Charge-Pump for White LED and Power Supply

RN5T651

Development Specifications

Rev. **3.4**

2009.05.20

RICOH

RICOH COMPANY, LTD.
Electronic Devices Company

Table of Contents

1. Outline

RN5T651 contains constant frequency charge pump to optimize for white LED application, step-down DC/DC converter and two low-noise LDOs. Output enable/disable, LEDs current setting and LDO output voltage setting are individually controllable through I2C.

2. Feature

- Power Supply Function
  - ✓ Step-down DC/DC converter × 1 (ON/OFF programmable)
  - ✓ LDO × 2 (ON/OFF programmable)
  - ✓ Over current Protection (ALL Regulators) and thermal shutdown

- White LED Charge Pump
  - ✓ Current capability: All currents capability 450mA
  - ✓ Flash at 300mA max.
  - ✓ Four Main LEDs at 25mA max.
  - ✓ Two Sub LEDs 25mA max.

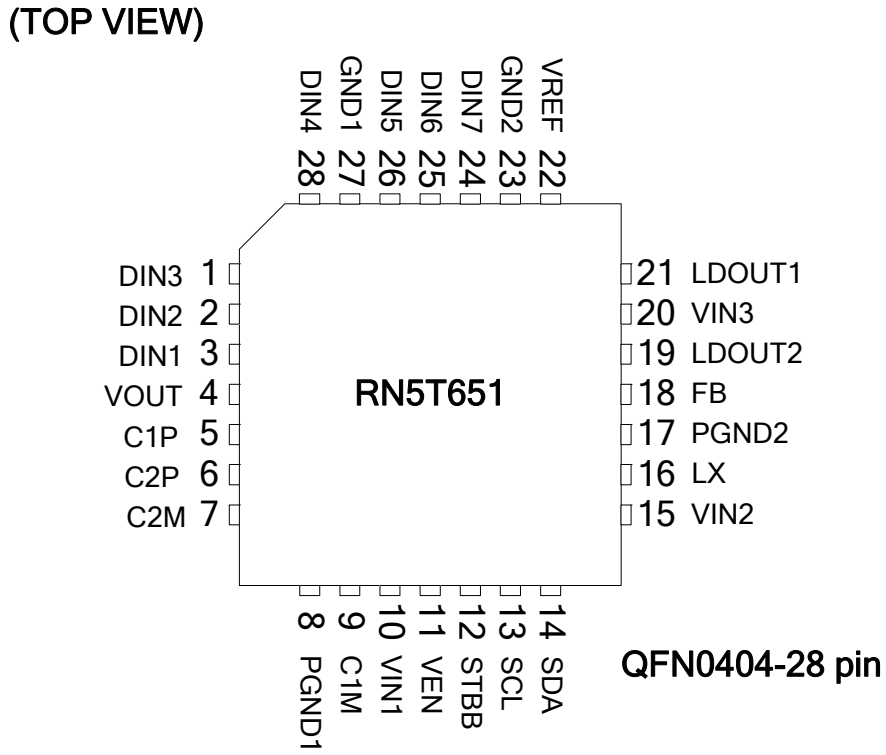
- I2C-Bus (Max 400kHz)
  - ✓ Address = 12h
  - ✓ ON/OFF control
  - ✓ Individual LEDs current value setting
  - ✓ Individual LDOs voltage value setting

- Others
  - ✓ Soft-start circuit
  - ✓ Short-circuit circuit, open-circuit and Thermal Protection

- Package
  - ✓ 28pin Thin QFN package (Body size: 4 x 4 x 0.8mm)

- Process
  - ✓ CMOS process

3. Pin Configuration



Pin No.	Name	Pin No.	Name	Pin No.	Name	Pin No.	Name
1	DIN3	8	PGND1	15	VIN2	22	VREF
2	DIN2	9	C1M	16	LX	23	GND2
3	DIN1	10	VIN1	17	PGND2	24	DIN7
4	VOUT	11	VEN	18	FB	25	DIN6
5	C1P	12	STBB	19	LDOUT2	26	DIN5
6	C2P	13	SCL	20	VIN3	27	GND1
7	C2M	14	SDA	21	LDOUT1	28	DIN4

Fig 3-1 Pin Configuration

4. Block Diagram

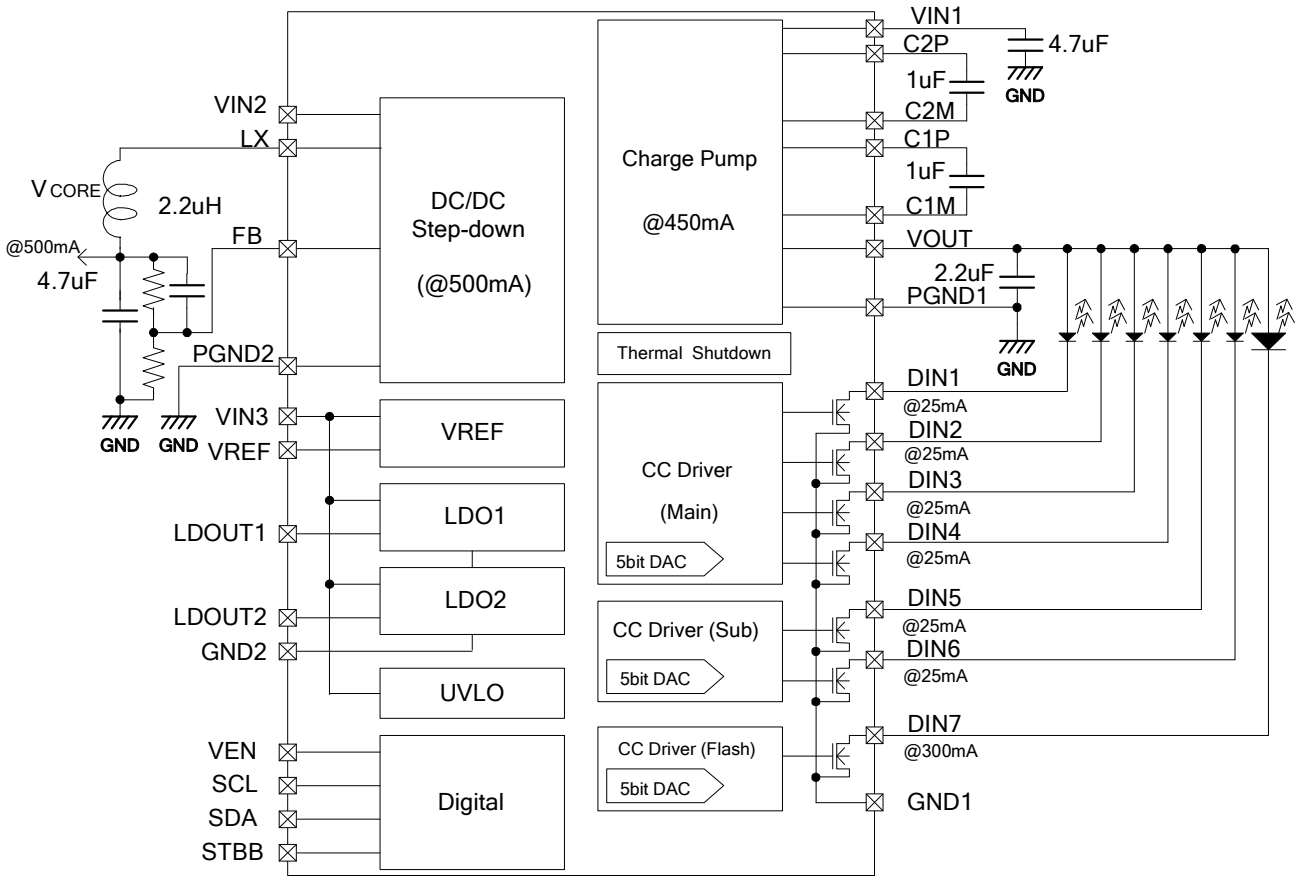


Fig 4-1 Block Diagram

5. Pin Description

No.	Name	I/O	Function	Notes
1	DIN3	O	LED driver current control output 3	
2	DIN2	O	LED driver current control output 2	
3	DIN1	O	LED driver current control output 1	
4	VOUT	O	LED driver voltage output	
5	C1P	-	Charge pump boost capacitor connection	
6	C2P	-	Charge pump boost capacitor connection	
7	C2M	-	Charge pump boost capacitor connection	
8	PGND1	-	Ground (charge pump)	
9	C1M	-	Charge pump boost capacitor connection	
10	VIN1	-	Power supply (charge pump)	
11	VEN	-	Voltage supply (I2C), enable input	
12	STBB	I	Strobe enable input	
13	SCL	I	I2C interface clock input	
14	SDA	I/O	I2C interface data input	
15	VIN2	-	Power supply (DC/DC convertor)	
16	LX	O	DC/DC convertor inductor switching pin	
17	PGND2	-	Ground (DC/DC convertor)	
18	FB	I	DC/DC convertor feed back pin	
19	LDOUT2	O	LDO2 output	
20	VIN3	-	Power supply	
21	LDOUT1	O	LDO1 output	
22	VREF	O	Bypass capacitor connecting pin	
23	GND2	-	Ground	
24	DIN7	O	LED driver current control output 7	
25	DIN6	O	LED driver current control output 6	
26	DIN5	O	LED driver current control output 5	
27	GND1	-	Ground	
28	DIN4	O	LED driver current control output 4	

