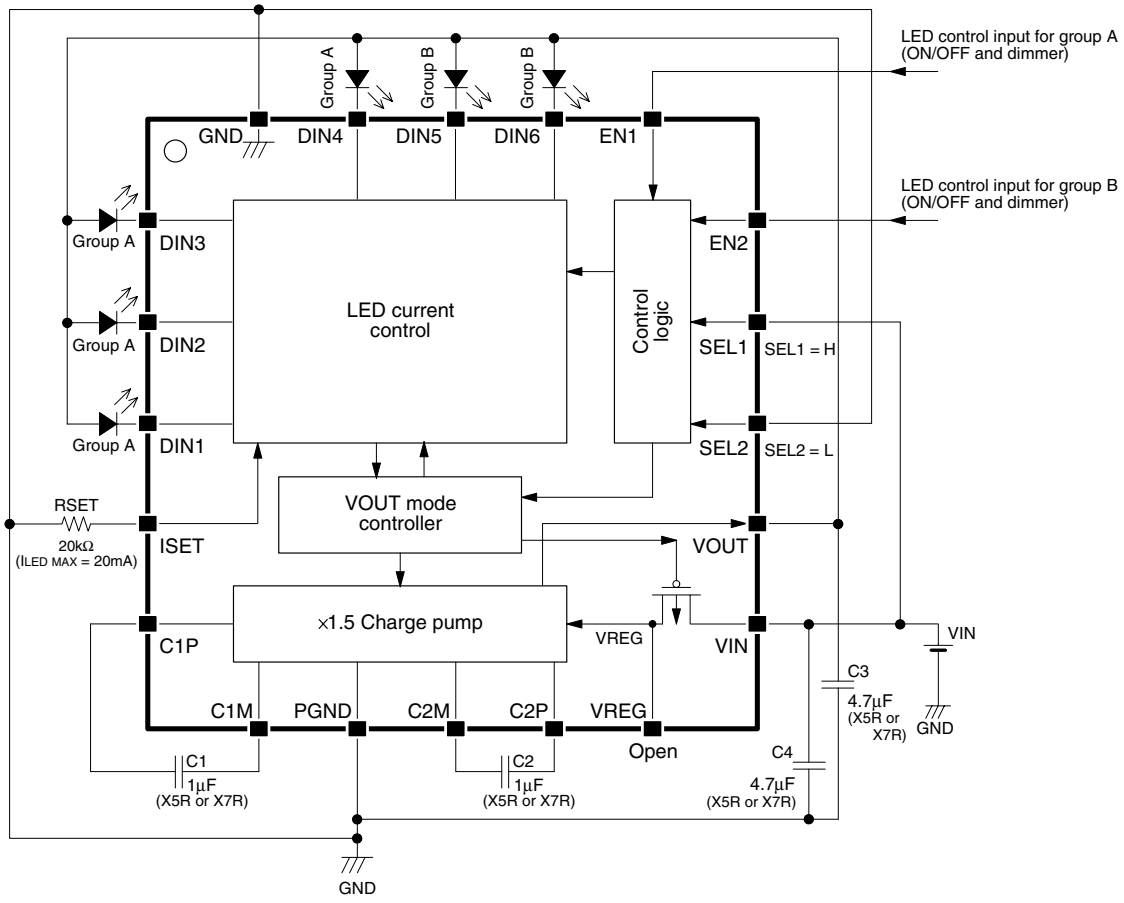
Group A = 4pcs (DIN1, DIN2, DIN3, DIN4)

Group B = 2pcs (DIN5, DIN6)

RSET = 20kΩ ($I_{LED\ MAX}$ = 20mA)

C1 = C2 = 1µF (X5R or X7R)

C3 = C4 = 4.7µF (X5R or X7R)



MODE 4:2 setting, $I_{LED\ MAX}$ = 20mA circuit example

MODE 3:3 setting

SEL1 = SEL2 = HIGH

EN1 = LED control input for group A (ON/OFF and dimmer)

EN2 = LED control input for group B (ON/OFF and dimmer)

