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S1F81310F0A
Technical Manual

SEIKO EPSON CORPORATION

Rev.1.0

TABLE OF CONTENTS

1. APPLICABLE DEVICES

This document applies to the S1F81310F0A white LED driver ICs.

2. OVERVIEW

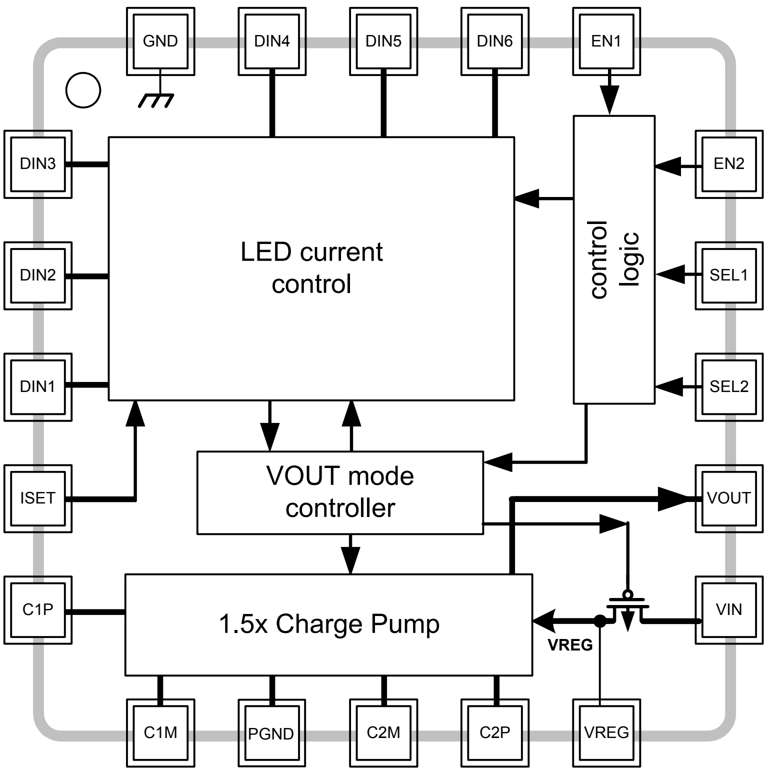
The S1F81310 is a charge-pump type white LED driver. It can drive up to 6 white LEDs connected in parallel from the VOUT output voltage. The LED driver current is controlled using a 6-channel LED current adjustment circuit. The LED brightness is determined by the current-setting resistance connected to ISET and by the input signals on EN1 and EN2, where the 6 channels can be divided into 2 groups (EN1 and EN2 inputs) using SEL1 and SEL2. The LED drive voltage VOUT automatically switches between 1.0x and 1.5x charge-pump boost mode, depending on the battery voltage, LED drive current, and the LED VF characteristics, to help extend battery life.

■ Features

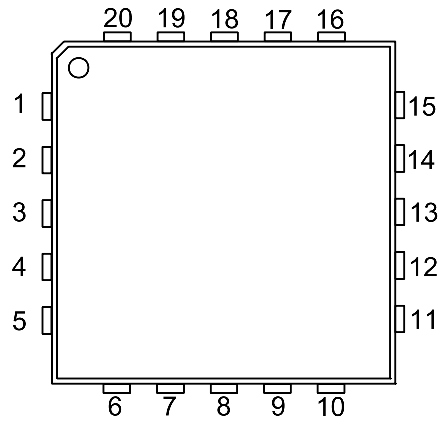
- ● Drives 1 to 6 white LEDs
- ● Low current variation between LEDs
- ● 2 EN input signal brightness controls
- ● 2-wire startup/brightness operation
- ● 2 LED brightness control groups
- ● Max. LED current set by external resistor
- ● Low noise charge-pump booster circuit
- ● Automatic booster circuit switching for low power consumption
- ● Soft-start circuit built-in
- ● Small package (QFN20)

● Input voltage range	: 2.7 to 4.6V
● IC current consumption	: 0.7mA (Typ@1.0x mode)
	: 2.0mA (Typ@1.5x mode)
● Max. output voltage	: 4.2V (trimmed)
● Max. output current	: 120mA
● Standby current	: 0.01µA (Typ.)
● Operating frequency	: 750kHz (Typ.)
● LED current	: 20mA (Typ@ISET=20kΩ,1.0x mode)
● 6-channel current	: ≤ ±3% variation

3. BLOCK DIAGRAM



4. PIN LAYOUT



5. PIN DESCRIPTION

No.	Name	I/O	Function
1	DIN3	O	LED drive current control 3 (connect to GND when not used)
2	DIN2	O	LED drive current control 2 (connect to GND when not used)
3	DIN1	O	LED drive current control 1 (connect to GND when not used)
4	ISET	I	LED drive current-setting resistor connection
5	C1P	—	Charge-pump booster capacitor connection 1P
6	C1M	—	Charge-pump booster capacitor connection 1M
7	PGND	—	Charge-pump ground connection
8	C2M	—	Charge-pump booster capacitor connection 2M
9	C2P	—	Charge-pump booster capacitor connection 2P
10	VREG	—	LED drive current control voltage monitor (Don't connect any lines)
11	VIN	—	Voltage supply
12	VOUT	O	LED drive voltage output
13	SEL2	I	Group setting input 2
14	SEL1	I	Group setting input 1
15	EN2	Ip	Group B enable input (active-HIGH)
16	EN1	Ip	Group A enable input (active-HIGH)
17	DIN6	O	LED drive current control 6 (connect to GND when not used)
18	DIN5	O	LED drive current control 5 (connect to GND when not used)
19	DIN4	O	LED drive current control 4 (connect to GND when not used)
20	GND	—	Ground

Ip: Input with pull-down resistor built-in

6. 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) *	mW
Operating temperature range	Ta	-30 to +85	°C
Storage temperature range	T_{stg}	-55 to +125	°C