Table 5-1 Pin Description

6. Functional Blocks

6.1 Regulators

6.1.1 LDO1 Electrical Characteristics

Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1 μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
VOUT1	Output Voltage	50 μA＜IOUT1＜300mA VOUT1+0.5V≦V_{BATT}(VIN)≦4.5V	-2%	1.50	+2%	V
IOUT1	Output Current	-			300	mA
ILIM1	Current Limit	VOUT1=POUT1－0.2V		500		mA
VDRP1	Drop-out Voltage	IOUT1=200mA, T_a =85℃		200		mV
$\frac{\Delta VOUT1}{\Delta VIN}$	Line Regulation	VOUT1+0.5V≦V_{BATT}(VIN)≦4.5V IOUT1=150mA		2.4		mV
$\frac{\Delta VOUT1}{\Delta IOUT1}$	Load Regulation	50 μA＜IOUT1＜300mA		25		mV
$\frac{\Delta VOUT1}{\Delta T_a}$	Output Voltage Temperature Coefficient	-40℃≦T_a≦85℃		±100		ppm/℃
RR1	Ripple Rejection	f=10Hz-10kHz, C_{out}=2.2 μF IOUT1=30mA		60		dB
EN1	Output Noise (RMS)	BW=100Hz-100kHz, C_{out}=2.2 μF IOUT1=30mA		35		μVrms
BC1	Bypass Capacitor	0 μA＜IOUT1＜300mA		2.2		μF
ISS1	Supply Current	Normal (IOUT1=Max)		50 *1		μA
		OFF			1	
POUT1	Programmable Output Voltage	IOUT1=300mA	-2%	1.50 1.80 2.50 2.60 2.80 3.00 3.10 3.30 1.85 * 2.40 * 2.55 * 2.70 * 2.85 * 2.90 * 3.20 *	+2%	V

Table 6-1 LDO1 Electrical Characteristics

Note*: Bypass capacitor: 2.2 μF, in mounted state.

For optimized phase compensation, the bypass capacitor must be the ceramic type.

6.1.2 LDO2 Electrical Characteristics

Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1 μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
VOUT2	Output Voltage	50 μA＜IOUT2＜300mA VOUT2+0.5V≦V_{BATT}(VIN)≦4.5V	-2%	1.50	+2%	V
IOUT21	Output Current	-			300	mA
ILIM2	Current Limit	VOUT1=POUT1－0.2V		500		mA
VDRP2	Drop-out Voltage	IOUT2=200mA, T_a =85℃		200		mV
$\frac{\Delta VOUT2}{\Delta VIN}$	Line Regulation	VOUT2+0.5V≦V_{BATT}(VIN)≦4.5V IOUT2=150mA		2.4		mV
$\frac{\Delta VOUT2}{\Delta IOUT2}$	Load Regulation	50 μA＜IOUT2＜300mA		25		mV
$\frac{\Delta VOUT2}{\Delta T_a}$	Output Voltage Temperature Coefficient	-40℃≦T_a≦85℃		±100		ppm/℃
RR2	Ripple Rejection	f=10Hz-10kHz, C_{out}=2.2 μF IOUT2=30mA		60		dB
EN2	Output Noise (RMS)	BW=100Hz-100kHz, C_{out}=2.2 μF IOUT1=30mA		35		μVrms
BC2	Bypass Capacitor	0 μA＜IOUT2＜300mA		2.2		μF
ISS2	Supply Current	Normal (IOUT2=Max)		50 *1		μA
		OFF			1	
POUT2	Programmable Output Voltage	IOUT2=300mA	-2%	1.50 1.80 2.50 2.60 2.80 3.00 3.10 3.30 1.85 * 2.40 * 2.55 * 2.70 * 2.85 * 2.90 * 3.20 *	+2%	V

Table 6-2 LDO2 Electrical Characteristics

Note*: Bypass capacitor: 2.2 μF, in mounted state.

For optimized phase compensation, the bypass capacitor must be ceramic type.

Note*1: Vref Block Supply Current typ 20 μA

ex)LDO1+LDO2+Vref =120 μA(typ)

LDO1+Vref=70 μA(typ)

6.2 Step-down DC/DC Converters

(a) Output voltage

The output voltage is decided according to the resistance ratio of external resistor. Please refer to the formulas in section 6.2.2 for the output voltage set.

(b) Additional components

It can be easily composed of DC/DC converters with only few kinds of external components such as inductor, capacitor and etc. For the output capacitors, ceramic type is recommended for voltage ripple.

(d) Protection circuits

Max Duty circuit limits maximum pulse width of DC/DC. Current Limit circuit limits peak current of LX at clock cycle of DC/DC. Latch type protection circuit starts working if the over-current condition keeps on for certain time. Latch-type protection circuit latches an internal driver by keeping it disable. To release the protection condition, enable it again after disabling DC/DC by setting Buck Enable register through I2C.

6.2.1 Step-down DC/DC Converter Block Diagram

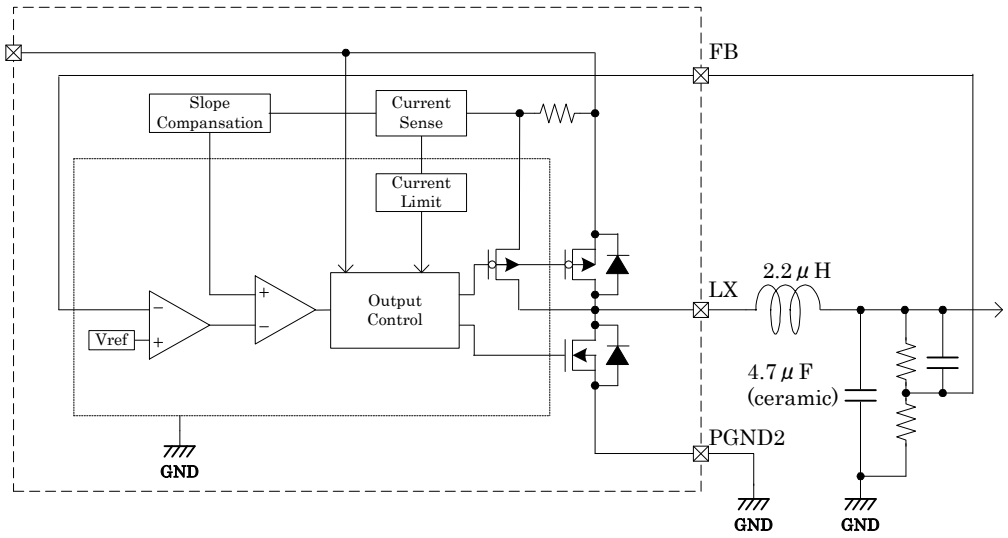
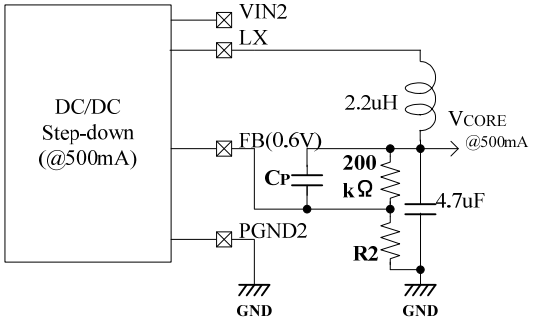


