

OVERVIEW

The SM8132A is a charge pump DC/DC converter that switches between $\times 1$ and $\times 1.5$ automatically. The SM8132A switches between $\times 1$ and $\times 1.5$ 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 SM8132A can respond to the variation of LED forward voltage. 4-channel of LED drive current control circuit is built-in, the SM8132A can control 1 to 4 lights of white LED, which are connected in parallel. The LED drive current per channel is set up by external resistor. Besides, the input signal controlling of EN pin allows ON/OFF and dimming.

FEATURES

- Battery life extension by automatic charge pump switch between $\times 1$ and $\times 1.5$ 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 (5k Ω :5mA/ch, 15k Ω :15mA/ch, 20k Ω :20mA/ch)
- 1-wire input controlling
- ON/OFF and brightness control by input signal controlling of EN pin
- Soft start circuit built-in
- Thermal shut down circuit built-in
- Supply voltage range
 - No-load current ($I_{OUT} = 0\text{mA}$): 2.7 to 4.6V
 - Load current ($I_{OUT} = 80\text{mA}$): 3.3 to 4.6V
- Maximum output voltage: 4.2V (typ)
- Maximum output current: 80mA (typ)
- Quiescent current
 - Not-switching ($\times 1$ mode): 0.3mA (typ)
 - Switching ($\times 1.5$ mode): 1.0mA (typ)
- Standby current (Power save mode): 0.01 μA (typ)
- Operating frequency ($\times 1.5$ mode): 750kHz (typ)
- LED drive current matching (RSET = 20k Ω): $\pm 3\%$
- Package: 16-pin QFN
WL-CSP (under development)

APPLICATIONS

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

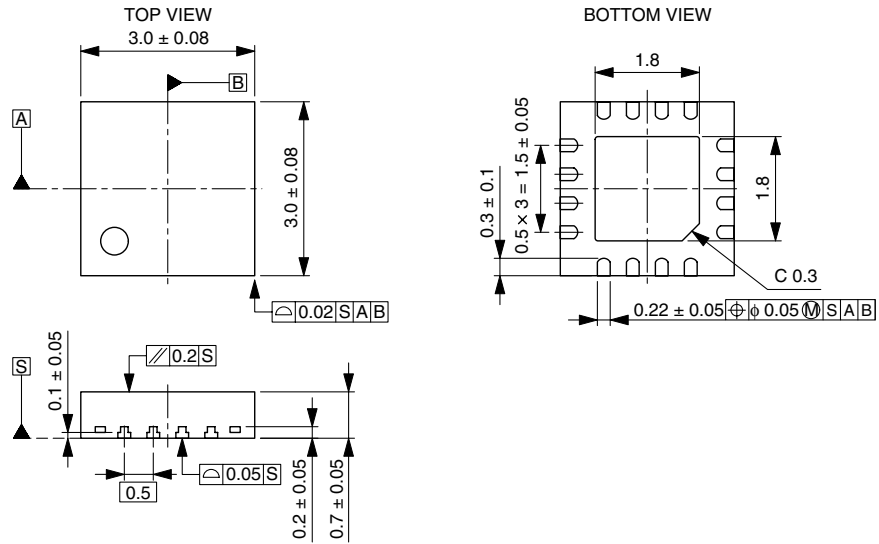
ORDERING INFORMATION

Device	Package
SM8132AB	16-pin QFN
SM8132AW	WL-CSP

PACKAGE DIMENSIONS

(Unit: mm)

QFN-16



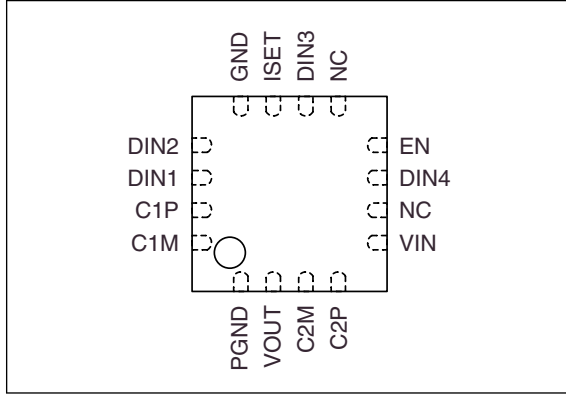
WL-CSP (under development)