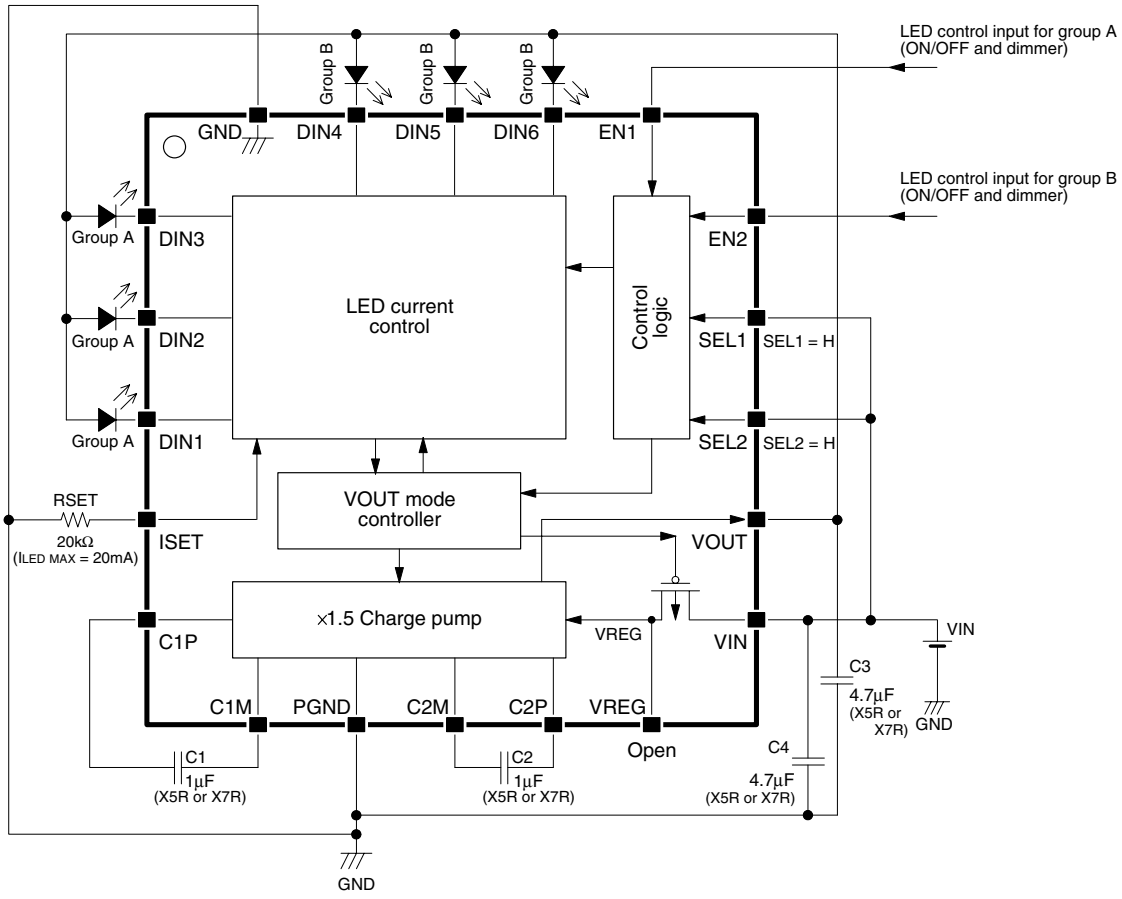
Group A = 3pcs (DIN1, DIN2, DIN3)

Group B = 3pcs (DIN4, DIN5, DIN6)

RSET = 20kΩ ($I_{LED\ MAX}$ = 20mA)

C1 = C2 = 1µF (X5R or X7R)

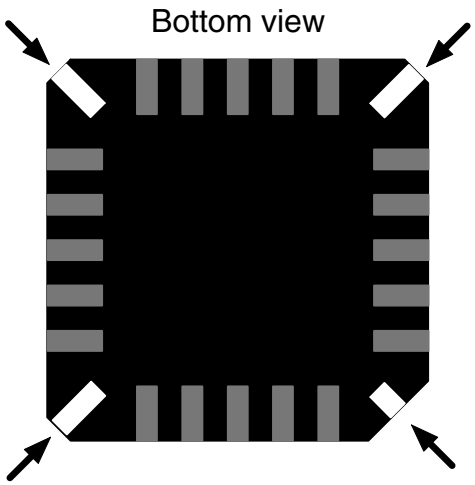
C3 = C4 = 4.7µF (X5R or X7R)



MODE 3:3 setting, $I_{LED\ MAX}$ = 20mA circuit example

ASSEMBLING PRECAUTION

Package corner metals are not IC I/O pins. Don't connect any lines to these corner metals.

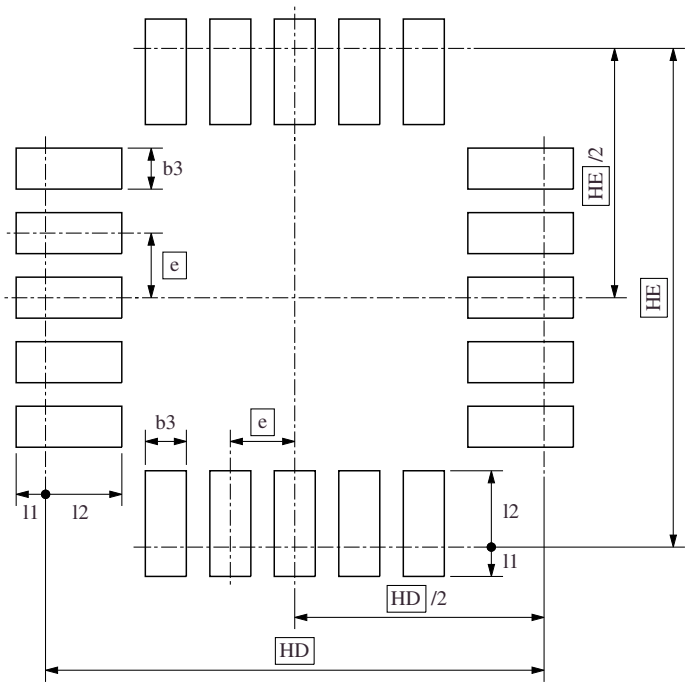


FOOTPRINT PATTERN

The optimum footprint varies depending on the board material, soldering paste, soldering method, and equipment accuracy, all of which need to be considered to meet design specifications.

(Unit: mm)

Package	HE	HD	e	b3	l1	l2
QFN-20	4.2	4.2	0.5	0.30 ± 0.05	0.20 ± 0.05	0.70 ± 0.05



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