Fig 6-1 Step-down DC/DC Converter Block Diagram

6.2.2 Output Voltage Setting Calculation Formula



C_P= 8pF

The output voltage (V_{CORE}) is decided by the following formula.

$$V_{CORE}=\frac{(R2+200k\Omega)\times 0.6}{R2}$$

(V_{CORE}=Output Voltage)

Vcore: 1.2V (R2=200kΩ)
1.5V (R2=133kΩ)
1.8V (R2=100kΩ)
2.5V (R2=63kΩ)
2.6V (R2=60kΩ)

6.2.3 Step-down DC/DC Convertors Electrical Characteristics

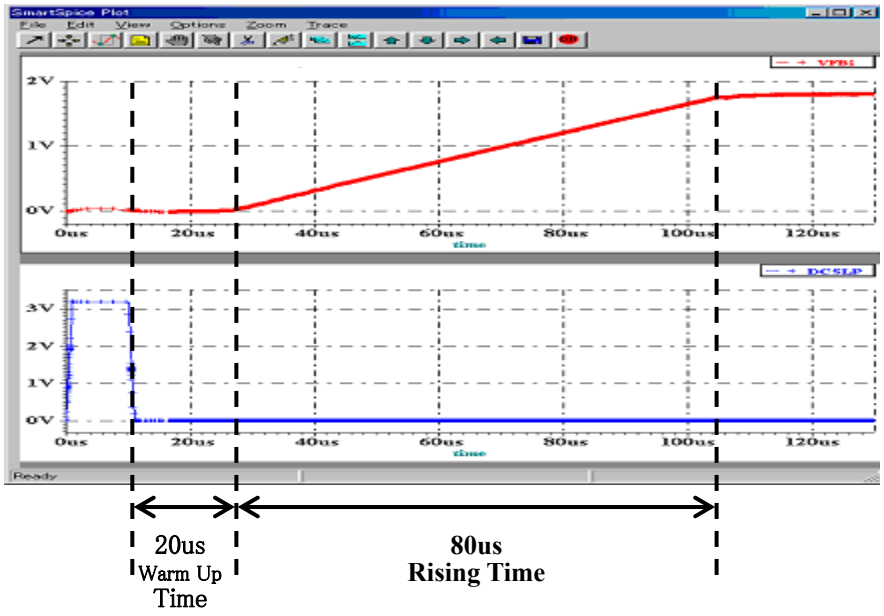
Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
Vbat	Input voltage	-	2.7		4.5	V
Voutdc	Output voltage range	Vbat=3.6V		1.2 ~ 2.6		V *1
ΔVout/ΔTa	Output voltage temperature coefficient	-40<Ta<85℃		±50		ppm/℃
Fosc	Switching frequency	Vbat=3.6V		2.5		MHz
Iss	Consumption current	Vbat=3.6V no load		3.5		mA
Ilx	Maximum output current1	Vbat =3.6V PWM Mode	500			mA
VLx	Limit current	Vbat=3.2～4.5V		1000		mA
Votr	Output transition response	Vbat=3.6V 1→120mA@ΔT=1μs		30	45	mV
Vrip	Output ripple voltage	Vbat=3.6V Iout=300mA		5	15	mV
Tprot	Protection delay time	Vbat=3.6V		1.6		ms
Tris	Rising time	Vbat=3.6V Cout=4.7μF -40<Ta<85℃			100	μs
Ronnch	Output Nch ON Resistance	Vbat=3.6V		0.4		Ω
Ronpch	Output Pch ON Resistance	Vbat=3.6V		0.4		Ω
Isd	Standby current	-		0.1		μA

Table 6-3 Step-down DC/DC Converter Electrical Characteristics

Note*1: The output voltages are selectable in ranges 1.2 ~ 2.6V by trimming.

6.2.4 (Reference waveform) Soft-start Waveforms (simulation result)



DC/DC Output Wave Form

Enable Internal Signal "L":Active

6.3 Thermal Shutdown Circuit

The thermal shutdown circuit is consisted of two temperature detection circuits and an op-amp.

6.3.1 Thermal Shutdown Block Diagram

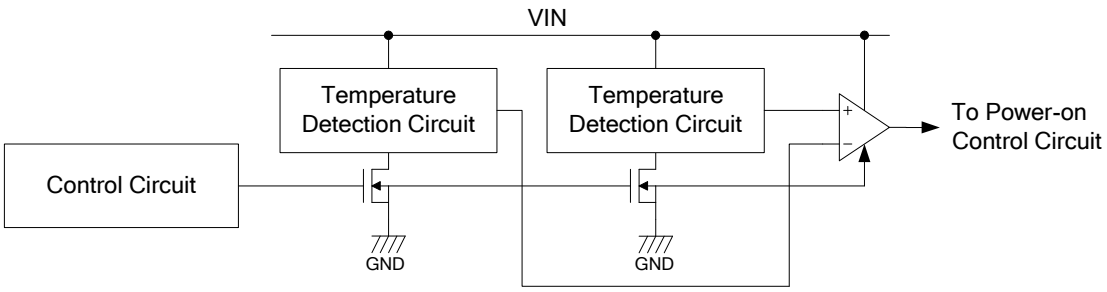


Fig 6-2 Thermal Shutdown Circuit Diagram

6.3.2 Thermal Shutdown Explanation of Operation

The overheat state can be detected by comparing the output voltages from two temperature detection circuits, which have different temperature Characteristics. If the overheat state is detected, internal POWERSW signal will fall down to "L", and RN5T651 will turn off to protect itself from overheating. When VEN signal is "H (Enable), the thermal shutdown function is effective.

6.3.3 Thermal Shutdown Electrical Characteristics

Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1 μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
T_{DET}	Detected Temperature	-		150		℃
T_{RET}	Return Temperature	-		100		℃
I_{SS}	Supply Current	-		10	20	μA

Table 6-4 Thermal Shutdown Electrical Characteristics

6.4 Charge Pump

RN5T651 charge pump drives up to six white LEDs and one strobe with regulated constant current for uniform intensity.

6.4.1 Block Diagram

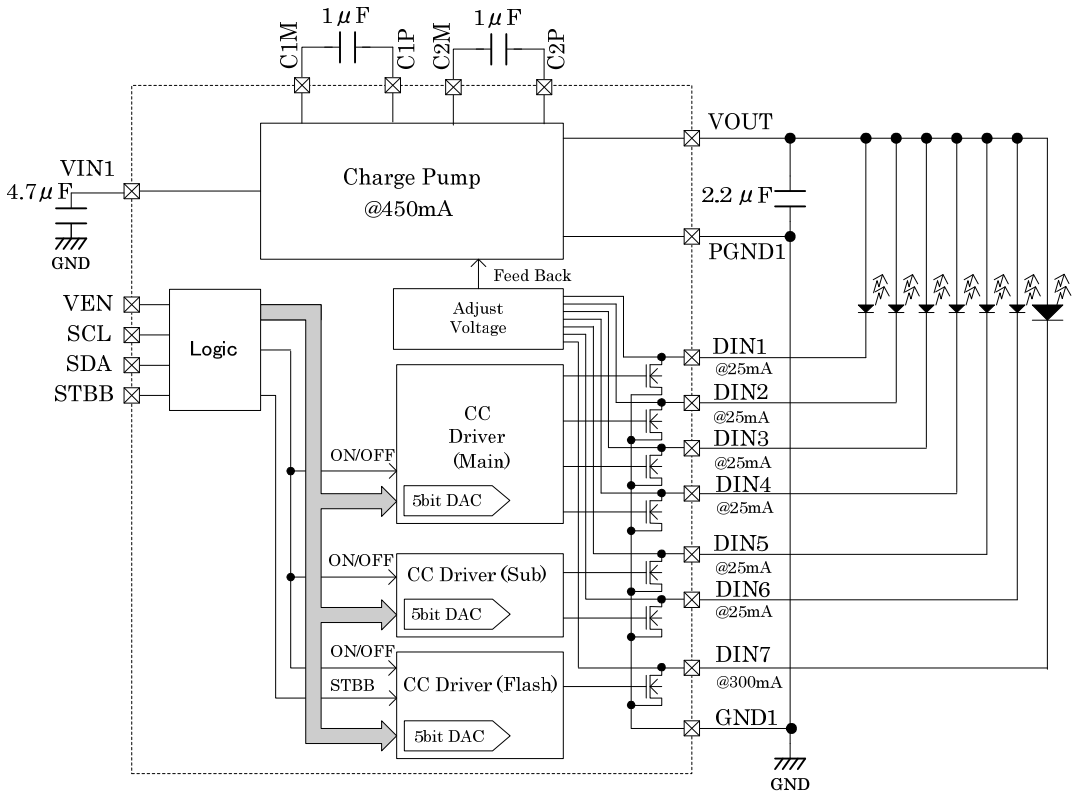


Fig 6-3 Charge Pump Circuit Diagram

6.4.2 Operation

Initial and 1x mode

When any channel is turned ON, charge pump output (VOUT) voltage becomes VIN1 voltage. In this time, Soft-start prevents the inrush current. As a result, RN5T651 starts at 1x mode.