TBD

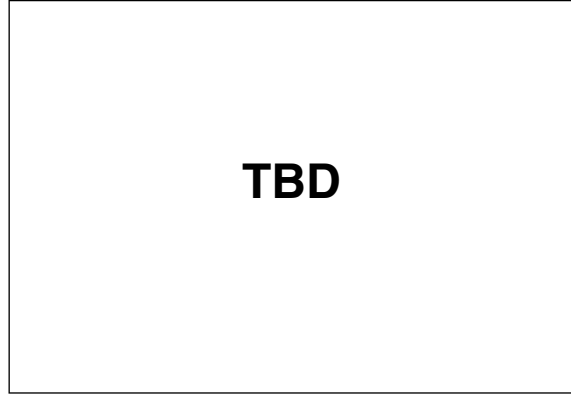
PINOUT

(Top view)

QFN-16



WL-CSP (under development)

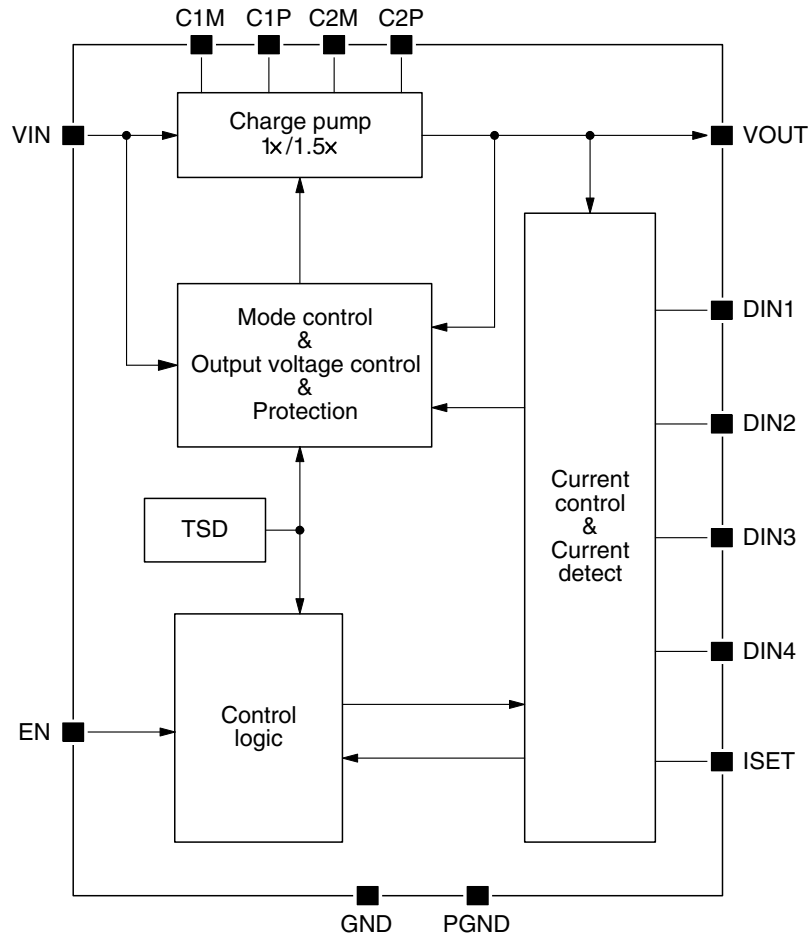


PIN DESCRIPTION

Number		Name	I/O	Description
QFN-16	WL-CSP			
1	-	PGND	-	Charge pump ground connection
2	-	VOUT	O	LED drive voltage output
3	-	C2M	-	Charge pump capacitor connection 2M
4	-	C2P	-	Charge pump capacitor connection 2P
5	-	VIN	-	Voltage supply
6	-	NC	-	No connection
7	-	DIN4	O	LED drive current control output 4 (connect to ground when not used)
8	-	EN	Ip ^{*1}	Enable data input (High active)
9	-	NC	-	No connection
10	-	DIN3	O	LED drive current control output 3 (connect to ground when not used)
11	-	ISET	I	LED drive current setting resistor connection
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	-	C1P	-	Charge pump capacitor connection 1P
16	-	C1M	-	Charge pump capacitor connection 1M

