

OVERVIEW

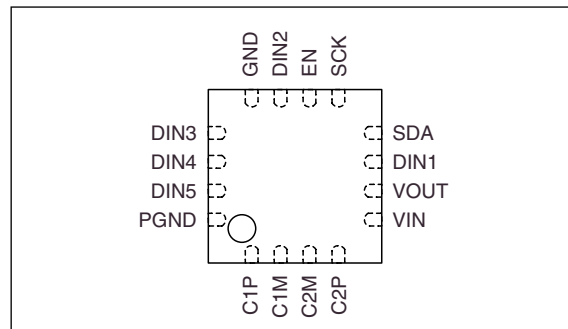
The SM8134A is a charge pump type white LED driver. It can drive 1 to 4 backlight white LED connected in parallel and 1 flash white LED, making the device ideal for camera-equipped cellular phones. The charge pump switches between $\times 1$ to $\times 1.5$ boost mode in response to LED drive current requirements to extend battery life to the maximum. 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). Each LED drive current is controlled by a 5-channel LED drive current control circuit. The backlight LED drive current and ON/OFF control, and flash LED drive current and ON/OFF control are all set by 3-wire serial interface data input. Also, an under voltage lockout (UVLO) circuit is built-in to prevent incorrect operation when the battery voltage drops.

FEATURES

- Noise reduction due to charge pump boost circuit
- Automatic charge pump switching to conserve power
- Drives 1 to 4 backlight white LED (30mA/ch at maximum setting)
- Drives a flash white LED (150mA at maximum setting)
- Backlight and flash white LED brightness adjustment
- 3-wire serial input interface for all setting and control
- Under voltage lockout (UVLO) circuit built-in
- Soft start circuit built-in
- Thermal protection circuit built-in
- Input voltage range
 - No-load current ($I_{OUT} = 0\text{mA}$): 2.7 to 4.6V
 - Load current ($I_{OUT} = 80\text{mA}$): 3.0 to 4.6V
 - Load current ($I_{OUT} = 180\text{mA}$): 3.3 to 4.6V
 - Load current ($I_{OUT} = 200\text{mA}$): 3.4 to 4.6V
- Quiescent current
 - Not-switching ($\times 1.0$ mode): 0.3mA (typ)
 - Switching ($\times 1.5$ mode): 1.7mA (typ)
- Standby current: 0.01 μA (typ)
- Operating frequency: 750kHz (typ)
- Maximum backlight LED current: 30mA/ch
- Maximum flash LED current: 150mA
- All LED total maximum current: 200mA
- Backlight LED current matching ($I_{LED} = 20\text{mA}$) : $\pm 3\%$
- Flash LED current accuracy ($I_{LED} = 150\text{mA}$) : $\pm 6.7\%$
- Packages: 16-pin QFN

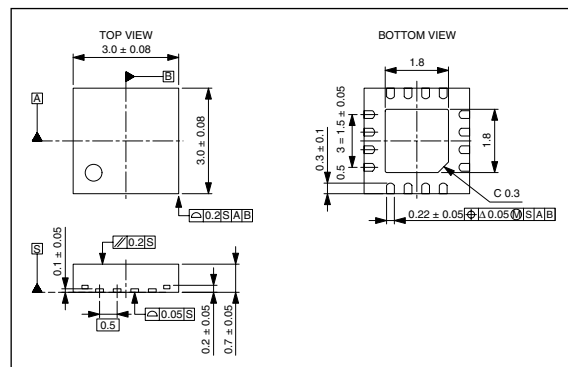
PINOUT

(Top view)



PACKAGE DIMENSION

(Unit: mm)