In 1x mode, the following relation is the condition to stay in 1x mode.

$$VOUT - Vf > 0.25V \quad (1)$$

Here, VOUT and Vf mean output of Charge pump and forward voltage of white LED, respectively. 0.25V means mode transition threshold, in case of setting at 25mA of Main or Sub.

1x or 1.5x transition

When the battery voltage decreases and DIN_ pin voltage becomes lower than 0.25V for 100us, RN5T651 starts charge pump in 1.5x mode.

In 1.5x mode, the following relation is the condition to stay in 1.5x mode.

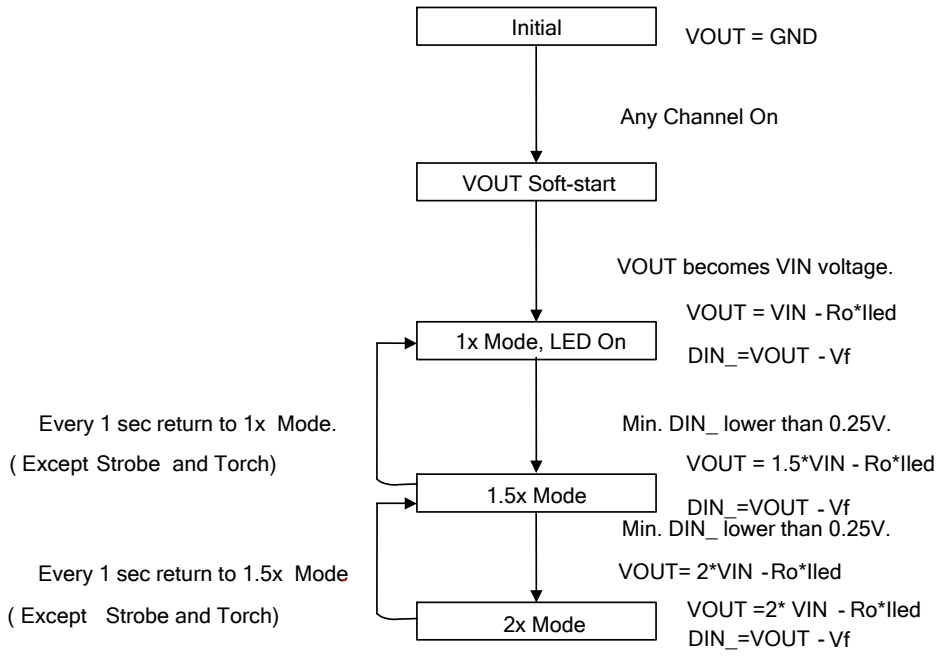
$$VOUT - Vf > 0.25V \quad (2)$$

In 1.5x mode, CP is switched to 1x mode about every 1 sec for 100us and judge the mode whether 1x or 1.5x.

1.5x or 2x transition

When the battery voltage decreases furthermore, and DINx_ pin voltage goes down below 0.25V for 100us, RN5T651 starts 2x mode from 1.5x mode. In 2x mode, CP is switched to 1.5x mode about every 1 sec for 100usec and judge the mode whether 2x or 1.5x.

1x/1.5x/2x mode transition



6.4.3 Protection circuit

When any DIN_ pin is floating or grounded, VOUT voltage is limited below protection voltage by gating on/off charge pump. In case any LED fails as an open circuit, VOUT voltage is also limited. Besides, when VOUT is smaller than approximately 1.2V, charge pump also stops.

6.4.4 Unused DIN_ pin

In case that there is any unused DIN_ pin, connect DIN_ to GND to avoid over voltage protection status.

6.4.5 Soft-start

When LEDs are turned ON, to prevent the inrush current, RN5T651 has Soft-start function. (The internal resistance gradually increases, just after LEDs enabled.)

6.4.6 Charge Pump Electrical Characteristics

Unless otherwise specified, VIN=3.6V, Ta=25℃, C1=C2=1uF, Cout=2.2uF

Parameter	Conditions	Min	Typ	Max	Units
Charge Pump					
Operating Voltage	VIN1 and VIN3 voltage	2.7		4.5	V
VOUT voltage (Over voltage)	Repeat On and Off in 1.5x or 2x		4.8		V
Over voltage detection hysteresis	-		0.1		V
Maximum Output current	VIN1=3.6V, VOUT=4.2V		450		mA
Output resistance: Ro	1x mode			1	Ohm
	1.5x mode			3	Ohm
	2x mode			5	Ohm
Switching Frequency	-		1.25		MHz
Soft-start time	-		0.12		msec
Supply current	1x mode, No load, (DET, Reference ON)			0.5	mA
	1.5x mode or 2x mode		5	6	mA
Standby supply current	VEN=0V, VIN1 and VIN3 current			1	uA
Current Limit	VOUT shorted		50		mA
LED Driver					
Maximum Sink current	DIN1-6		25		mA
	DIN7		300		mA
LED current accuracy (Main, Sub)	Code=1F, DIN_=0.25V	-5		5	%
LED current accuracy (Flash)	Code=1F, DIN7=0.4V	-5		5	%
LED current matching	Main or Sub, respectively. *1	-5		5	%
1x to 1.5x, 1.5x to 2x transition threshold	At lowest DINx pin, DIN1-6		250		mV
1x to 1.5x, 1.5x to 2x transition threshold	At lowest DINx pin, DIN7		400		mV
1x to 1.5x, 1.5x to 2x transition time	Chattering noise reduction		100		us
DIN1-7 leakage in shutdown	-		0.01		uA

Table 6-5 Charge Pump Electrical Characteristics

Note*1: Matching is defined (Iave_ - Iled_) / Iave_. Iave_ means the average current of Main or Sub, respectively.

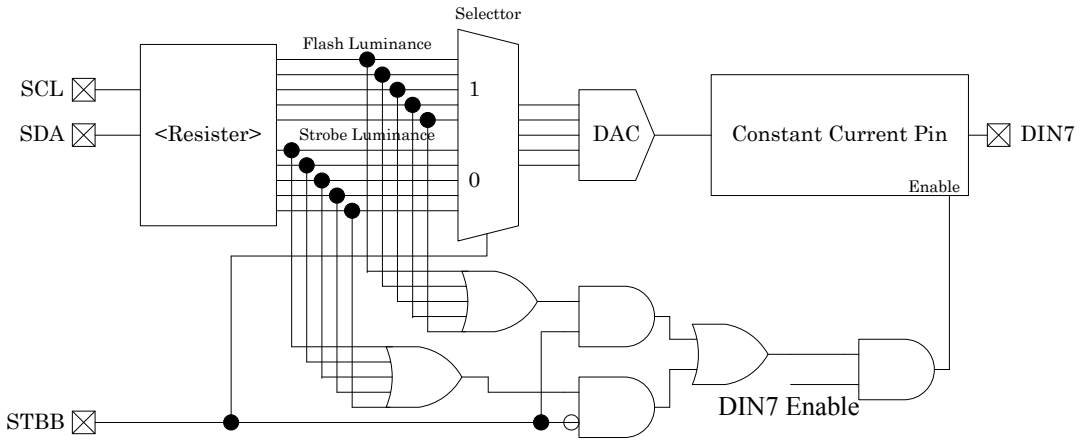
Matching is defined without Vf voltage difference between channels.

For Main, Iave_main = (Iled1 + Iled2 + Iled3 + Iled4) / 4

For Sub, Iave_sub = (Iled5 + Iled6) / 2

6.4.7 STBB Logic Input

STBB input is used to control the flash LEDs without accessing I2C. When STBB is driven to "L", the flash LEDs are driven by the current set in Strobe Luminance register. Driving STBB low overrides the flash LEDs set by I2C. With STBB high, the flash LEDs becomes controllable by I2C.