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

BLOCK DIAGRAM



SPECIFICATIONS

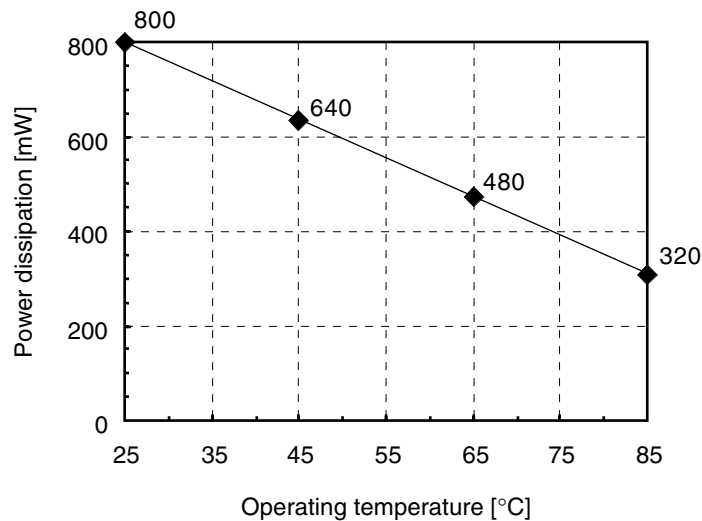
Absolute Maximum Ratings

GND = 0V

Parameter	Symbol	Rating	Unit
VIN voltage range	V_{IN}	-0.3 to 5.5	V
Input voltage range	V_{EN}	$V_{GND} - 0.3$ to $V_{IN} + 0.3$	V
Output voltage range	V_{DIN1} to 4	$V_{GND} - 0.3$ to $V_{IN} + 0.3$	V
	V_{OUT}	5.5	V
VOOUT output current	I_{OUT}	500	mA
Power dissipation	P_D	800 ($T_a = 25^\circ\text{C}$)* ¹	mW
Junction temperature	T_{JMAX}	+125	°C
Storage 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.



Recommended Operating Conditions

GND = 0V

Parameter	Pin	Symbol	Conditions	Rating			Unit
				min	typ	max	
Supply voltage range	VIN	V_{IN0}	×1.0 mode, $I_{OUT} = 0\text{mA}$	2.7	3.6	4.6	V
		V_{IN}	×1.5 mode, $I_{OUT} = 80\text{mA}$	3.3	3.6	4.6	V
Input voltage range	EN	V_{ES}	Each logic-level pin	0	–	V_{IN}	V
Ambient temperature range	–	T_a		-30	–	+85	°C

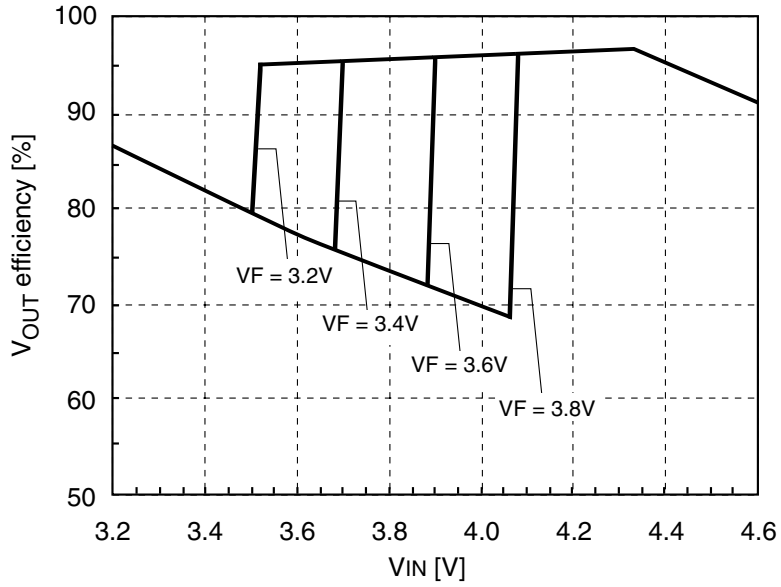
Electrical Characteristics

$V_{IN} = 3.6V$, $GND = 0V$, $T_a = 25^\circ C$ unless otherwise noted.

