

CHARGE PUMP RGBW LED DRIVER WITH PROGRAMMABLE SELF-RUNNING PATTERNS

April 2024

GENERAL DESCRIPTION

The IS31FL3195 is a compact and efficient 4-channel charge pump LED driver with programmable sequence operation for automated RGBW lighting effects. It is capable of driving 1 to 4 LEDs with a low drop-out and current matching so all 4 LEDs maintain consistent brightness. Each channel can support up to 20mA of current.

The built-in charge pump (CP) structure will automatically toggle between 1x, 1.5x operation depending on the battery's state of charge. This DC/DC converter operates at a high switching frequency which enables the use of small external capacitors and achieves 92% peak total efficiency. The IS31FL3195 is optimized for battery applications. To conserve battery life, the charge pump goes into high impedance mode whenever the IS31FL3195 is shutdown consuming less than 1 μ A.

The IS31FL3195 can operate in either "Current Level" or "Programmable Sequence" mode. In Current Level mode, the output current of each output is independently programmed and controlled in 256 steps to simplify color mixing. In programmable sequence mode, the timing characteristics for each output can be individually adjusted to maintain a pre-established pattern sequence without requiring any additional MCU interaction, thus saving valuable system resources.

The IS31FL3195 is available in a small QFN-16 (4mm $\times$ 4mm) and WLCSP-16 (1.88mm $\times$ 2.08mm, 0.45mm ball pitch, 0.2mm ball diameter) packages. It operates from 2.7V to 5.5V over the temperature range of -40°C to +85°C.

With automated lighting effects and a DC/DC charge pump, the small package IS31FL3195 is ideal for low power battery applications.

FEATURES

- 2.7V to 5.5V supply voltage
- Charge pump
 - 1x, 1.5x operating modes
 - Highly efficient across battery state of charge
 - 1MHz constant frequency
 - Enter 1.5x mode if any of the four OUTx pins < 150mV (50mV~300mV selectable)
- Power saving operating
 - 1 μ A Shutdown current
 - 640 μ A Quiescent operating current (CP1x mode)-
 - Two selectable sleep modes
 - Sleep 1 Mode: 38 μ A
 - Sleep 2 Mode: 1 μ A
 - Auto sleep mode if all OUTx outputs are off for >30s.
- Support four LEDs - RGBW
 - Resistor sets LED current up to 20mA
 - 8-bit dot correction
- LEDs can operate with pre-established lighting patterns
 - Run without a micro
 - Fixed number of iterations or non-stop operation
 - Each channel has its own fade registers (TS-T4) with independent start/stop
- 1MHz I2C bus interface
 - Automatic address increment function
 - 4 selectable I2C address locations
- Over-temperature protection
- QFN-16 (4mm $\times$ 4mm) and WLCSP-16 (1.88mm $\times$ 2.08mm, 0.45mm ball pitch, 0.2mm ball diameter) packages
- Operating temperature range is -40°C ~ +85°C
- RoHS & Halogen-Free Compliance
- TSCA Compliance

APPLICATIONS

- Internet-of-Things (IOT)
- Low-power battery applications
- Wearable applications
- Hand-held devices requiring visual notifications