6.5 UVLO(Under Voltage Lock Out)

Operating Conditions (unless otherwise specified) C_{REFO} = 1 μF, T_a = 25℃

Symbol	Parameter	Condition	Min	Typ	Max	Units
$V_{Release}$	Under voltage lock out threshold	VCCVIN rising		2.25		V
V_{Detect}	Under voltage lock out threshold	VCCVIN falling	2.05	2.20	2.35	V
V_{HYS}	UVLO Hysteresis	-		50		mV

Table 6-6 UVLO Electrical Characteristics

6.6 CPU Interface

RN5T651 uses I2C -Bus system for CPU connection through 2-wires. Connection and transfer system of I2C -Bus are described in the following sections.

6.6.1 Start and Stop Condition

Within the procedure of I2C, unique situations arise which are defined as Start and Stop conditions.

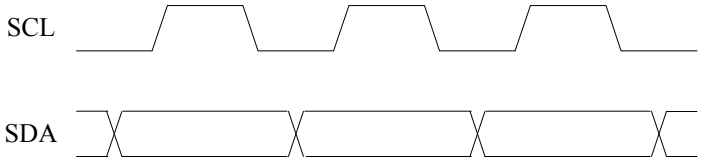


Fig 6-4 I2C -Bus Data Transmission

An “H” to “L” transition on SDA line while SCL is “H” indicates a Start condition. An “L” to “H” transition on SDA line while SCL is “H” defines a Stop condition. Start and Stop conditions are always generated by master (Refer to the figure below). The bus is considered to be busy after the start condition. The bus is considered to be free again a certain time after the stop condition.

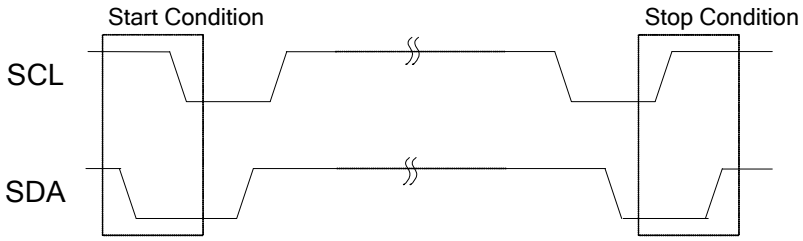


Fig 6-5 I2C-Bus Start and Stop Condition

6.6.2 Data Transmission and its Acknowledge

After start condition, data is transmitted by 1byte (8bits). The number of bytes that can be transmitted per transmission is not limited. Receiver must send an acknowledge signal to the transmitter every time 8bit data is transmitted.

Data transmission must be accompanied by acknowledge signal. The acknowledge-related clock pulse is generated by the master. The transmitter releases SDA line during the acknowledge clock pulse.

The receiver must pull down SDA line during the acknowledge clock pulse so that it remains stable “L” during “H” period of this clock pulse.

If a master–receiver is involved in a transfer, it must signal the end of the data to the slave-transmitter by not generating an acknowledge signal on the last byte that was clocked out of the slave. The slave-transmitter must release the data line to allow the master to generate a Stop condition.

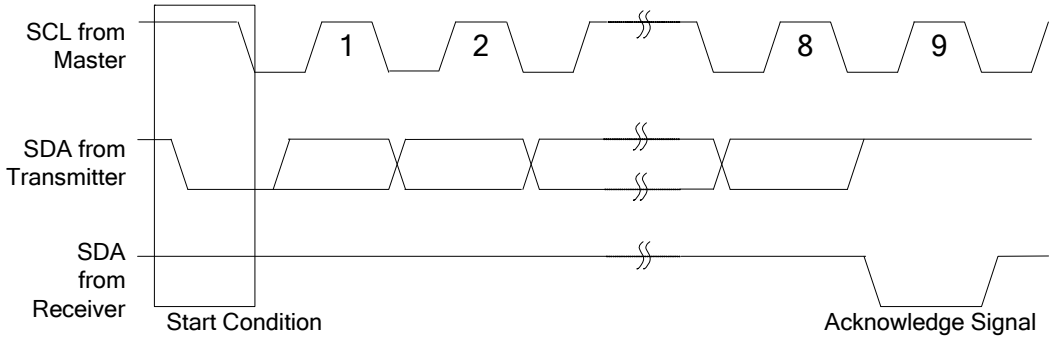


Fig 6-6 I2C-Bus Data Transmission and its Acknowledge

6.6.3 I2C-Bus Slave Address

After Start condition, a slave address is sent. This address is 8 bits long followed by. The slave address of RN5T651 are specified at “0001 0010b”

	A7	A6	A5	A4	A3	A2	A1	A0
Setting value	0	0	0	1	0	0	1	0

A7～A0: Slave Address

Fig 6-7 Slave Address of RN5T651

6.6.4 Data Transmission Write Format

The transmission format for the slave address allocated to each IC is defined by I2C-Bus standard. However transmission method of address information of each IC is not defined. RN5T651 transmits data to the internal address pointer at 1byte continue to the slave address and write command. For the data transmission, please transmit MSB first from Master and following data in sequence. Also, Master should receive MSB first when it receives data from the slave.

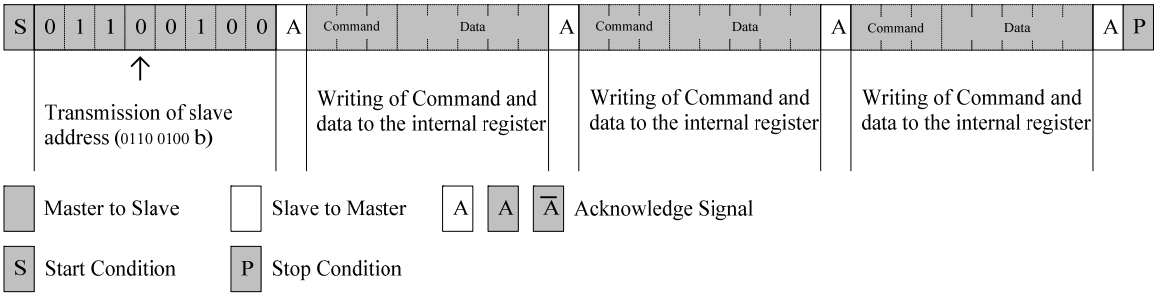


Fig 6-8 Data Transmission Write Format

6.6.5 Internal Register Write-in Timing

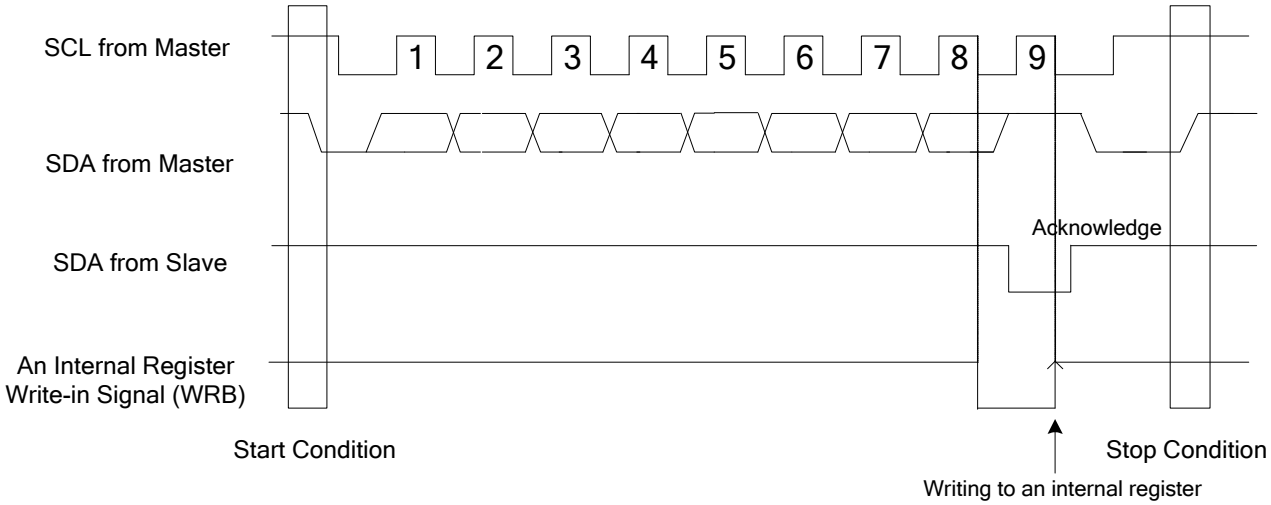
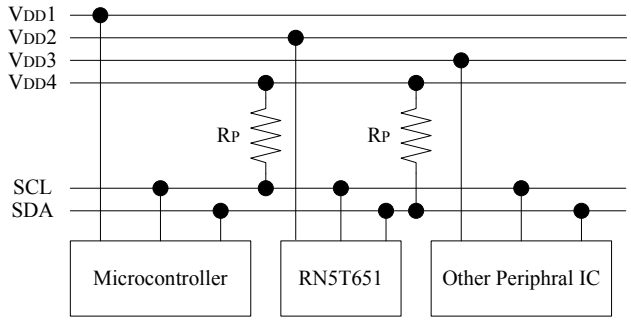