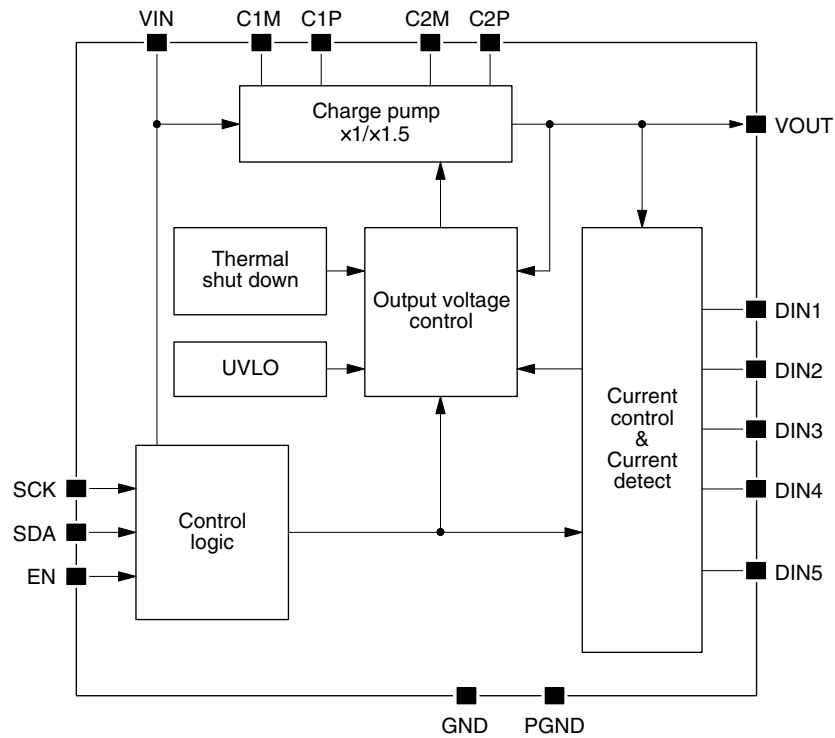
APPLICATIONS

- Cellular phone
- Digital still camera
- PDA
- Portable games

ORDERING INFORMATION

Device	Package
SM8134AB	16-pin QFN

BLOCK DIAGRAM



PIN DESCRIPTION

Number	Name	I/O	Description
1	C1P	-	Charge pump capacitor connection 1P
2	C1M	-	Charge pump capacitor connection 1M
3	C2M	-	Charge pump capacitor connection 2M
4	C2P	-	Charge pump capacitor connection 2P
5	VIN	-	Voltage supply
6	VOUT	O	LED drive voltage output
7	DIN1	O	LED drive current control output 1 (connect to ground when not used)
8	SDA	I	Serial data input
9	SCK	I	Serial data clock input
10	EN	I	Serial interface enable input
11	DIN2	O	LED drive current control output 2 (connect to ground when not used)
12	GND	-	Ground
13	DIN3	O	LED drive current control output 3 (connect to ground when not used)
14	DIN4	O	LED drive current control output 4 (connect to ground when not used)
15	DIN5	O	LED drive current control output 5 (connect to ground when not used)
16	PGND	-	Charge pump ground connection

SPECIFICATIONS

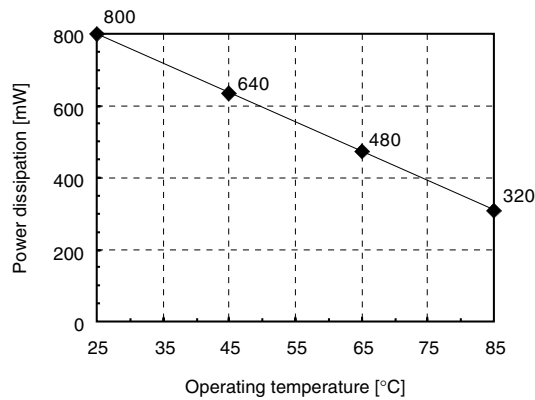
Absolute Maximum Ratings

GND = PGND = 0V

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

Parameter	Symbol	Rating	Unit
Supply voltage range	V_{IN}	-0.3 to 5.5	V
Input voltage range	V_{EN}, V_{SCK}, V_{SDA}	-0.3 to $V_{IN} + 0.3$	V
Output voltage range	$V_{DIN1 \text{ to } 5}$	-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.



Recommended Operating Conditions

GND = PGND = 0V

Parameter	Pin	Symbol	Conditions	Rating			Unit
				min	typ	max	
Supply voltage range	VIN	V_{IN1}	×1.0 mode, $I_{OUT} = 0\text{mA}$	2.7	3.6	4.6	V
		V_{IN2}	×1.5 mode, $I_{OUT} = 80\text{mA}$, $V_F = 3.5\text{V}^{*1}$	3.0	3.6	4.6	V
		V_{IN3}	×1.5 mode, $I_{OUT} = 180\text{mA}$, $V_F = 3.5\text{V}^{*1}$	3.3	3.6	4.6	V
		V_{IN4}	×1.5 mode, $I_{OUT} = 200\text{mA}$, $V_F = 3.5\text{V}^{*1}$	3.4	3.6	4.6	V
Input voltage range	EN, SCK, SDA	V_{ES}	Each logic-level pin	0	—	V_{IN}	V
Ambient temperature range	—	T_a		-30	—	+85	°C

*1. The maximum value of V_F in the drive LED

Electrical Characteristics

DC Characteristics

GND = 0V, $V_{IN} = 3.6V$, $T_a = 25^\circ C$ 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	VIN	I_{DD1}	$\times 1.0$ mode, no load	–	0.3	1.0	mA
		I_{DD2}	$\times 1.5$ mode, no load	–	1.7	4.0	mA
Maximum output voltage	VOUT	V_{OUT}	$\times 1.5$ mode VOUT maximum voltage	4.6	4.9	5.2	V
Maximum output current	VOUT	I_{OUT}	$\times 1.5$ mode	200	–	–	mA
Operating frequency	C1M	f_{OSC}	$\times 1.5$ mode switching frequency	650	750	850	kHz
Internal circuit power-ON reset time ^{*1}	VIN	T_{POR}	Time from when power is applied until internal circuit reset	–	0.05	1.0	ms
Soft start time	DIN1 to 5	T_{SS}	Time between EN signal falling edge and LED turning ON	–	1.0	3.0	ms
LED drive pin leakage current	DIN1 to 5	$I_{LEAK1\ to\ 5}$	Standby mode, $V_{DIN1\ to\ 5} = V_{IN}$	–	0.01	1.00	μA
LED drive current matching	DIN1 to 4	ΔI_{LED}	$\times 1.0$ mode, matching between channels with $I_{LED1\ to\ 4} = 20mA$ setting	–3.0	–	+3.0	%
LED drive current 1	DIN1 to 4	$I_{LED1\ to\ 4}$	$\times 1.0$ mode, $I_{LED1\ to\ 4} = 20mA$ setting	19.0	20.0	21.0	mA
LED drive pin voltage 1 ^{*2}	DIN1 to 4	$V_{DIN1\ to\ 4}$	$I_{LED1\ to\ 4} = 20mA$ setting	–	160	–	mV
LED drive current 2	DIN5	I_{LED5}	$\times 1.5$ mode, I_{LED5} maximum setting	140	150	160	mA
LED drive pin voltage 2 ^{*2}	DIN5	V_{DIN5}	I_{DIN5} maximum setting	–	400	–	mV
Under voltage lockout threshold ^{*3}	–	V_{UV}	V_{IN} falling	1.6	1.9	2.2	V
Thermal protection circuit operating temperature ^{*1}	–	T_{SD}		–	170	–	$^\circ C$
Thermal protection circuit hysteresis ^{*1}	–	T_{SDHYS}		–	20	–	$^\circ C$
Logic-level input voltage	EN, SCK, SDA	V_{IH}	HIGH-level input voltage range	1.8	–	–	V
		V_{IL}	LOW-level input voltage range	–	–	0.6	V
Logic-level input current	EN, SCK, SDA	I_{IL}	EN = SCK = SDA = VIN	–	–	1.0	μA
		I_{IH}	EN = SCK = SDA = GND	–1.0	–	–	μA