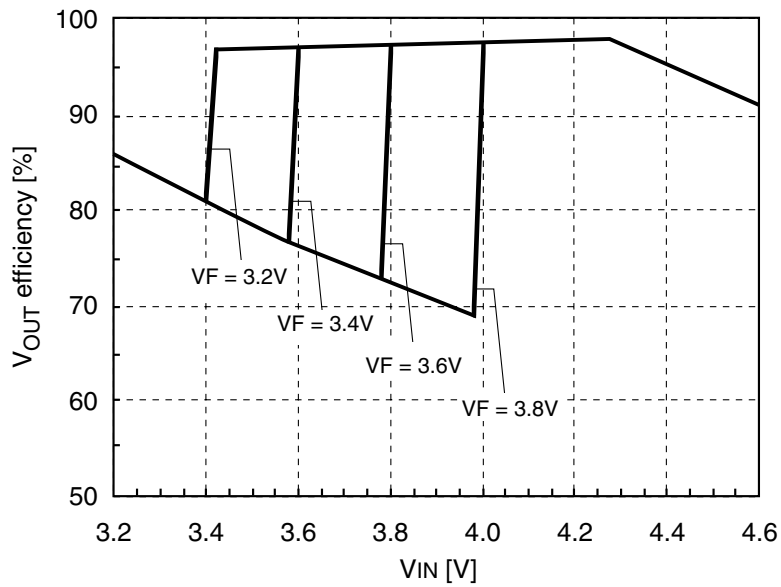
Parameter	Pin	Symbol	Condition	Rating			Unit
				min	typ	max	
Standby current	VIN	I_{STB}	Power-save mode	–	0.01	1.00	μA
Quiescent current	VIN	I_{DD1}	$\times 1.0$ mode, $I_{OUT} = 0mA$	–	0.3	1.0	mA
		I_{DD2}	$\times 1.5$ mode, $I_{OUT} = 0mA$	–	1.0	3.0	mA
Output voltage	VOUT	V_{OUT}	$\times 1.5$ mode, $I_{OUT} = 80mA$	4.0	4.2	4.4	V
Maximum output current	VOUT	I_{OUT}	$\times 1.5$ mode	80	–	–	mA
Operating frequency	C1M	f_{OSC}	$\times 1.5$ 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	1.00	ms
Soft start time	DIN1 to 4	T_{SS}	EN startup \rightarrow I_{LED} rising edge	–	1.3	5.0	ms
LED drive pin leakage current	DIN1 to 4	$I_{leak1\ to\ 4}$	Power-save mode, DIN pin = 4.2V	–	0.01	1.00	μA
LED drive current	DIN1 to 4	$I_{LED1\ to\ 4}$	$\times 1.0$ mode, RSET = 20k Ω	19.0	20.0	21.0	mA
LED drive current matching	DIN1 to 4	ΔI_{LED}	$\times 1.0$ mode, matching between channels with I_{LED} maximum setting	–3.0	–	+3.0	%
LED drive pin voltage	DIN1 to 4	$V_{DIN1\ to\ 4}$	$\times 1.0$ mode, RSET = 20k Ω	–	160	–	mV
LED drive current setting resistance ^{*1}	ISET	RSET	RSET maximum value	–	–	50	k Ω
Input signal frequency ^{*1}	EN	f_{ENIN}	EN input pulse duty 50%, maximum signal input frequency	–	–	150	kHz
Input pulse width ^{*1}	EN	T_{ENH}	Minimum EN pulse HIGH-level width	3.0	–	–	μs
		T_{ENL}	Minimum EN pulse LOW-level width	3.0	–	–	μs
Hold time	EN	T_{CEH}	Time from when EN = LOW until LED drive circuit shutdown	1.17	1.37	1.63	ms
Input voltage	EN	V_{IH}	HIGH-level input voltage range	1.8	–	–	V
		V_{IL}	LOW-level input voltage range	–	–	0.6	V
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

V_{OUT} Efficiency



Efficiency of P_{IN} vs. P_{OUT}
 (LED × 4pcs, I_{LED} = 20mA, I_{OUT} = 80mA)



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

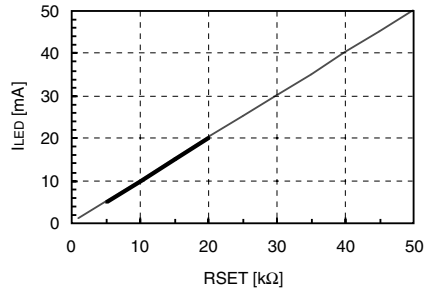
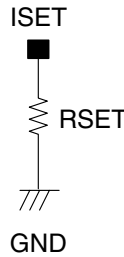
FUNCTIONAL DESCRIPTION

LED Drive Current Setting

The SM8132A 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

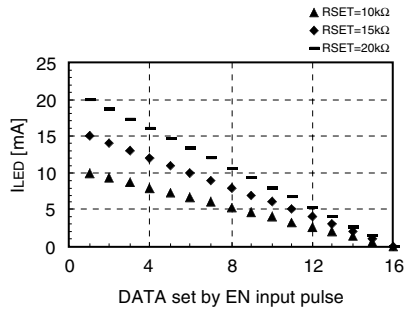
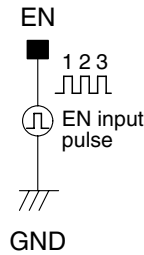
The maximum drive current per LED (when DATA = 1) is determined by the external resistance connected to ISET. For example, if $I_{LED\ MAX} = 15\text{mA}$, from the graph below, a resistance “RSET” of $15\text{k}\Omega$ should be connected between ISET and GND. Note that while RSET can have a maximum resistance $50\text{k}\Omega$, the total LED output current must not exceed the maximum output current of 80mA .