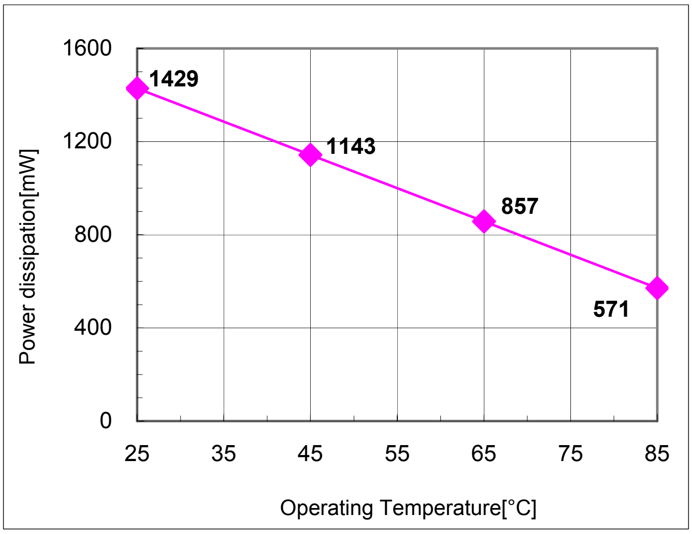
When mounted on a 34 x 40 x 1.6mm glass epoxy board, the power dissipation is related to the operating temperature by the following equation.

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

Maximum junction temperature : T_{MAX} =125°C

Operating temperature : Ta [°C]

Thermal resistance : θ_J = 70 [°C /W]



7. ELECTRICAL CHARACTERISTICS

Ta = 25°C, VIN = 3.6V, GND = 0V unless otherwise noted

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

*1: Design guaranteed value

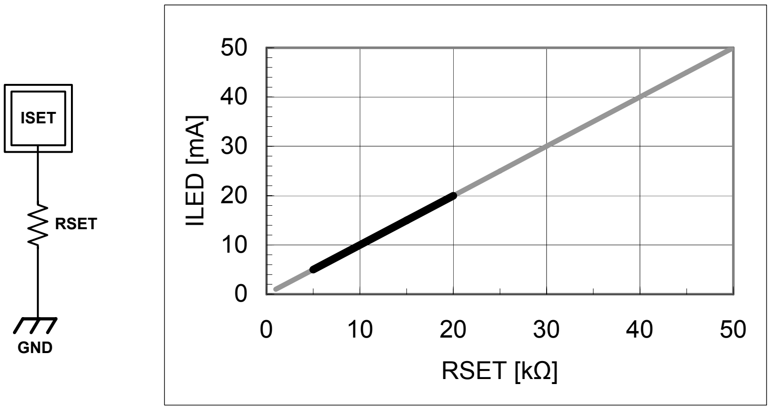
8. FUNCTIONAL DESCRIPTION

A. LED Current Setting

The S1F81310 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

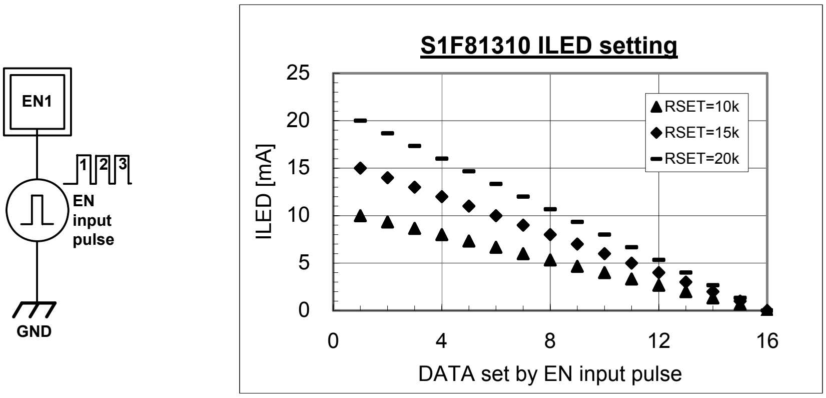
The maximum drive current per LED (when DATA=1) is determined by the external resistance connected to ISET. For example, if ILEDmax=15mA, from the graph below, a resistance RSET of 15kΩ should be connected between ISET and GND. Note that while RSET can have a maximum resistance 50kΩ, the total LED output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



LED 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 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 (ILEDmax) set by RSET. On the 16th pulse (DATA=16), the LED current drive 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 current setting variation using EN input pulse modulation

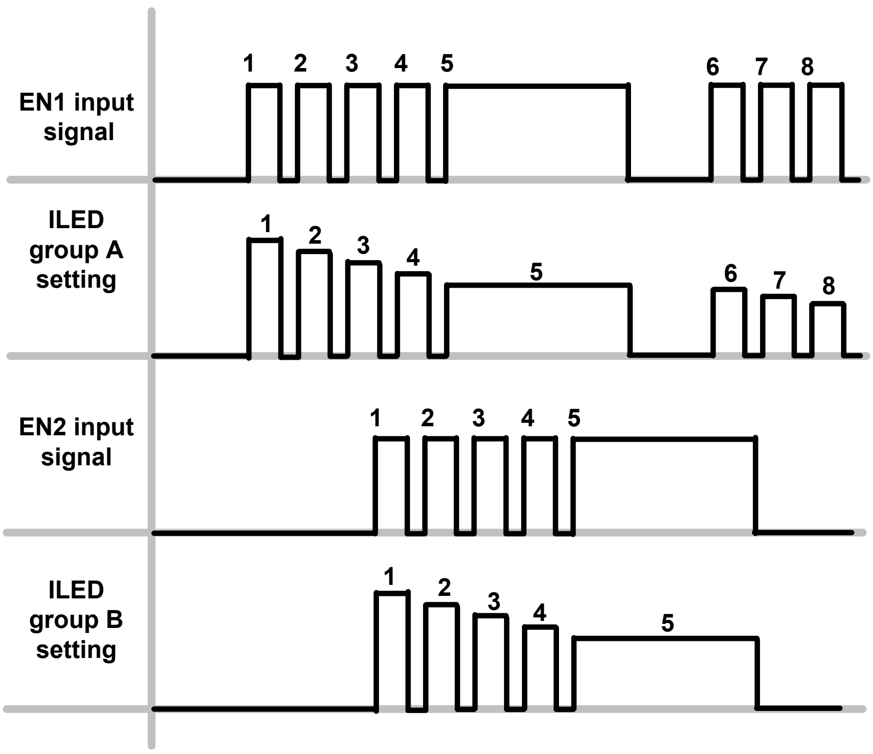
LED current setting and EN input pulse count