*1. Design guaranteed value

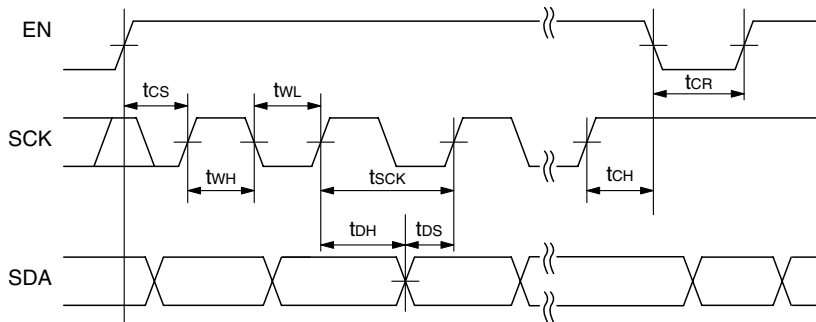
*2. Pin voltage value which switching $\times 1.0$ mode to $\times 1.5$ mode when LED current shortage detection

*3. When UVLO is active, the output is stopped and internal register is reset.

AC Characteristics

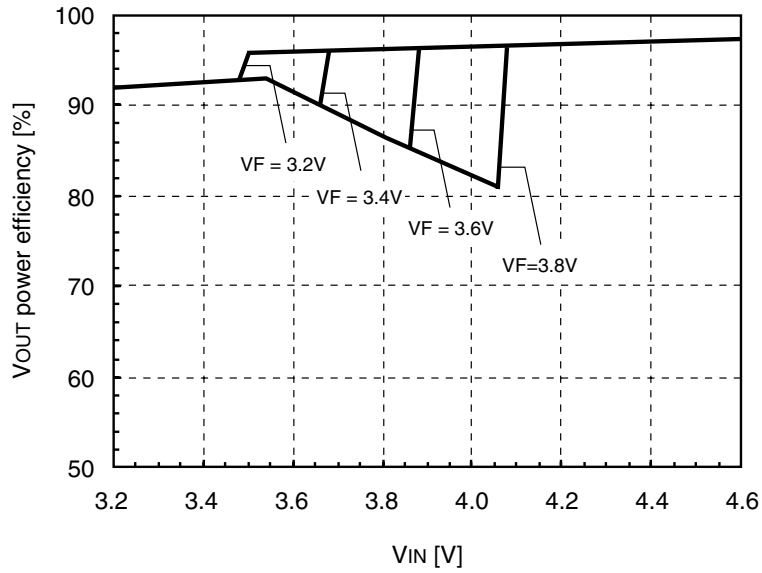
GND = 0V, $V_{IN} = 3.6V$, $T_a = 25^\circ C$ unless otherwise noted.

Parameter	Symbol	Condition	Rating			Unit
			min	typ	max	
SCK clock cycle	t_{SCK}		2000	–	DC	ns
SCK HIGH-level pulse width	t_{WH}		800	–	–	ns
SCK LOW-level pulse width	t_{WL}		800	–	–	ns
EN setup time	t_{CS}		1000	–	–	ns
EN hold time	t_{CH}		800	–	–	ns
EN recovery time	t_{CR}		1000	–	–	ns
Write data setup time	t_{DS}		600	–	–	ns
Write data hold time	t_{DH}		600	–	–	ns