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

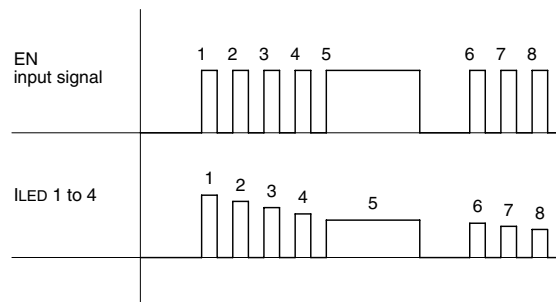
Table. LED drive current setting and EN input pulse count

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 EN, 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.

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.

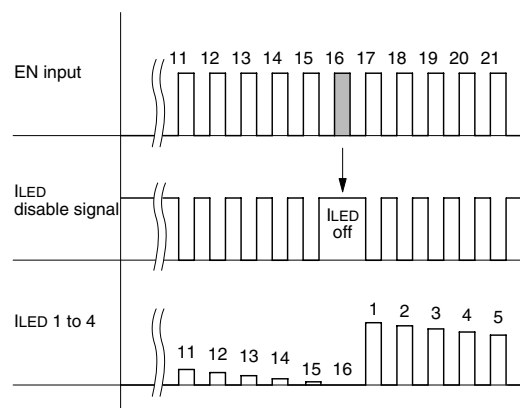


EN input signal and LED drive current setting

- The LED drive current is set by the number of EN input signal rising-edge. 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, $I_{LED} = 0\text{mA}$ and the LED drive circuit shuts down.



LED drive current setting disable interval

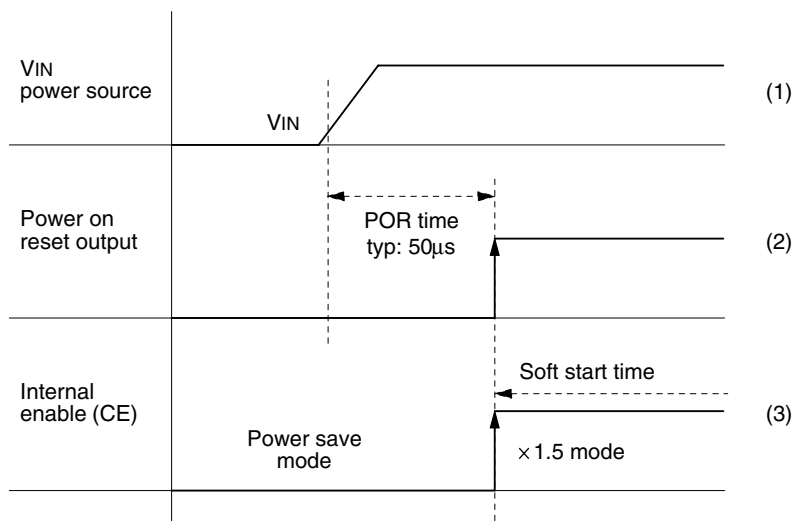
When EN is held LOW for an extended interval, the internal enable signal “CE” goes LOW and the device enters power-save mode. In this mode, the EN input internal counter is reset and subsequent rising-edge pulses on EN restart the counter from DATA = 1.

V_{OUT} Output Circuit Mode Switching

The SM8132A switches between 3 output states: power-save mode (standby state), $\times 1.0$ mode (VIN through mode), and $\times 1.5$ mode ($\times 1.5$ charge pump boost). This automatically adjusts the V_{OUT} output to match the drive LED characteristics and reduces the total power dissipation. Switching to and from $\times 1.0$ and $\times 1.5$ mode occurs automatically in an internal circuit, and cannot be controlled using an external input.

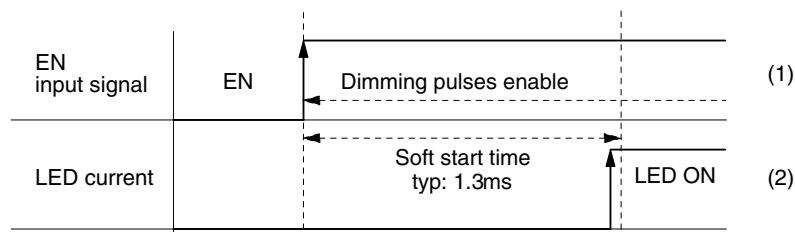
Power-ON internal reset time

The SM8132A switches from standby condition (power-save mode) to normal operating condition ($\times 1.0/\times 1.5$ mode) on the first rising edge of EN. Note that if the VIN supply voltage is applied when EN is HIGH, startup occurs after the internal power-ON reset time (approximately 50 μ s) expires. At startup, operation commences in $\times 1.5$ 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 50 μ s 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.