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													
ILED	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 current setting (startup)]

An internal startup signal goes HIGH on the first rising edge of either EN1 or EN2, and LED current starts after the soft-start time expires. The LED current adjustment circuit sets the current by counting the input pulses on EN, hence the EN input voltage must be switched H → L → H 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 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 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.



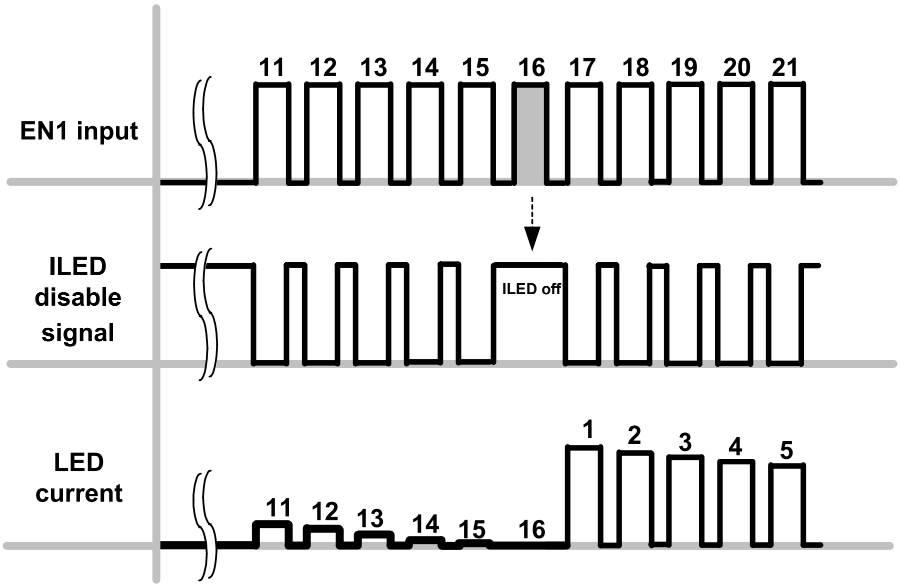
The LED current is set by the number EN input signal rising-edge pulses. When the EN input signal is LOW, the LED drive circuit is disabled and the LED current does not flow. No LED current flows at startup until after the soft-start time expires.

The internal enable signal CE goes HIGH after the first rising edge of the EN1 input signal, but if EN2 input is LOW the LED drive circuit is disabled and no LED current flows in group B. EN1 is independent of the EN2 input rising edge pulses.

EN input signal and LED current setting

[EN input signal and LED current setting (disable interval)]

The LED 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, ILED = 0mA and the LED drive circuit shuts down.



The LED current data is set by the number of EN input signal pulses using a 4-bit counter (16-step). On the 16th pulse, the current stops and the current set value is 0mA. On the 17th pulse, the count starts from DATA = 1.

LED 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 6-0 group setting, EN2 should be connected to EN1. Also, any unused DIN LED drive pins should be connected to GND.

SEL setting and LED drive pin grouping

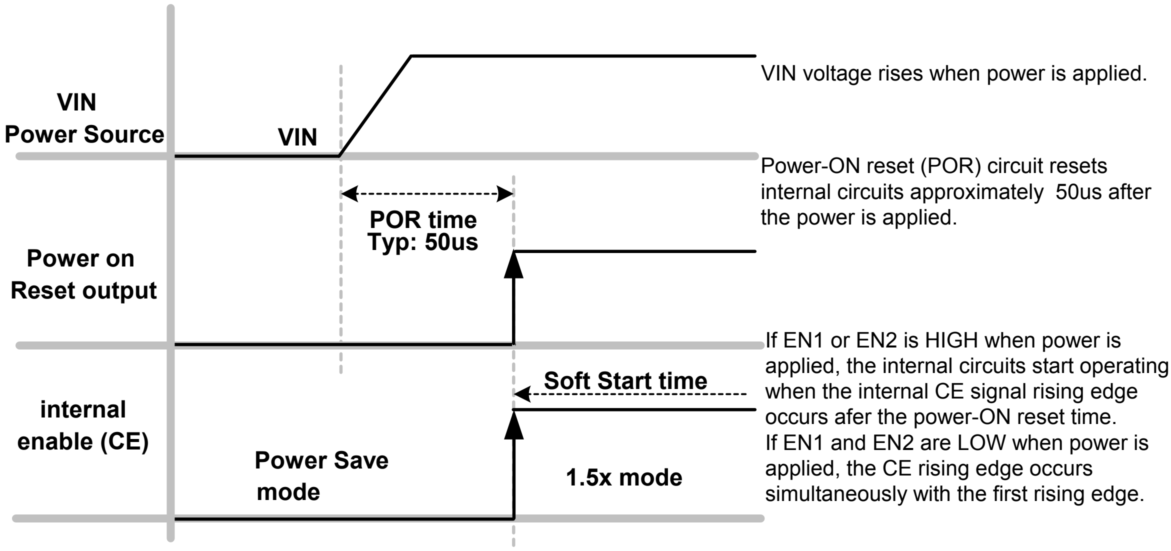
Mode	SEL input		LED control signal					
	SEL1	SEL2	DIN1	DIN2	DIN3	DIN4	DIN5	DIN6
6-0 group	L	L	EN1	EN1	EN1	EN1	EN1	EN1
5-1 group	L	H	EN1	EN1	EN1	EN1	EN1	**EN2**
4-2 group	H	L	EN1	EN1	EN1	EN1	**EN2**	**EN2**
3-3 group	H	H	EN1	EN1	EN1	**EN2**	**EN2**	**EN2**