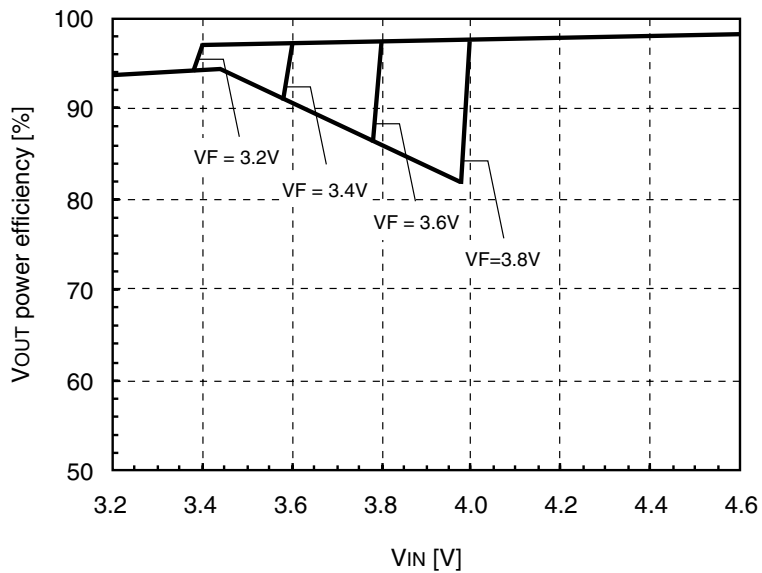


Data input timing diagram

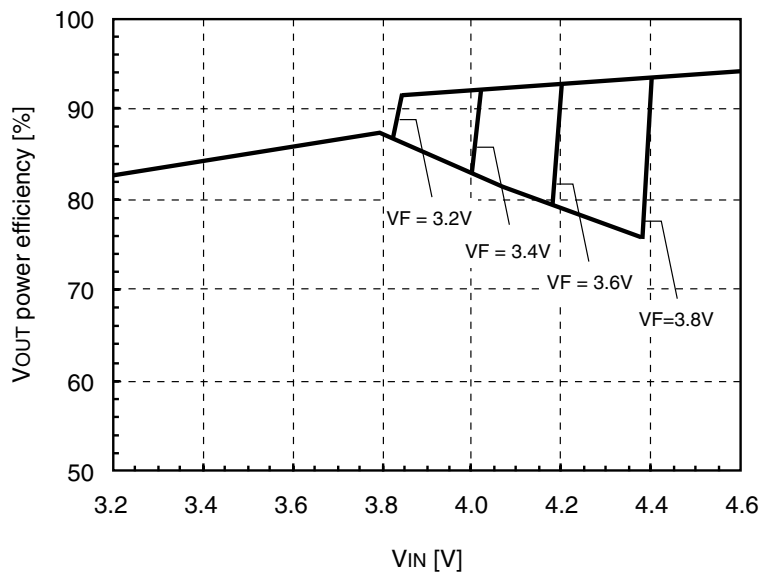
V_{OUT} EFFICIENCY



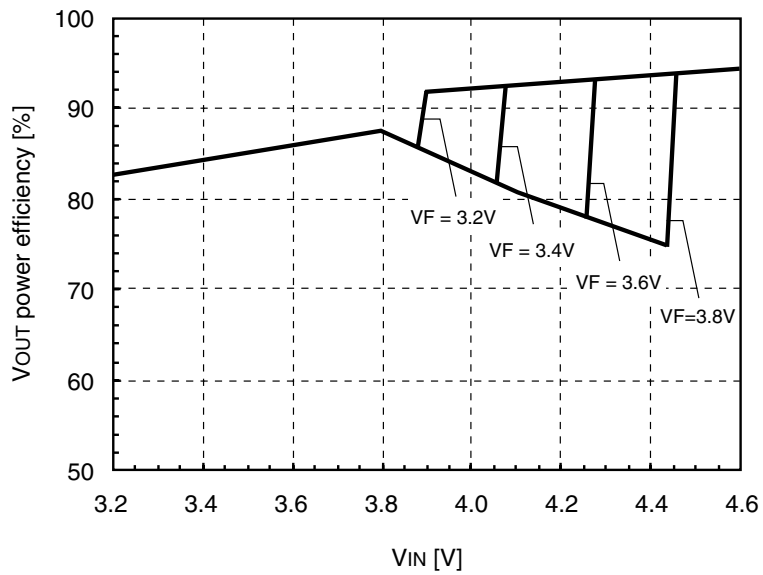
Efficiency of P_{IN} vs. P_{OUT}
 Backlight LED × 4pcs, I_{LED1 to 4} = 20mA,
 Flash LED × 1pc, I_{LED5} = 0mA,
 I_{OUT} = 80mA



Efficiency of P_{IN} vs. P_{OUT}
 Backlight LED × 3pcs, I_{LED1 to 4} = 16mA,
 Flash LED × 1pc, I_{LED5} = 0mA,
 I_{OUT} = 48mA



Efficiency of P_{IN} vs. P_{OUT}
 Backlight LED \times 4pcs, $I_{LED1\text{ to }4} = 20\text{mA}$,
 Flash LED \times 1pc, $I_{LED5} = 120\text{mA}$,
 $I_{OUT} = 200\text{mA}$



Efficiency of P_{IN} vs. P_{OUT}
 Backlight LED \times 3pcs, $I_{LED1\text{ to }4} = 16\text{mA}$,
 Flash LED \times 1pc, $I_{LED5} = 150\text{mA}$,
 $I_{OUT} = 198\text{mA}$

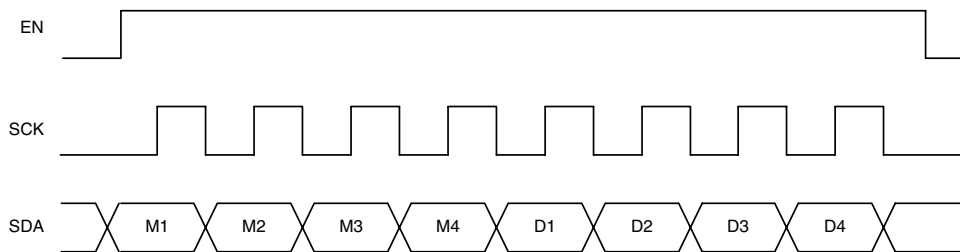
FUNCTIONAL DESCRIPTION

Serial Interface

The SM8134A uses a 3-wire serial interface to control each setting. Input data on SDA is input MSB first in an 8 clock pulse cycle structure, with the first 4 cycles of data setting the mode and the next 4 the corresponding mode data. Data bits on SDA are read as received data on the rising edges of the SCK clock after EN goes HIGH. Only the leading 8 bits on SDA are read after EN goes HIGH and all subsequent input data bits are ignored, but the received data is reflected in SM8134A operation with timing almost simultaneous with the EN falling edge. Conversely, if less than 8 bits are input on SDA, the data is ignored to prevent incorrect operation. All registers are write-only, and their status cannot be read. After power is applied, an internal power-ON reset circuit initializes all registers to logic level LOW in standby mode. However, the possibility exists that there may be insufficient reset time, depending on the VIN input voltage rise time and fall time, so reset mode (0H or EH) should be expressly invoked after power is applied. There is no restriction in the input sequence when setting parameters. However, since the parameters are set in the same order as the data input sequence and the time taken from LED ON/OFF data input to LED dimming data input can exceed the soft start time, it is highly advisable to enter the LED dimming data first. The charge pump circuit, that supplies the LED drive voltage, starts whenever any parameter in address 5H (LED ON register) is set to 1, with the LED drive voltage output on VOUT. Conversely, when all parameters in address 5H are set to 0, all other parameter data settings input after reset are retained in standby mode. The serial interface pins EN, SDA, and CSK are CMOS inputs, thus the input voltage on VIN must be a logic-level voltage and should not be left open circuit (floating).