Fig 6-9 Internal Register Write-in Timing

6.6.6 Connection of I2C-Bus

2 wires of SCL and SDA are connected to I2C-Bus and used for transmitting clock pulses and data individually. All ICs connected to these two lines are designed not to be clamped, even though the voltage which exceeds its power supply voltage is supplied through the input and output pins. Open drain pins are for output. This construction allows the communication of signals between Ics, which have the different supply voltages, by adding a pull-up resistor to each signal line as shown in the figure below. Each IC is designed not to give any effect on SCL and SDA signal lines even though their power is turned off individually.



*1) For data interface, the following conditions must be met:
$V_{DD4} \geq V_{DD1}$
$V_{DD4} > V_{DD2}$
$V_{DD4} > V_{DD3}$
*2) When the master is one, the microcontroller is ready for driving SCL to "H" and R_P of SCL may not be required.

Fig 6-10 Connection of I2C-Bus

6.6.7 AC Characteristics of I2C-Bus

Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1 μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
f_{SCL}	SCL Clock Frequency	-			400	kHz
t_{BUF}	Bus Free Time Between a Precedent and Start	-	4.7			μs
t_{LOW}	SCL Clock "L" Time	-	1.3			μs
t_{HIGH}	SCL Clock "H" Time	-	0.6			μs
$t_{SU;STA}$	Start Condition Setup Time	-	0.6			μs
$t_{HD;STA}$	Start Condition Hold Time	-	0.6			μs
$t_{SU;STO}$	Stop Condition Setup Time	-	0.6			μs
$t_{HD;DAT}$	Data Hold Time	-	0			μs
$t_{SU;DAT}$	Data Setup Time	-	100*1			ns
t_R	Rising Time of SCL and SDA (Input)	-			300	ns
t_F	Falling Time of SCL and SDA (Input)	-			300	ns
t_{SP}	Spike Width that can be Removed with Input Filter	-			50	ns
t_{VENSET}	VEN to Start Condition Setup Time	-	100			μs
$t_{VENHOLD}$	VEN to Stop Condition Hold Time	-	100			μs

Note*: All the above-mentioned values are corresponding to V_{IH} min and V_{IL} max level.

Note*1: Standard mode is allowed in I2C bus standard. For Standard mode, it needs to satisfy the condition; tSU; DAT>=250ns.

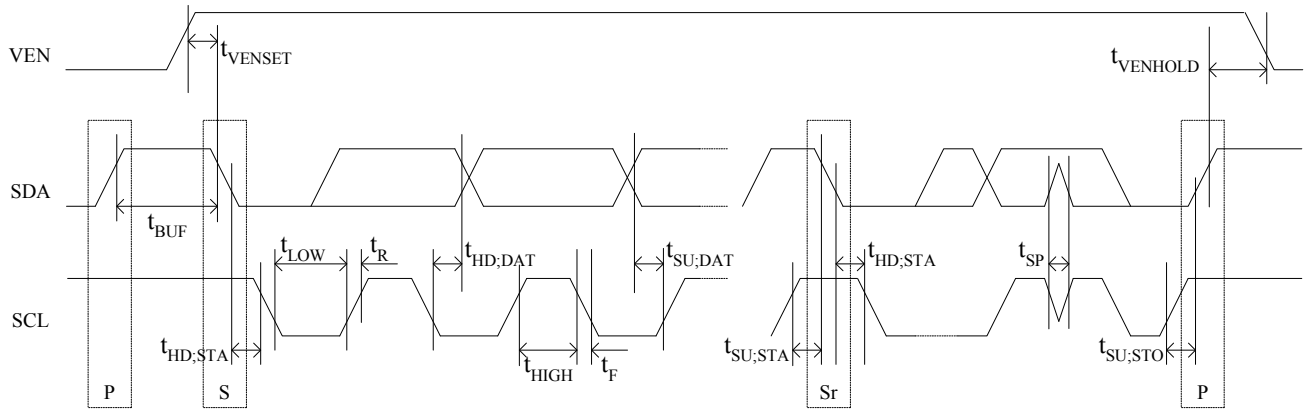


Fig 6-11 AC Characteristics of I2C-Bus

7. Register

7.1 Register Map

Function	SDA Control Byte							
	COMMAND			DATA				
	C2	C1	C0	D4	D3	D2	D1	D0
Main Luminance	0	0	0	31-steps 25mA / LED max. 000 00000 = off				
Initial value				0	0	0	0	0
Sub Luminance	0	0	1	31-steps 25mA / LED max. 001 00000 = off				
Initial value				0	0	0	0	0
Flash Luminance	0	1	0	31-steps 300mA max,I2C enabled, 010 00000 = off				
Initial value				0	0	0	0	0
Strobe Luminance	0	1	1	31-steps 300mA max, STBB enable, 011 00000 = off				
Initial value				0	0	0	0	0
LDO1 Output Voltage	1	0	0	x	16 steps			
Initial value				0	0	0	0	0
LDO2 Output Voltage	1	0	1	x	16 steps			
Initial value				0	0	0	0	0
Buck Enable	1	1	0	On / Off\	x	x	x	x
Initial value				0	0	0	0	0
Others Function	1	1	1	Main Enable	Sub Enable	DIN7 Enable	LDO1 Enable	LDO2 Enable
Initial value				0	0	0	0	0

Note*: C2 is MSB, and D0 is LSB.

Do not write "1" in Buck Enable Register [D3:D0].

Table 7-1 Register Map

7.2 Main / Sub / Flash / Strobe Luminance

Each sink current of DIN1-4, 5, 6, and 7 can be set by the code of D4-D0.

LED Current (mA)				Data				
Main	Sub	Flash	Strobe	D4	D3	D2	D1	D0
off	**off**	**off**	**off**	0	0	0	0	0
0.8	0.8	9.7	9.7	0	0	0	0	1
1.6	1.6	19.4	19.4	0	0	0	1	0
2.4	2.4	29.0	29.0	0	0	0	1	1
3.2	3.2	38.7	38.7	0	0	1	0	0
4.0	4.0	48.4	48.4	0	0	1	0	1
4.8	4.8	58.1	58.1	0	0	1	1	0
5.6	5.6	67.7	67.7	0	0	1	1	1
6.5	6.5	77.4	77.4	0	1	0	0	0
7.3	7.3	87.1	87.1	0	1	0	0	1
8.1	8.1	96.8	96.8	0	1	0	1	0
8.9	8.9	106	106	0	1	0	1	1
9.7	9.7	116	116	0	1	1	0	0
10.5	10.5	126	126	0	1	1	0	1
11.3	11.3	135	135	0	1	1	1	0
12.1	12.1	145	145	0	1	1	1	1
12.9	12.9	155	155	1	0	0	0	0
13.7	13.7	165	165	1	0	0	0	1
14.5	14.5	174	174	1	0	0	1	0
15.3	15.3	184	184	1	0	0	1	1
16.1	16.1	194	194	1	0	1	0	0
16.9	16.9	203	203	1	0	1	0	1
17.7	17.7	213	213	1	0	1	1	0
18.5	18.5	223	223	1	0	1	1	1
19.4	19.4	232	232	1	1	0	0	0
20.2	20.2	242	242	1	1	0	0	1
21.0	21.0	252	252	1	1	0	1	0
21.8	21.8	261	261	1	1	0	1	1
22.6	22.6	271	271	1	1	1	0	0
23.4	23.4	281	281	1	1	1	0	1
24.2	24.2	290	290	1	1	1	1	0
25.0	25.0	300	300	1	1	1	1	1

Note*: Defaults are shown in **Bold**.