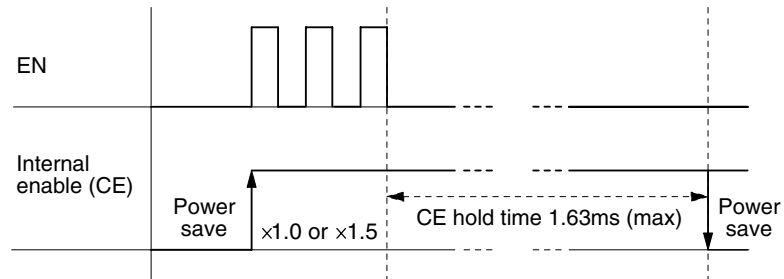


Soft start time and LED current

- (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 $\times 1.0/\times 1.5$ mode to power-save mode when EN goes 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.

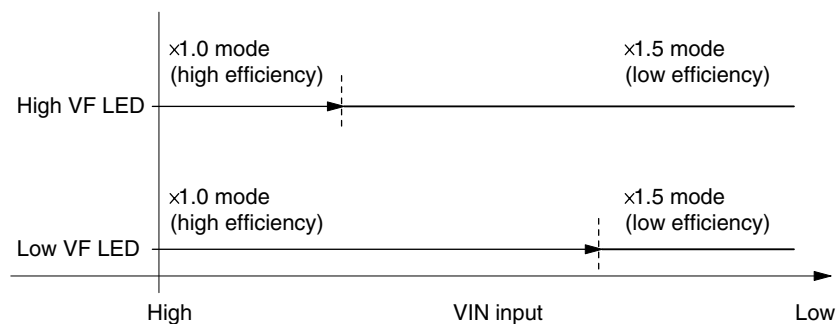


EN input signal and internal enable signal "CE"

- If the EN input signal is held for an interval greater than the "CE" hold time 1.63ms (max), the SM8132A 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.

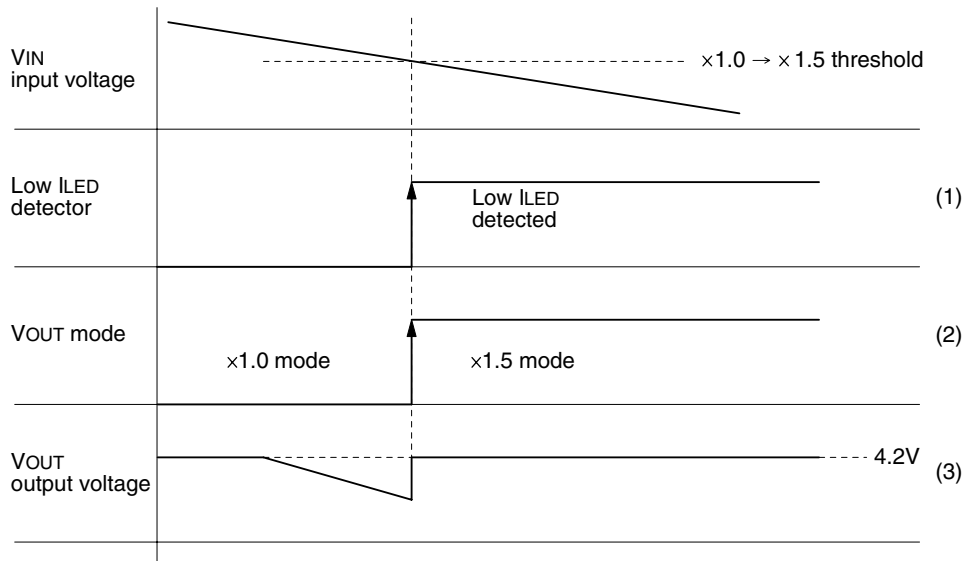
Switching from $\times 1.0$ mode to $\times 1.5$ mode

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 $\times 1.0$ 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 $\times 1.0$ 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 $\times 1.0$ 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 $\times 1.0$ mode, then the LED drive circuit low-current detector operates, the V_{OUT} output is automatically switched to $\times 1.5$ mode, and the charge pump boosts the output voltage. This occurs even if only one LED low-current condition is detected among the 4-channel LED drive circuits, thus it is recommended that LEDs have small "VF" variation to optimize the total efficiency.