Control Data

Mode selection data				Setting data			
M1	M2	M3	M4	D1	D2	D3	D4
MSB	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	LSB



Control data input sequence

■ Mode selection

Mode data	0H	2H	4H	5H	EH	Other
Mode	Reset	DIN1 to 4 dimming	DIN5 dimming	LED ON	Reset	NPC test
M1-M2-M3-M4	L-L-L-L	L-L-H-L	L-H-L-L	L-H-L-H	H-H-H-L	—

Mode data “0H”: Reset register
Mode data “EH”: Reset register

Setting data	D1	D2	D3	D4
High	All system data reset and standby			
Low				

Reset mode is selected if EN goes LOW 4 clock cycles after 0H or EH mode select data is input, regardless of when power is applied or the parameter set data bits. When reset mode is selected, all data input previously is reset, thus dimming and control data must be reentered.

Mode data “2H”: DIN1 to 4 dimming register
Mode data “4H”: DIN5 dimming register

Setting data	D1	D2	D3	D4	DIN1 to 4	DIN5	Unit
0H	Low	Low	Low	Low	0	0	mA
1H	Low	Low	Low	High	2	10	mA
2H	Low	Low	High	Low	4	20	mA
3H	Low	Low	High	High	6	30	mA
4H	Low	High	Low	Low	8	40	mA
5H	Low	High	Low	High	10	50	mA
6H	Low	High	High	Low	12	60	mA
7H	Low	High	High	High	14	70	mA
8H	High	Low	Low	Low	16	80	mA
9H	High	Low	Low	High	18	90	mA
AH	High	Low	High	Low	20	100	mA
BH	High	Low	High	High	22	110	mA
CH	High	High	Low	Low	24	120	mA
DH	High	High	Low	High	26	130	mA
EH	High	High	High	Low	28	140	mA
FH	High	High	High	High	30	150	mA

Note. “H”: Hexadecimal

Note. Target values only. Current rating accuracy is not guaranteed.

D1 to D4 setting data bits control the LED current in 15 steps.

Mode data “5H”: LED ON register

Setting data	D1	D2	D3	D4
High	DIN _{1 to 4} ON	–	DIN5 ON	–
Low	DIN _{1 to 4} OFF	–	DIN5 OFF	–

This register controls the DIN_{1 to 4} and DIN5 ON/OFF state. Each state is ON when the corresponding bit is HIGH, and OFF when LOW. Each circuit starts when the corresponding bit in address 5H (D1 or D3) is set HIGH, transferring from standby mode. It is recommended that these data settings be held LOW when possible to control current consumption.

Thermal Shutdown Circuit (Overheating Protection)

The thermal shutdown circuit operates whenever the IC temperature exceeds approximately 170°C for whatever reason. V_{OUT} output recommences when the IC temperature falls below approximately 150°C. In that case, the setting register is saved.

Under Voltage Lockout Circuit (UVLO)

When a V_{IN} voltage falls below the 1.9V (typ), the under voltage lockout circuit operates, initializing all the registers to logic 0. In this mode, all previous data is reset, thus all dimming and LED control data must be input again.

V_{OUT} Output Circuit Mode Switching

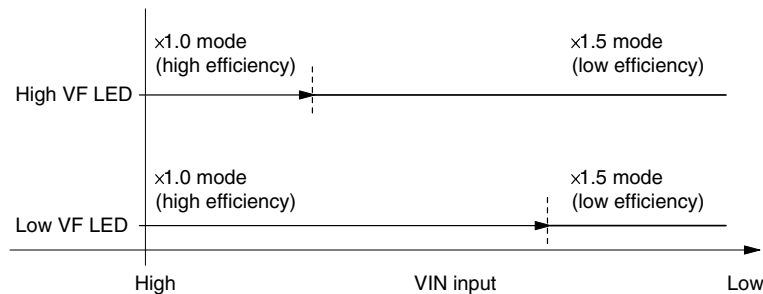
The SM8134A switches between 3 output states: standby mode (standby state), ×1.0 mode (V_{IN} through mode), and ×1.5 mode (×1.5 charge pump boost). This automatically adjusts the V_{OUT} output to match the drive LED characteristics and reduces the total power dissipation. Switching to and from ×1.0 and ×1.5 mode occurs automatically in an internal circuit, and cannot be controlled using an external input.

Switching to standby mode

The internal circuit operating mode switches from ×1.0/×1.5 mode to standby mode when Reset resistor (mode data “0H”, “EH”) was input, suppressing current consumption.

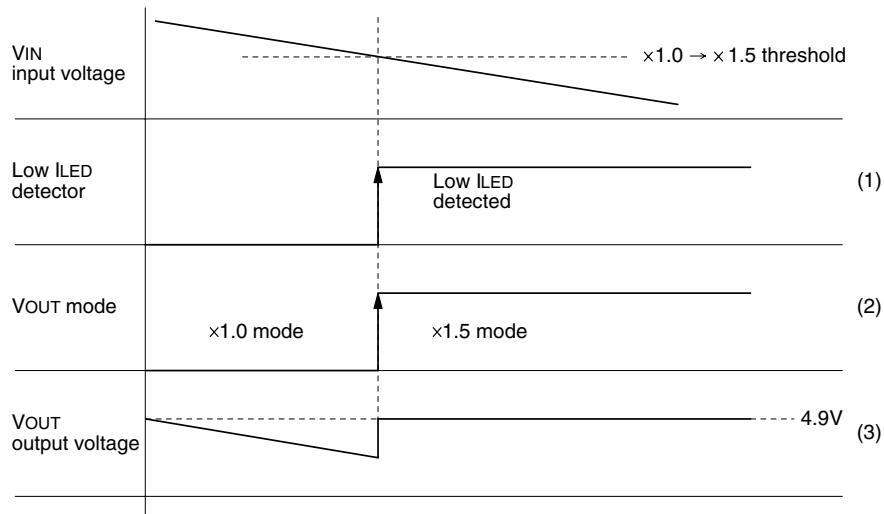
Switching from ×1.0 mode to ×1.5 mode

If the LED drive current set by serial interface can be driven 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 4.9V. 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 LED drive current set by serial interface 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 5-channel LED drive circuits, thus it is recommended that LEDs have small “VF” variation to optimize the total efficiency.