7.3 LDO1 / LDO2 Output Voltage

Each output voltage of LDO1 and LDO2 can be set by the code of D3-D0. And enable/disable of the output can be individually set by D4 bit.

LDO Voltage (V)		Data			
LDO1	LDO2	D3	D2	D1	D0
1.50	1.50	0	0	0	0
1.80	1.80	0	0	0	1
2.50	2.50	0	0	1	0
2.60	2.60	0	0	1	1
2.80	2.80	0	1	0	0
3.00	3.00	0	1	0	1
3.10	3.10	0	1	1	0
3.30	3.30	0	1	1	1
1.85	1.85	1	0	0	0
2.40	2.40	1	0	0	1
2.55	2.55	1	0	1	0
2.70	2.70	1	0	1	1
2.85	2.85	1	1	0	0
2.90	2.90	1	1	0	1
3.20	3.20	1	1	1	0
1.50	1.50	1	1	1	1

7.4 Buck Enable

ON/OFF of DC/DC can be set by D4 bit.

Buck Enable (D4)

D4	Function
1	DC/DC convertor Output Enable
0	DC/DC convertor Output Disable

7.5 Others Function

Bit	DATA		Function
D4	Main Enable	1	Enable
		0	Disable
D3	Sub Enable	1	Enable
		0	Disable
D2	DIN7 Enable	1	Enable
		0	Disable
D1	LDO1 Enable	1	Enable
		0	Disable
D0	LDO2 Enable	1	Enable
		0	Disable

Note*: The relations between each bit of the other function registers and each register are AND conditions.

8. Electrical Characteristics

8.1 Absolute Maximum Ratings

The operation exceeding "Absolute Maximum Ratings"below may cause permanent damage to the device.

The operation of the device within the stated ratings below is not guaranteed.

Symbol	Item	Condition	Rated value	Units
VIN1 VIN2 VIN3 VEN	Power Supply Voltage	Battery Voltage Input Pins	-0.3～6.0	V
VIN	Input Voltage Range	All Input Pins	-0.3～VEN+0.3	V
PD	Package Allowable Dissipation	Mounted on Board, T_a =70℃	1826	mW
T_{stg}	Storage Temperature	-	-55～+125	℃

8.2 Recommendation of Operation Conditions

Symbol	Item	Condition	Min	Typ	Max	Units
VIN	Power Supply Voltage1	Battery Voltage Input Pins	2.7	3.6	4.5	V
VEN	Power Supply Voltage	-	1.8	3.0	4.2	V
T_a	Temperature of Operation	-	-40		+85	℃

8.3 General Characteristics

Symbol	Item	Condition	Min	Typ	Max	Units
I_{SSVEN}	VEN Supply Current	SCL=SDA=STBB=VEN		1		μA
I_{SHUT}	Shutdown Supply Current (All output off)	VEN=3.0V, I2C ready, TA=25℃		2.5		μA
		VEN=3.0V, I2C ready, TA=85℃				
		VEN=0V, I2C off, TA=25℃		1		
		VEN=0V, I2C off, TA=85℃				

8.4 DC Characteristics

Digital part Input

(Input Pin) SCL, SDA, STBB

Operating Conditions (unless otherwise specified) V_{BATT} = 3.6V, C_{REFO} = 1 μF, T_a = 25℃

Symbol	Item	Condition	Min	Typ	Max	Units
V_{IH}	"H" Input Voltage	-	VEN x 0.7			V
V_{IL}	"L" Input Voltage	-			VEN x0.3	V
V_{OL}	"L" Output Voltage	I_{OL}=-3mA			0.3	V
I_{IL}	Input Leakage Current	V=0～VEN	-3		3	μA
I_{OZ}	Off Leakage Current	V=0～VEN	-3		3	μA