B. VOUT Output Circuit Mode Switching

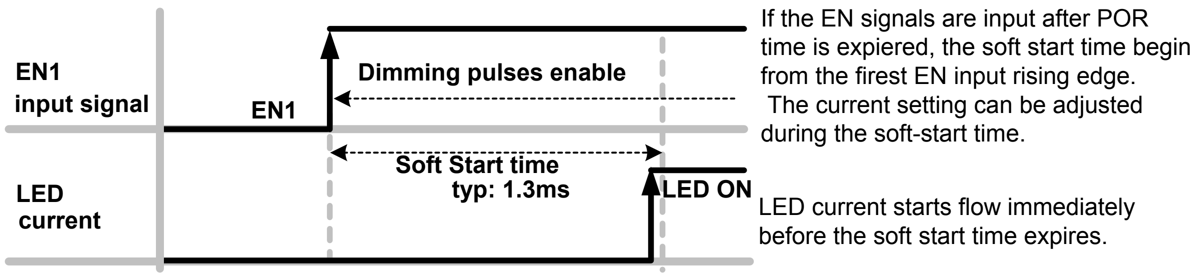
The S1F81310 switches between 3 output states: power-save mode (standby state), 1.0x mode (VIN through mode), and 1.5x mode (1.5x charge-pump boost). This automatically adjusts the VOUT output to match the drive LED characteristics and reduces the total power dissipation. Switching to and from 1.0x and 1.5x mode occurs automatically in an internal circuit, and cannot be controlled using an external input.

[Power-ON internal reset time]

The S1F81310 switches from standby condition (power-save mode) to normal operating condition (1.0x/1.5x 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 50us) expires.
At startup, operation commences in 1.5x mode for a fixed interval during the soft-start time in order to determine whether a LED is connected to each DIN pin.



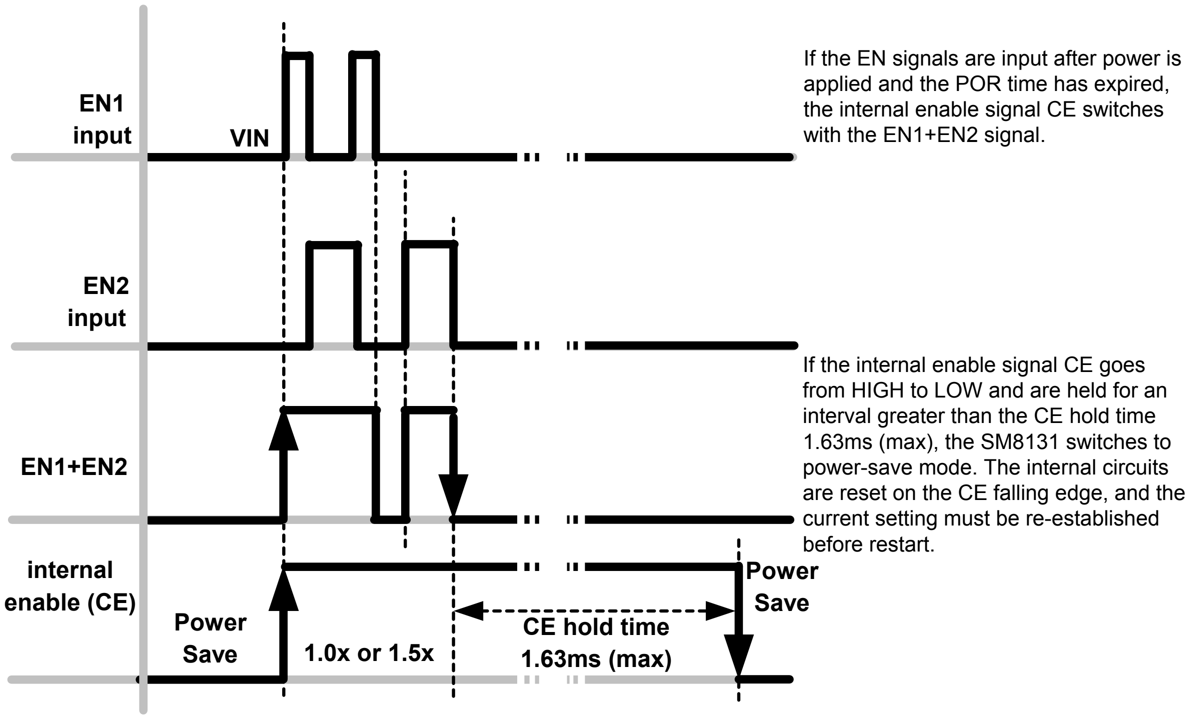
Power-ON reset operation



Soft start time and LED current

[Switching to power-save mode]

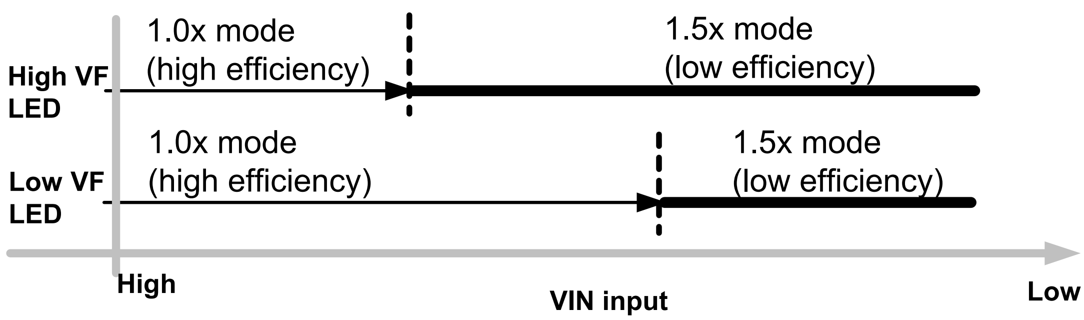
The internal circuit operating mode switches from 1.0x/1.5x mode to power-save mode when both EN1 and EN2 go LOW and do not switch HIGH for an interval of 1.63ms (max). This function turns the LEDs OFF and automatically transfers internal circuit control to power-save mode, suppressing current consumption.