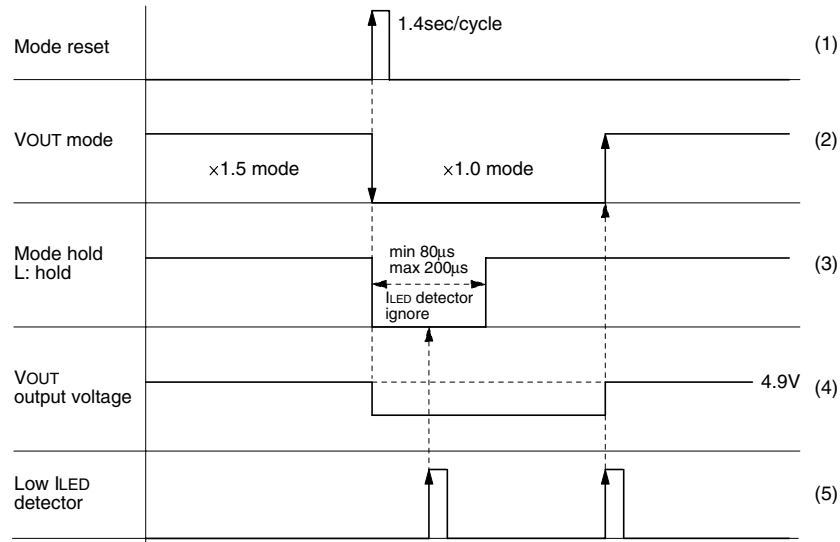
V_{IN} voltage drop and V_{OUT} output voltage

- (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 4.9V 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

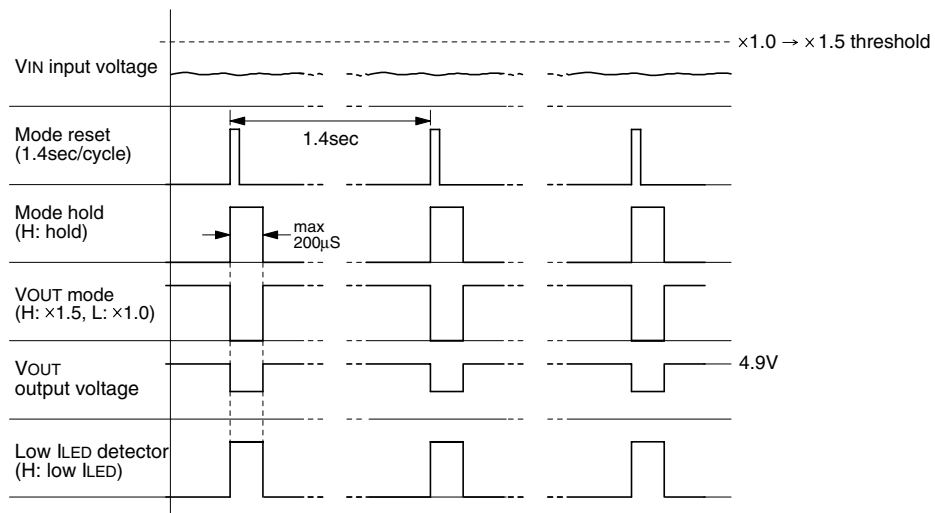
V_F increases immediately after the LED current starts to flow, and then decreases as the LED temperature increases due to the heating effect of the current flow. It can take about 10 seconds for the LED temperature to stabilize and for V_F to reach equilibrium, and V_F may fluctuate more than 200mV. 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 SM8134A 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 μs (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.



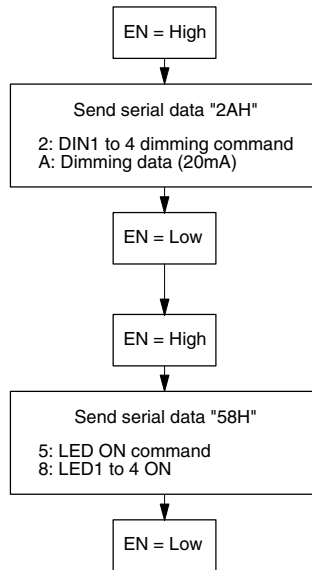
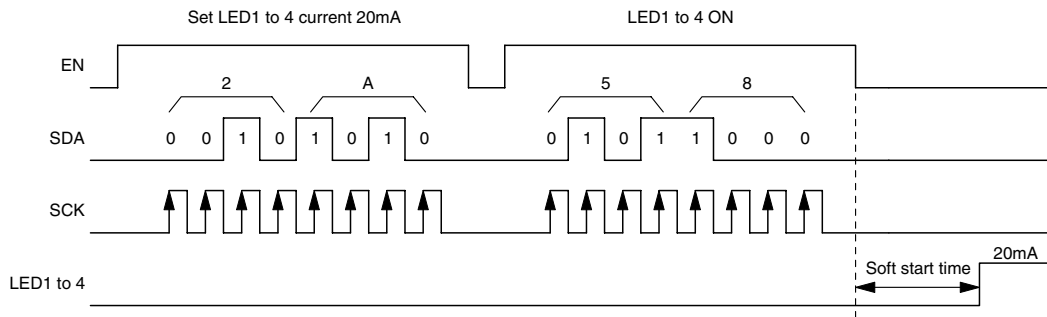
V_{OUT} drop due to the mode reset single

STARTUP SEQUENCE

After power is applied to the SM8134A or when a reset input occurs (reset register mode setting), the internal power-ON reset circuit initializes all registers to their default value of 0. Consequently, all required data for LED drive operation must be input using the serial interface. The registers can be addressed in arbitrary sequence. Note that the registers are set in the same sequence as they are addressed.