Terminal Equivalent Circuit

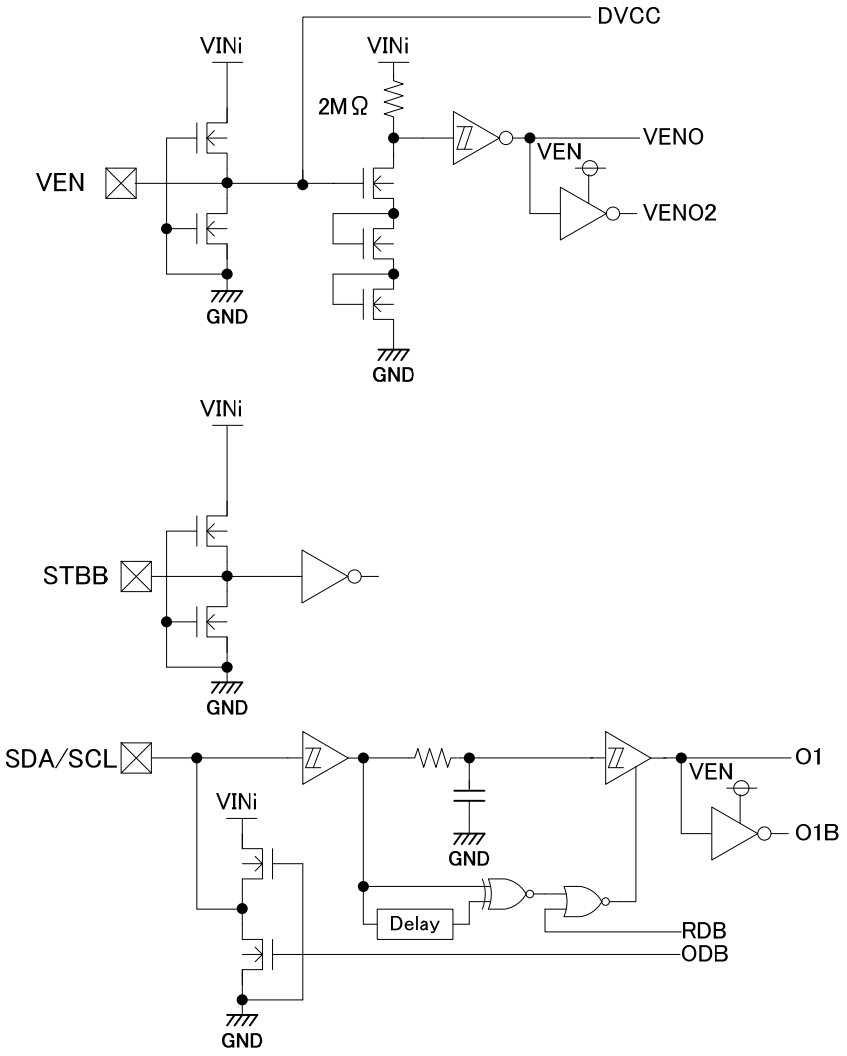


Fig 8-1 Terminal Equivalent Circuit

9. Additional Application Circuit

(1) Dual Main 4 LEDs and Sub 2 LEDs

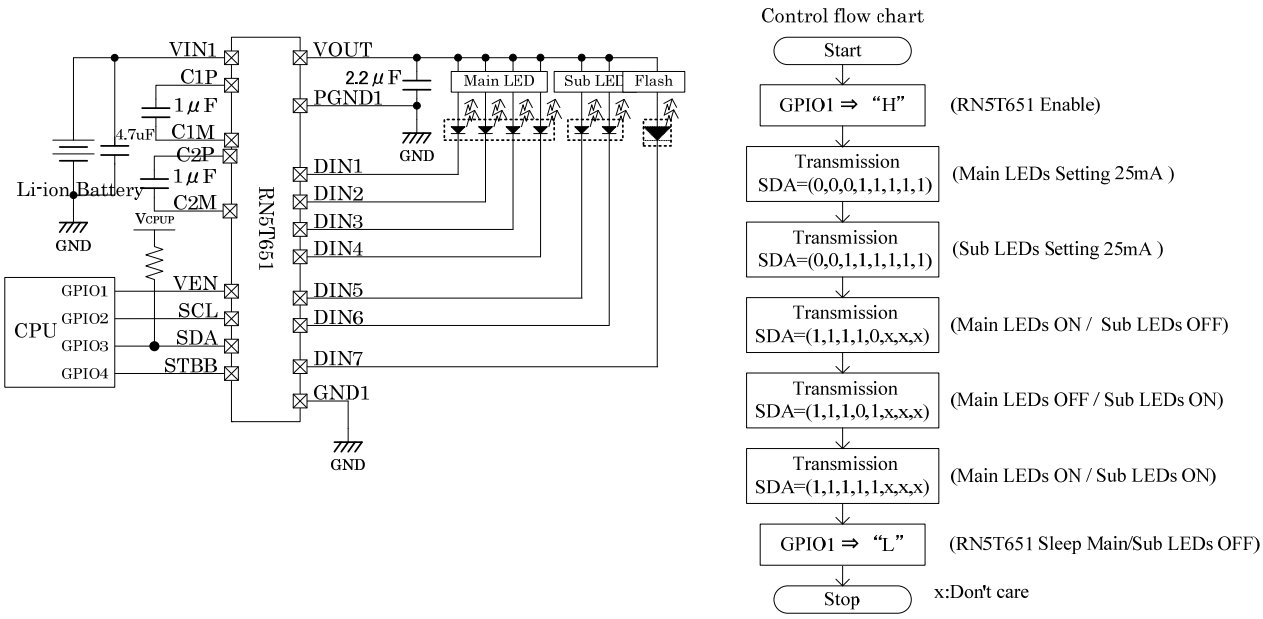
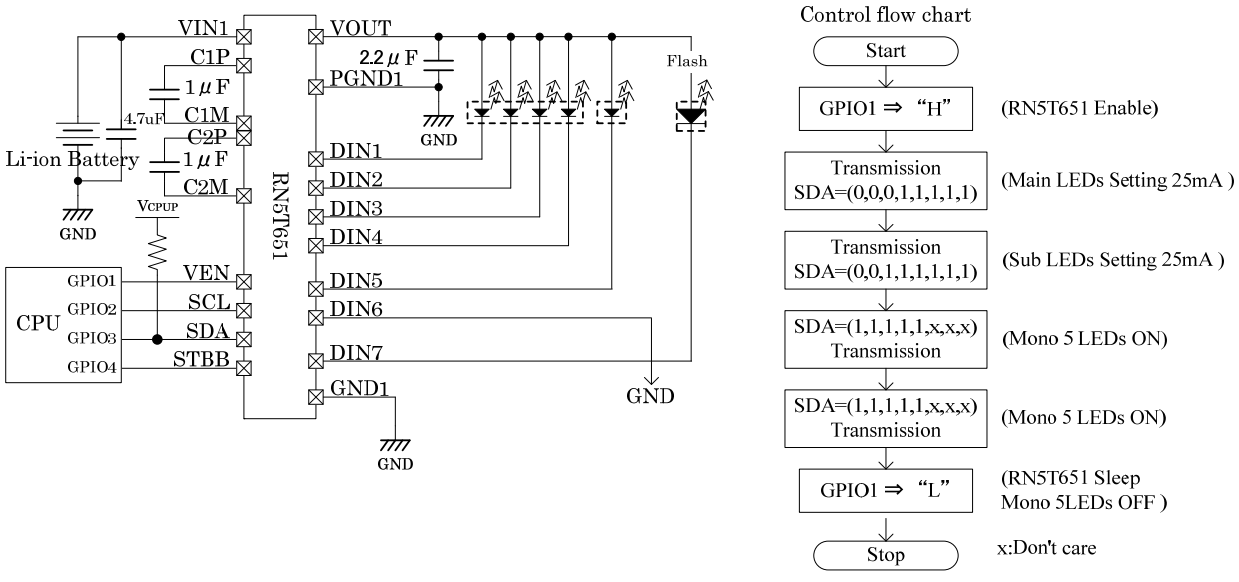


Fig 9-1 Dual Main 4 LEDs and Sub 2 LEDs

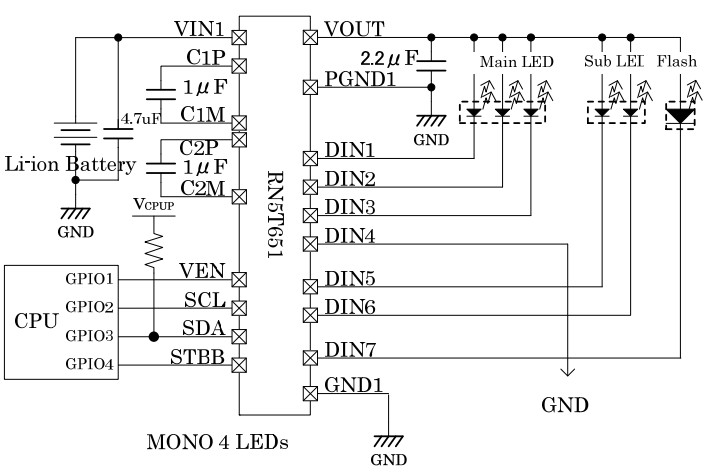
(2) Mono 5 LEDs

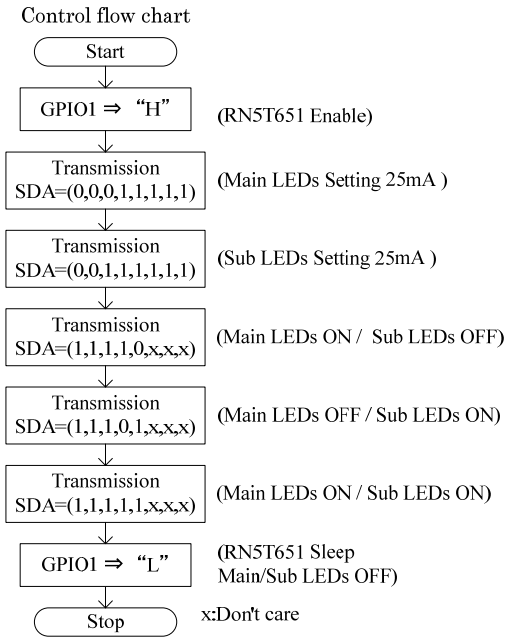


Note*: Please connect DIN6 to GND.

Fig 9-2 Mono 5 LEDs

(3) Dual Main 3 LEDs and Sub 2 LEDs

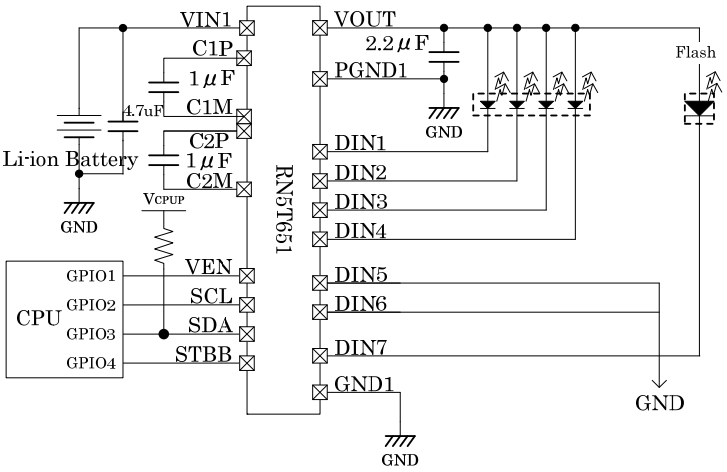


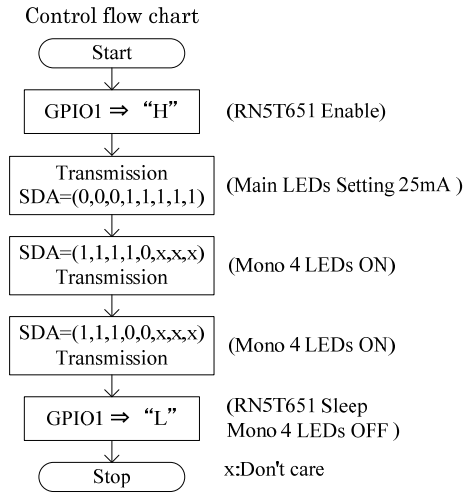


Note*: Please connect DIN4 to GND.

Fig 9-3 Dual Main 3 LEDs and Sub 2 LEDs

(4)Mono 4 LEDs





Note*: When DIN5 and 6 are not used, write "0" into D3 of the other function registers or connect DIN5 and DIN6 to GND.

Fig 9-4 Mono 4 LEDs

10. Package Information