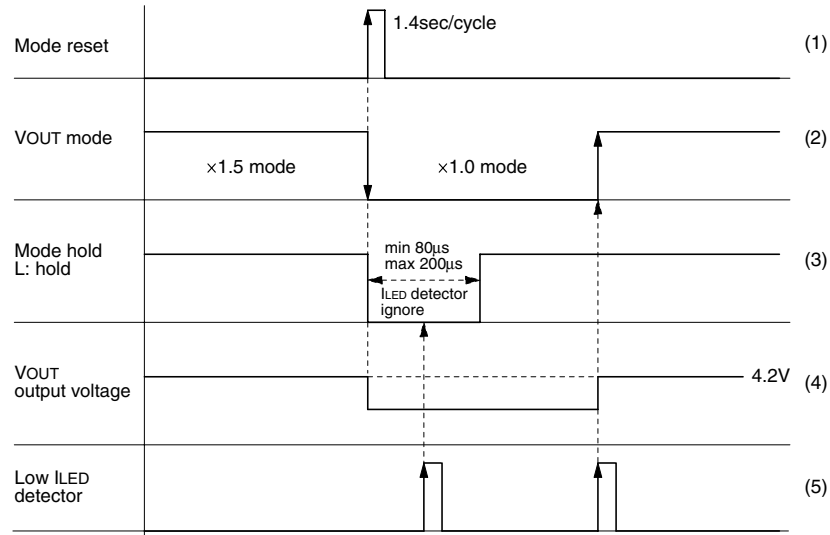
V_{IN} voltage drop and V_{OUT} output voltage

- (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 $\times 1.5$ mode (charge pump mode).
- (3) Prior to switching to $\times 1.5$ 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 $\times 1.5$ mode.

Switching from $\times 1.5$ mode to $\times 1.0$ mode

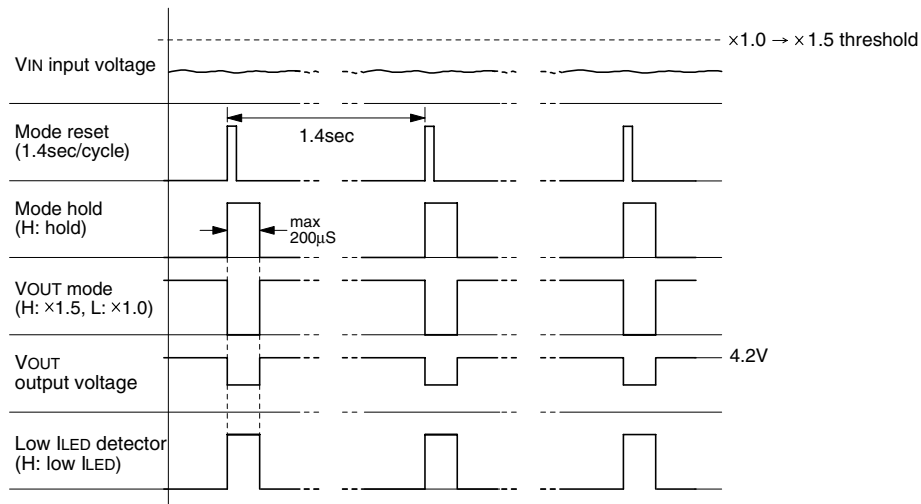
V_F increases immediately after the LED current starts to flow, and then decreases as the LED temperature increases due to the heating effect of the current flow. It can take about 10 seconds for the LED temperature to stabilize and for V_F to reach equilibrium, and V_F may fluctuate more than 200mV. The V_F fluctuation is affected by the ambient temperature and LED current setting, and has a large effect on the automatic mode switching voltage tolerances. To counter the effects of V_F fluctuation, the SM8132A outputs a mode reset signal once every 1.4 seconds which automatically switches the output mode to $\times 1.0$, and then a determination is made whether to make the $\times 1.0 \rightarrow \times 1.5$ mode switch.



Switching from $\times 1.5$ to $\times 1.0$ mode due to the mode reset signal

- (1) Mode reset signal is output once every 1.4 seconds.
- (2) Switching from $\times 1.5$ to $\times 1.0$ mode due to the mode reset signal pulse.
- (3) The mode hold time of 200 μ s (max) starts when output switches to $\times 1.0$ 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 $\times 1.0$ 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 $\times 1.0$ 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 $\times 1.0$ mode, but the output will stay in $\times 1.0$ mode and not return to $\times 1.5$ mode for the duration of the mode hold time. Consequently, the V_{OUT} output is not boosted during the $85\mu\text{s}$ (min) to $200\mu\text{s}$ (max) mode hold time and the voltage drops and the LED brightness is reduced. However, the LEDs are OFF for a maximum of $200\mu\text{s}$ 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

PERIPHERAL PARTS

About the External Capacitors

The best capacitors for use with the SM8132A 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