EN input signal and internal enable signal CE

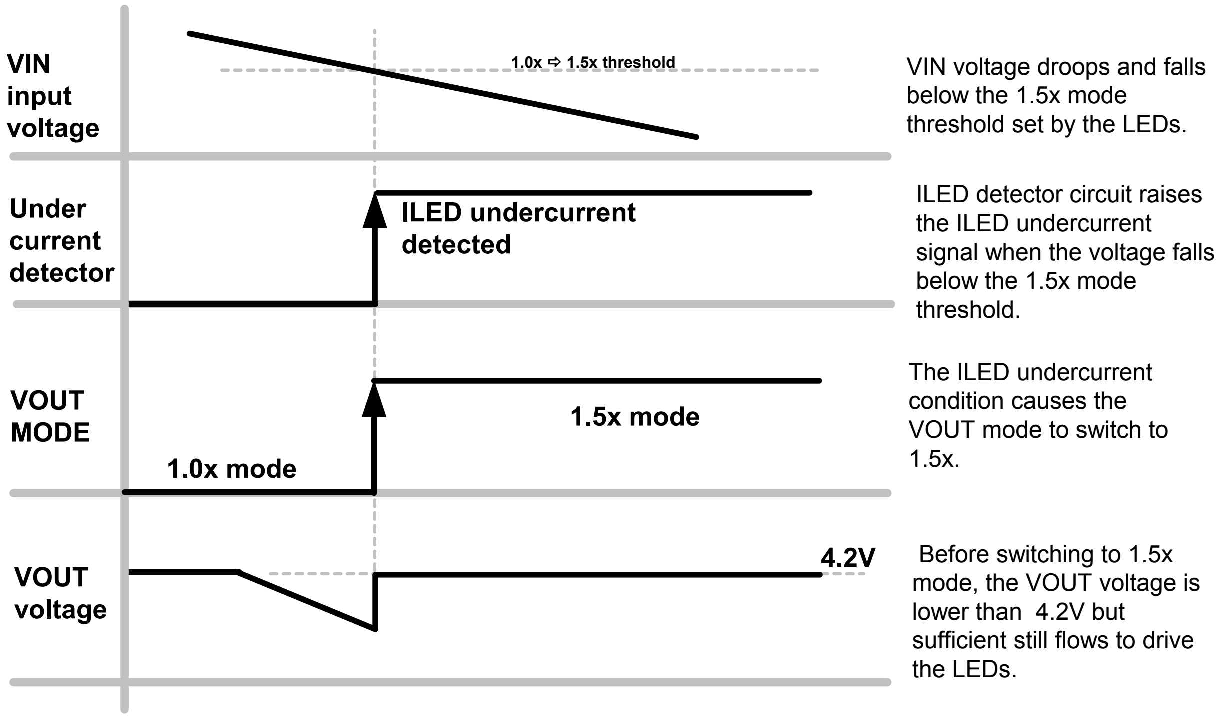
[Switching from 1.0 × mode to 1.5 × mode]

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



VOUT mode switching time comparison due to drive LED VF variation

If the VIN voltage falls or RSET increases such that the LED current is too low in 1.0x mode, then the LED drive circuit undercurrent detector operates, the VOUT output is automatically switched to 1.5x mode, and the charge pump boosts the output voltage. This occurs even if only one LED undercurrent 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.

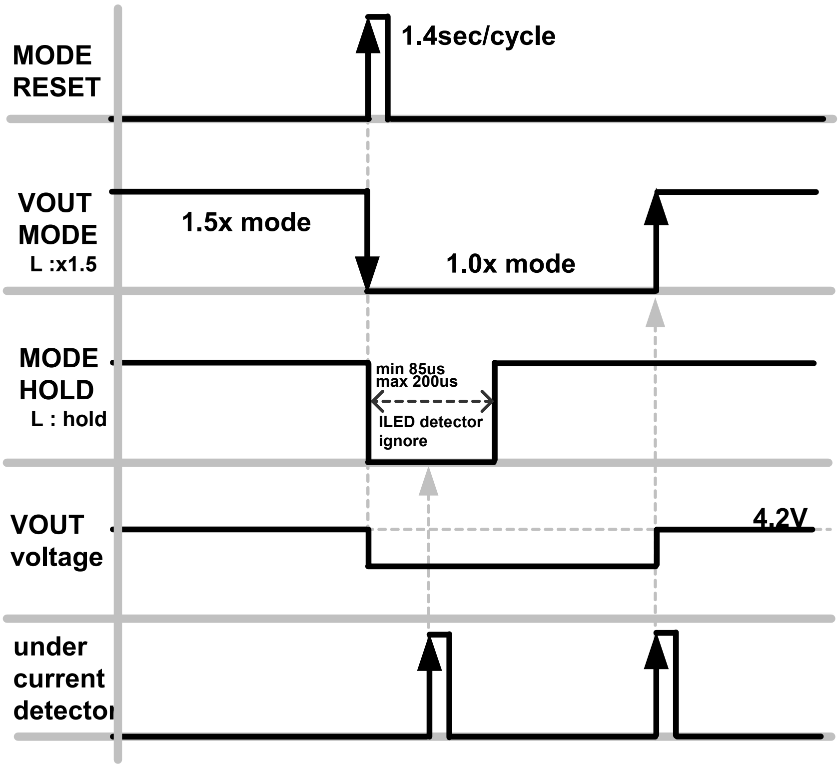


VIN voltage drop and VOUT output voltage

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 current, the undercurrent detector does not operate and the device cannot switch to 1.5x 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 S1F81310 outputs a mode reset signal once every 1.4 seconds which automatically switches the output mode to 1.0x, and then a determination is made whether to make the 1.0x → 1.5x mode switch.