Example 1. Set LED1 to LED4 to 20mA drive without group setting

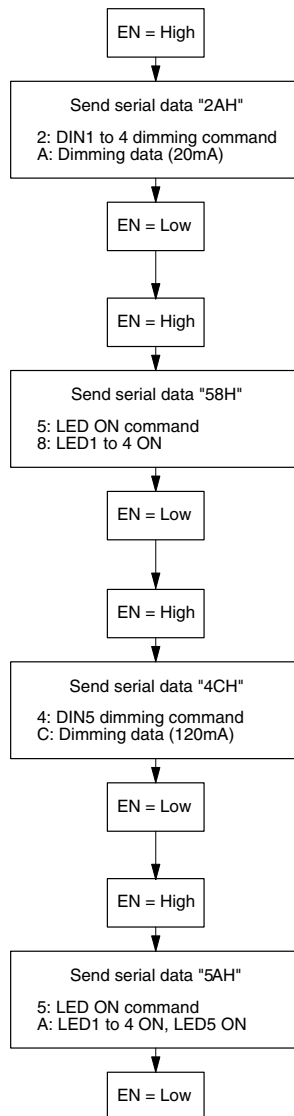
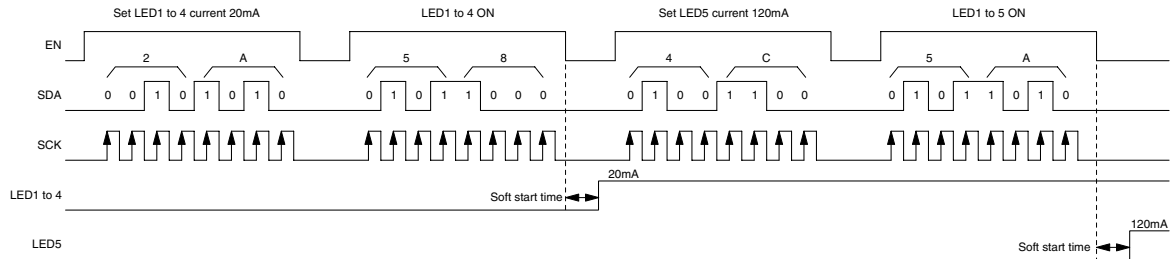
Set EN HIGH, input “2AH” using the serial interface, set EN LOW (LED1 to 4 current setting 20mA), set EN HIGH, input “58H”, set EN LOW, LED1 to LED4 turn ON after the soft start ends.



Example 1 input waveform

Example 2. Set LED1 to LED4 to 20mA and LED5 to 120mA drive

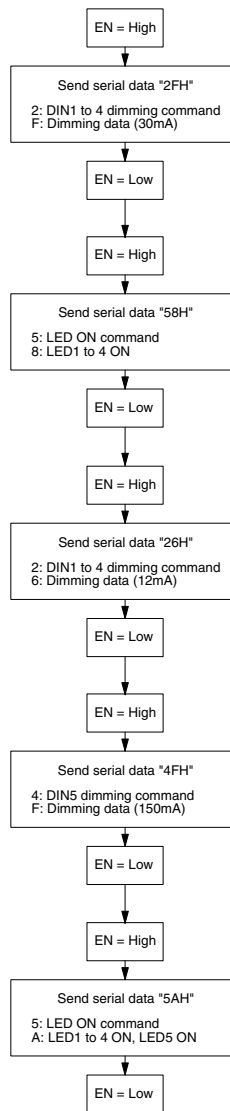
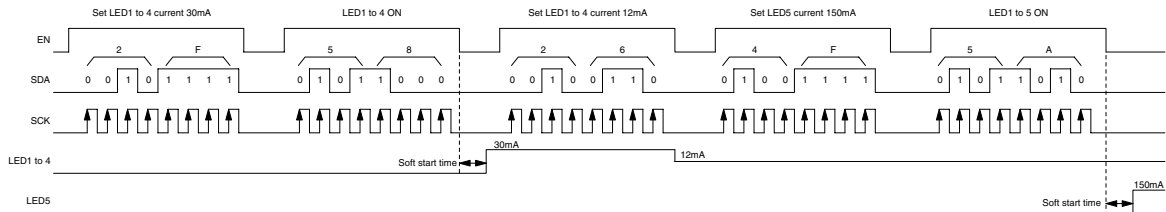
Input "2AH" (LED1 to 4 current setting 20mA), "4CH" (LED5 current setting 120mA), "58H" (LED1 to 4 ON) on successive EN cycles using the serial interface. LED1 to LED4 turn ON after the soft start ends. Then input "5AH" (LED1 to 5 ON) and in addition to LED1 to LED4, LED5 turns ON.