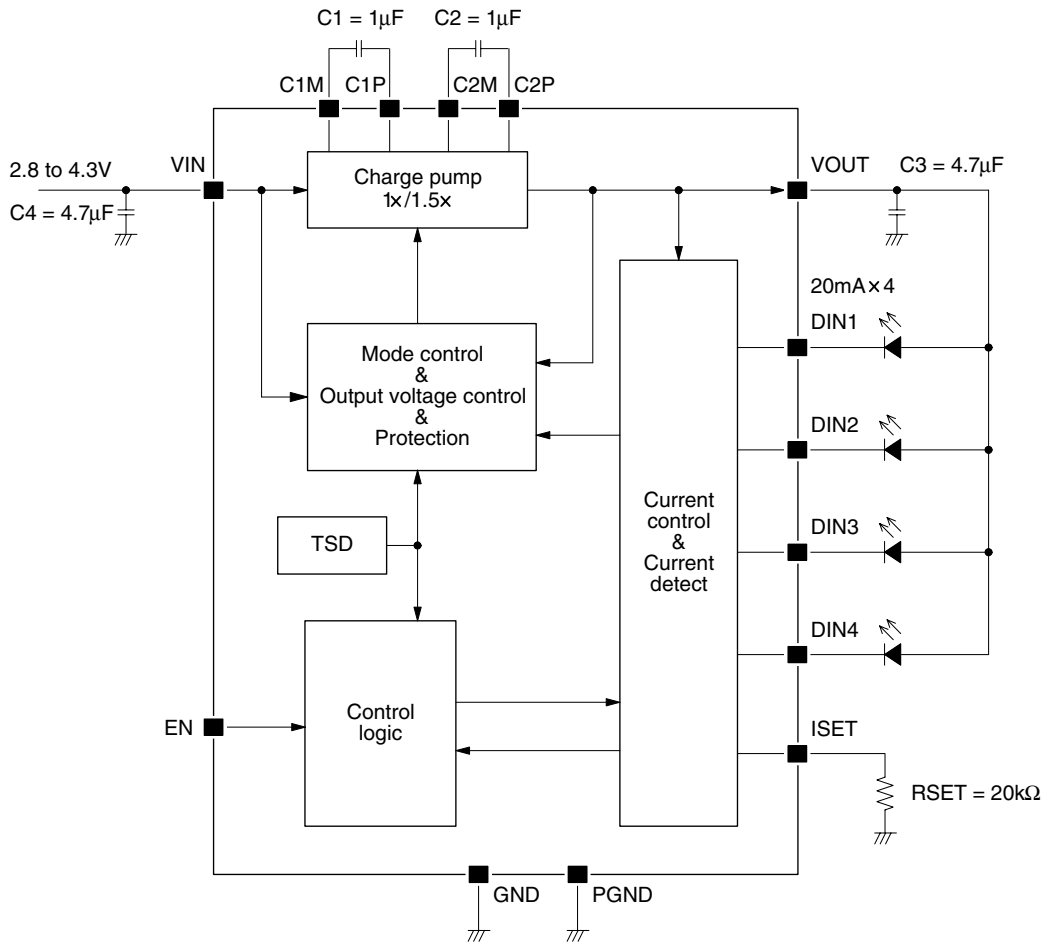
About the Input Capacitor "C4"

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.

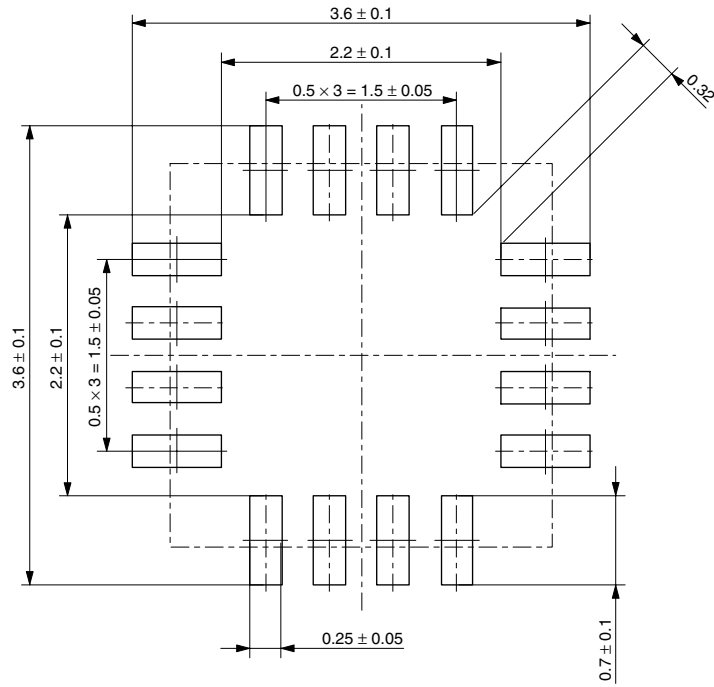
TYPICAL APPLICATION CIRCUITS



$I_{LED\ MAX} = 20mA$ circuit example

Note. If the driving LED is less than 4 pcs, unused DIN pins should be connect to GND.

FOOTPRINT PATTERN



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