Mode reset signal is output once every 1.4 seconds.

Switching from 1.5x to 1.0x mode due to mode reset signal pulse.

The mode hold time of 200us (max) starts when output switches to 1.0x mode. During this interval, the mode is not switched even if an ILED undercurrent condition is detected.

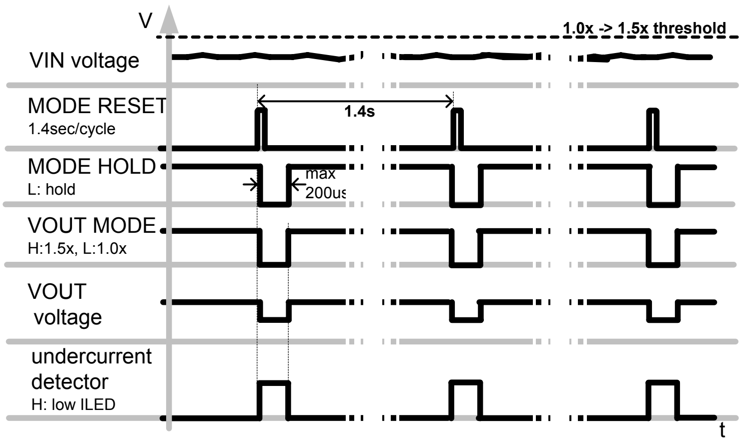
If VIN is low, the VOUT voltage momentarily drops because the boost function stops as a result of switching to 1.0x mode.

The ILED 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.

Switching from 1.5x to 1.0x mode due to the mode reset signal

A mode hold signal of 200μs (max) duration is output immediately after the output switches to 1.0x mode as a result of the mode reset signal. During this interval, the VOUT output is fixed in 1.0x mode and the LED undercurrent detector signal is ignored.

For example, if the VIN voltage is low and the VOUT output voltage in 1.0x 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 1.0x mode, but the output will stay in 1.0x mode and not return to 1.5x mode for the duration of the mode hold time. Consequently, the VOUT output is not boosted during the 85us (min) to 200us (max) mode hold time and the voltage drops and the LED brightness is reduced. However, the LEDs are OFF for a maximum of 200us only, and this is not discernible to the naked eye and thus is not a problem.



VOUT drop due to the mode reset signal

C. VIN Input Voltage Range

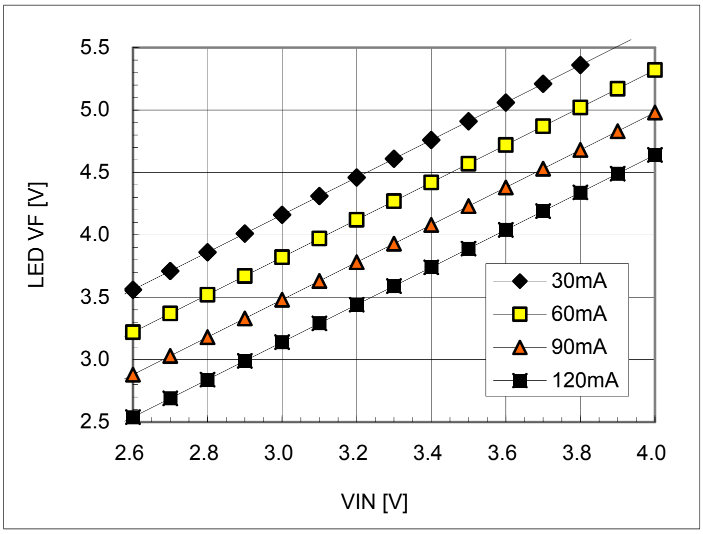
The VIN minimum input voltage value to ensure rated drive current flows in each LED is determined by the ILED setting (largest setting if divided into 2 groups), the total load current IOUT on pin VOUT, and the LED forward-direction voltage drop VF, as given in the following equations:

$VF \leq 1.5*VIN - 10*IOUT - 8*ILED$ ... Eqn ①
$VIN \geq (VF + 10*IOUT + 8*ILED)/1.5$ ... Eqn ②

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 VIN = 3.5V, ILED = 20mA, and IOUT = 120mA, then VF is given by equation as follows:

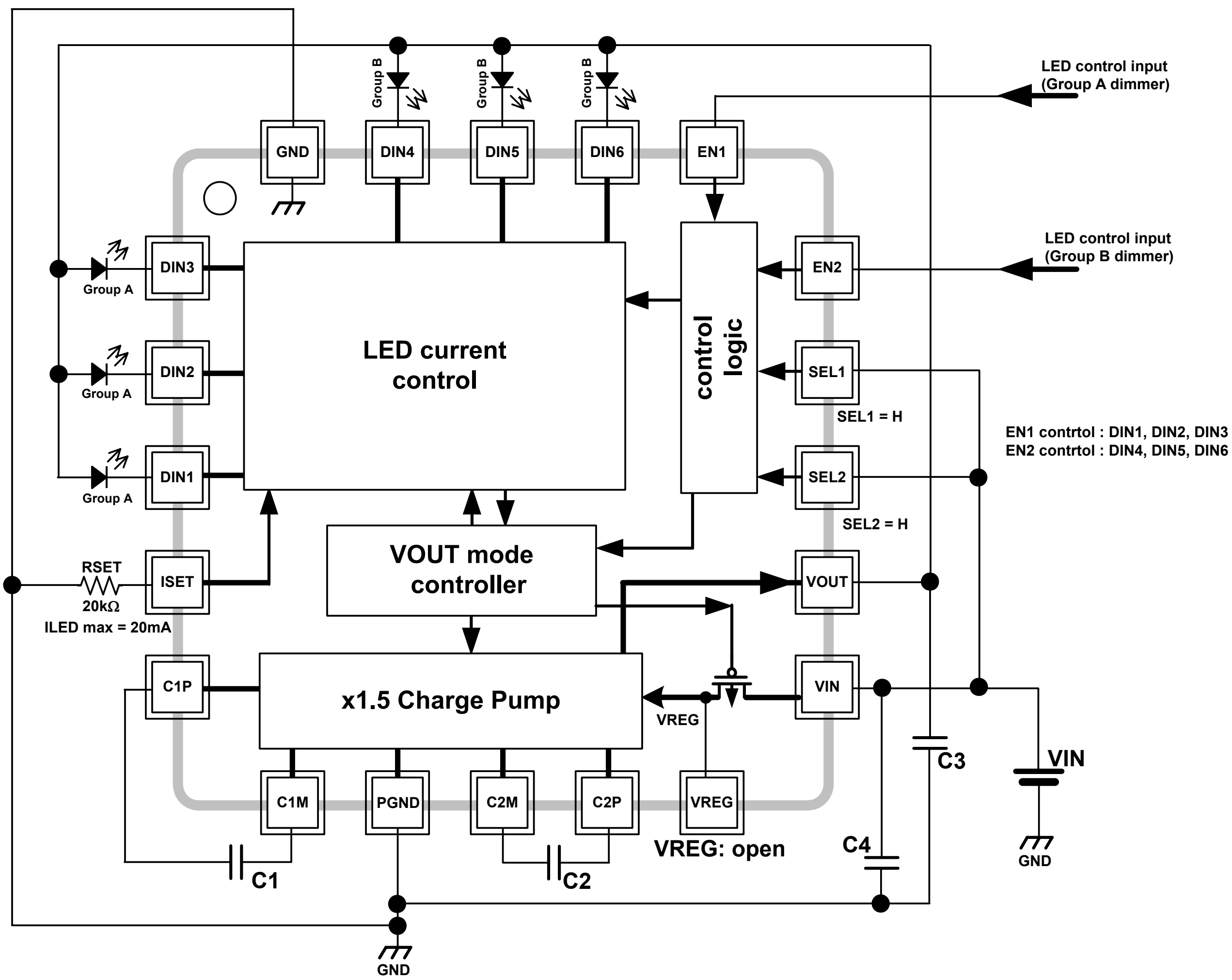
$1.5*3.5 - 10*0.12 - 8*0.02 = 3.89V$

Thus if LEDs with VF of 3.89V or lower rating at ILED = 20mA are used, the device will provide sufficient drive current. If VIN falls and the drive LED VF exceeds the calculated value, VIN will take ILED down with it below the required setting. The relationship in equation is shown graphically for values of IOUT = 30/60/90/120mA.



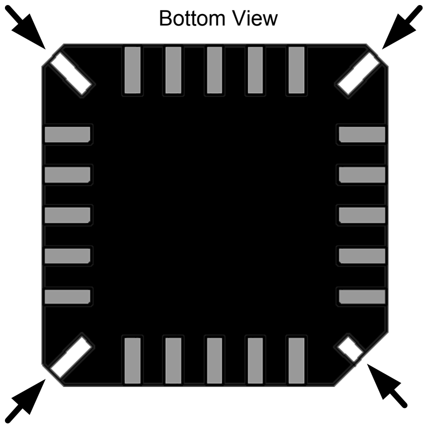
VIN voltage and LED forward-direction voltage drop limit value

9. TYPICAL APPLICATION CIRCUIT



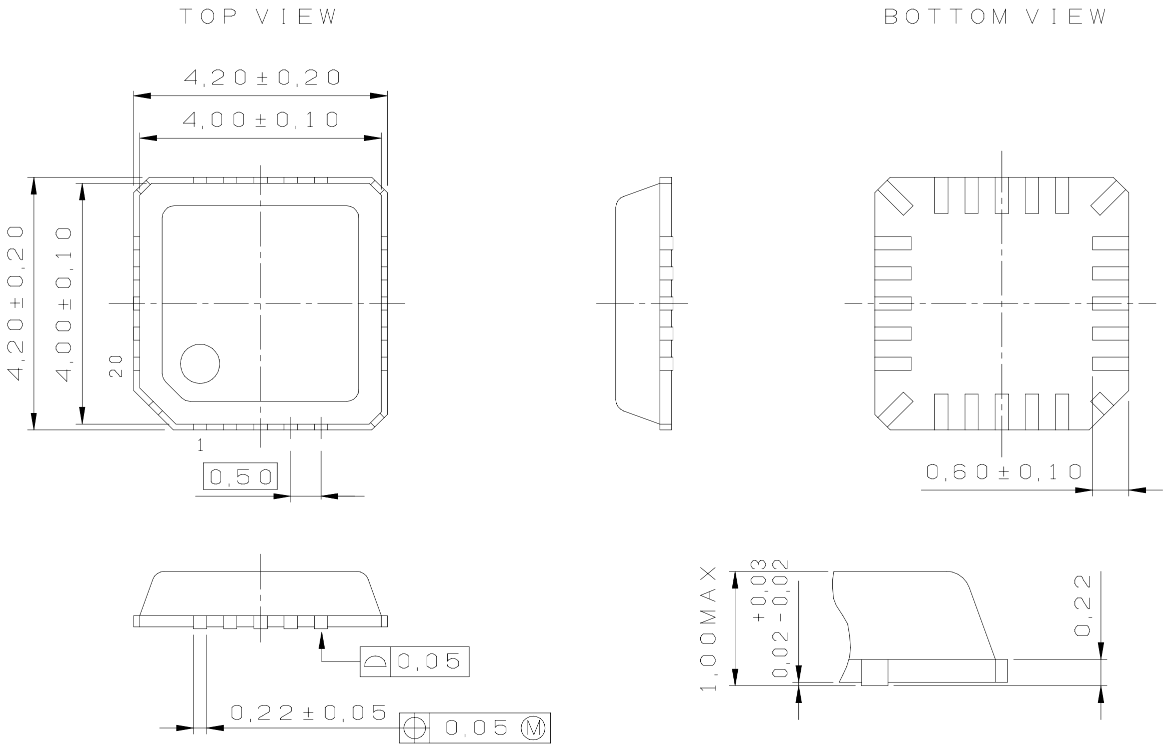
<u>**Group 3-3 setting, ILEDmax = 20mA circuit example**</u>