Example 2 input waveform

Example 3. Set LED1 to LED4 to 30mA drive, and then change LED 1 to LED4 to 12mA drive and set LED5 to 150mA drive

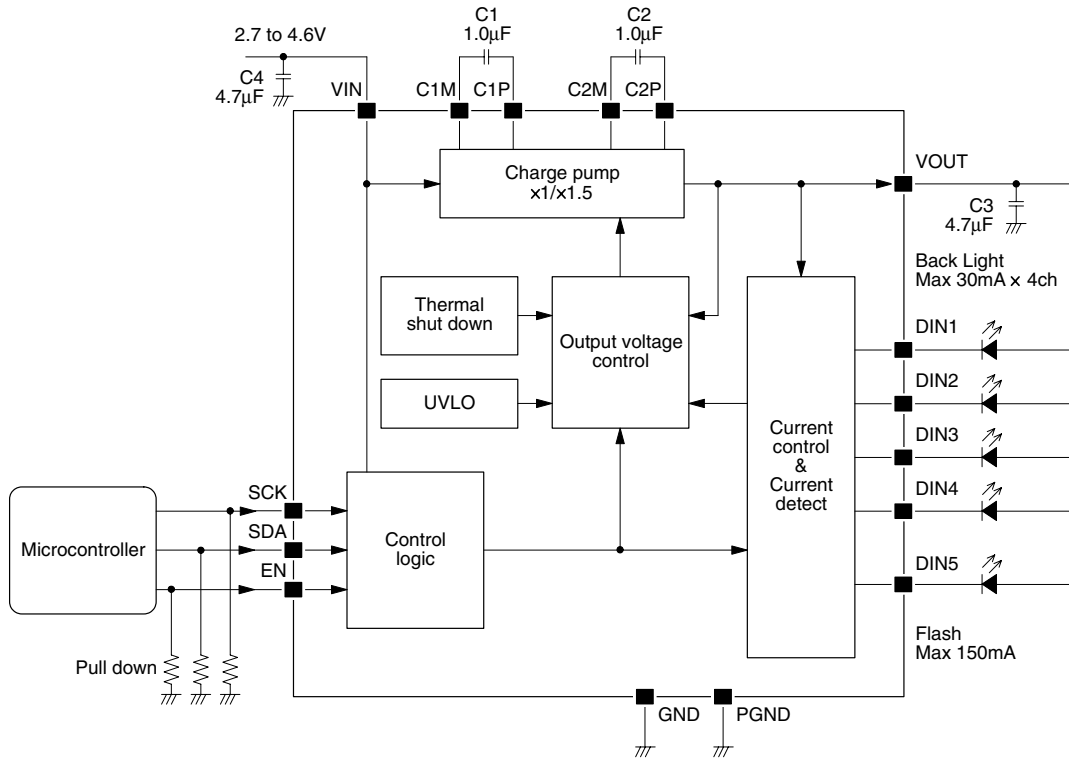
Input “2FH” (LED1 to 4 current setting 30mA) and “58H” (LED1 to 4 ON) using the serial interface. LED1 to LED4 turn ON after the soft start ends. Then input “26H” (LED1 to 4 current setting 12mA), the current of LED1 to LED4 change to 12mA. Moreover input “4FH” (LED5 current setting 150mA) and “5AH” (LED1 to 5 ON), LED5 turns ON in addition to LED1 to LED4. The total current of LED1 to LED5 should be set not exceeding 200mA.



Example 3 input waveform

TYPICAL APPLICATION CIRCUIT

In circuits where the SM8134A logic-level inputs would become open circuit (floating) when the microcontroller supply stops, pull-down resistors should be connected to each logic-level signal input.



Note. If the driving LEDs are less than 5 pcs, the unused DIN pins should be connected to GND.

PERIPHERAL PARTS

About the External Capacitors

The best capacitors for use with the SM8134A 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

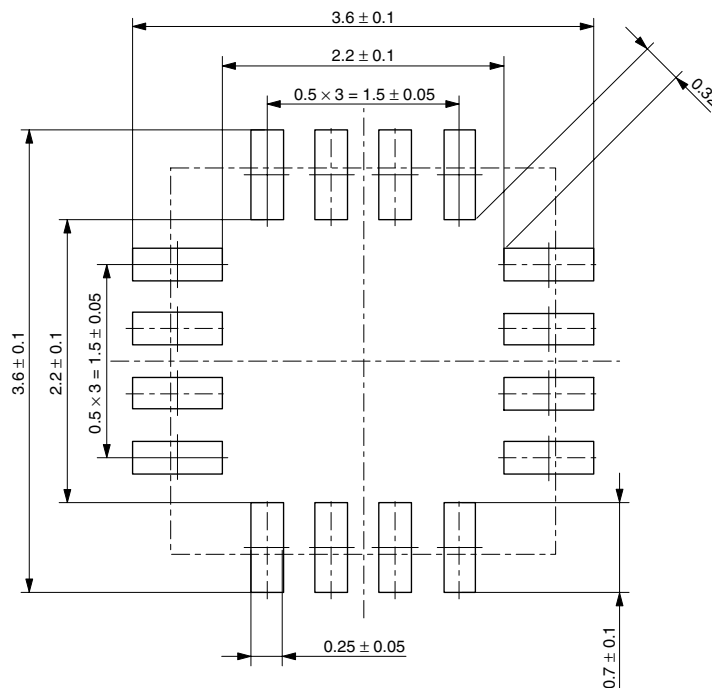
Lower temperature limit	High temperature limit	Maximum allowable capacitance change from + 25°C (0V DC)
X = -55°C	5 = +85°C	F = ± 7.5%
Y = -30°C	6 = +105°C	P = ± 10%
Z = +10°C	7 = +125°C	R = ± 15%
	8 = +150°C	S = ± 22%
		T = +22%/-33%
		U = +22%/-56%
		V = +22%/-82%

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.

FOOTPRINT PATTERN



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NC0417BE 2006.04