10. ASSEMBLING PRECAUTION



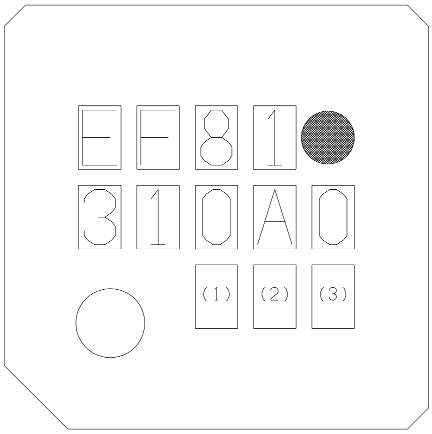
Package corner metals are not IC I/O pins. Don’t connect any lines to these corner metals.

11. PACKAGE DIMENSIONS



Unit (mm) (Weight: 0.039g)
(Plate of PIN: Sn-Bi)

12. PACKAGE MARKINGS



(1) to (3) : Date Code

EPSON

International Sales Operations

AMERICA

EPSON ELECTRONICS AMERICA, INC.
HEADQUARTERS
150 River Oaks Parkway
San Jose, CA 95134, U.S.A.
Phone: +1-800-228-3964 FAX: +1-408-922-0238

SALES OFFICES
West
1960 E.Grand Avenue Flr 2
El Segundo, CA 90245, U.S.A.
Phone: +1-800-249-7730 FAX: +1-310-955-5400

Central
101 Virginia Street, Suite 290
Crystal Lake, IL 60014, U.S.A.
Phone: +1-800-853-3588 FAX: +1-815-455-7633

Northeast
301 Edgewater Place, Suite 210
Wakefield, MA 01880, U.S.A.
Phone: +1-800-922-7667 FAX: +1-781-246-5443

Southeast
3010 Royal Blvd. South, Suite 170
Alpharetta, GA 30005, U.S.A.
Phone: +1-877-332-0020 FAX: +1-770-777-2637

EUROPE

EPSON EUROPE ELECTRONICS GmbH
HEADQUARTERS
Riesstrasse 15
80992 Munich, GERMANY
Phone: +49-89-14005-0 FAX: +49-89-14005-110

DÜSSELDORF BRANCH OFFICE
Altstadtstrasse 176
51379 Leverkusen, GERMANY
Phone: +49-2171-5045-0 FAX: +49-2171-5045-10

FRENCH BRANCH OFFICE
1 Avenue de l' Atlantique, LP 915 Les Conquerants
Z.A. de Courtaboeuf 2, F-91976 Les Ulis Cedex, FRANCE
Phone: +33-1-64862350 FAX: +33-1-64862355

BARCELONA BRANCH OFFICE
Barcelona Design Center
Edificio Testa, C/Alcalde Barnils 64-68, Modulo C 2a planta
E-08190 Sant Cugat del Vallès, SPAIN
Phone: +34-93-544-2490 FAX: +34-93-544-2491

UK & IRELAND BRANCH OFFICE
8 The Square, Stockley Park, Uxbridge
Middx UB11 1FW, UNITED KINGDOM
Phone: +44-1295-750-216/+44-1342-824451
FAX: +44-89-14005 446/447

Scotland Design Center
Integration House, The Alba Campus
Livingston West Lothian, EH54 7EG, SCOTLAND
Phone: +44-1506-605040 FAX: +44-1506-605041

ASIA

EPSON (CHINA) CO., LTD.
23F, Beijing Silver Tower 2# North RD DongSanHuan
ChaoYang District, Beijing, CHINA
Phone: +86-10-6410-6655 FAX: +86-10-6410-7320

SHANGHAI BRANCH
7F, High-Tech Bldg., 900, Yishan Road,
Shanghai 200233, CHINA
Phone: +86-21-5423-5522 FAX: +86-21-5423-5512

EPSON HONG KONG LTD.
20/F., Harbour Centre, 25 Harbour Road
Wanchai, Hong Kong
Phone: +852-2585-4600 FAX: +852-2827-4346
Telex: 65542 EPSCO HX

EPSON Electronic Technology Development (Shenzhen) LTD.
12/F, Dawning Mansion, Keji South 12th Road,
Hi- Tech Park, Shenzhen
Phone: +86-755-2699-3828 FAX: +86-755-2699-3838

EPSON TAIWAN TECHNOLOGY & TRADING LTD.
14F, No. 7, Song Ren Road,
Taipei 110
Phone: +886-2-8786-6688 FAX: +886-2-8786-6677

HSINCHU OFFICE
No. 99, Jiangong Road,
Hsinchu City 300
Phone: +886-3-573-9900 FAX: +886-3-573-9169

EPSON SINGAPORE PTE., LTD.
1 HarbourFront Place,
#03-02 HarbourFront Tower One, Singapore 098633
Phone: +65-6586-5500 FAX: +65-6271-3182

SEIKO EPSON CORPORATION
KOREA OFFICE
50F, KLI 63 Bldg., 60 Yoido-dong
Youngdeungpo-Ku, Seoul, 150-763, KOREA
Phone: +82-2-784-6027 FAX: +82-2-767-3677

GUMI OFFICE
2F, Grand B/D, 457-4 Songjeong-dong,
Gumi-City, KOREA
Phone: +82-54-454-6027 FAX: +82-54-454-6093

SEIKO EPSON CORPORATION
SEMICONDUCTOR OPERATIONS DIVISION

IC Sales Dept.
IC Marketing Group
421-8, Hino, Hino-shi, Tokyo 191-8501, JAPAN
Phone: +81-42-587-5814 FAX: +81-42-587-5117

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