IS31FL3195

TYPICAL APPLICATION CIRCUIT

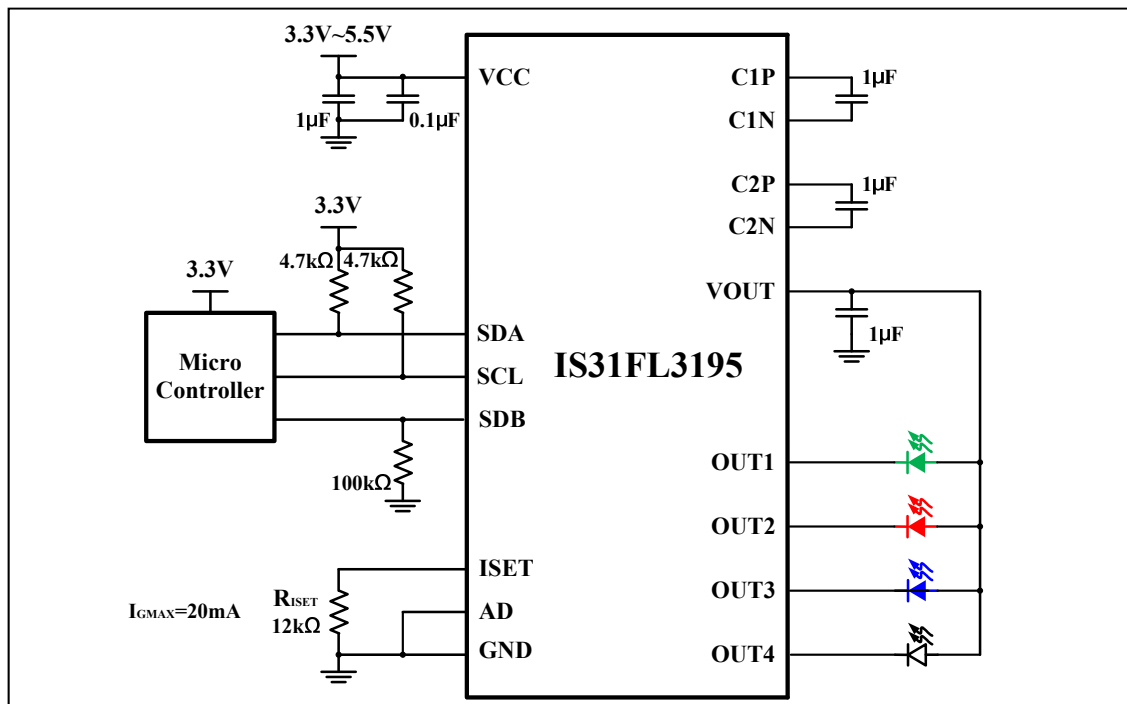
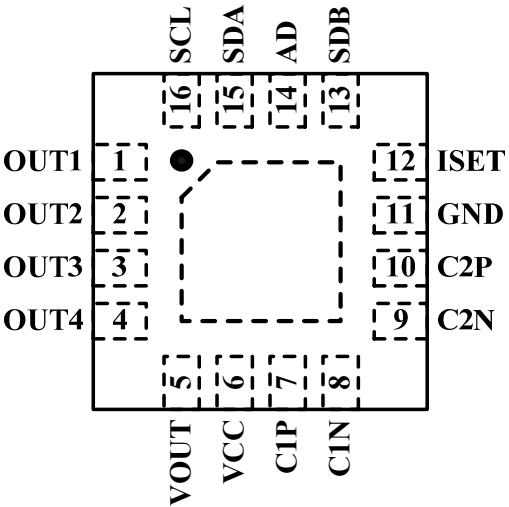
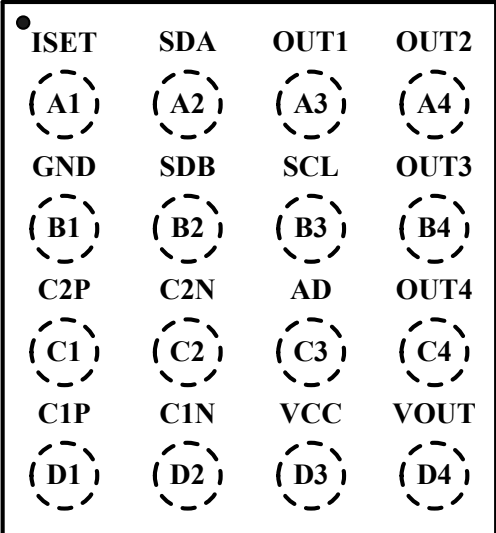


Figure 1 Typical Application Circuit

PIN CONFIGURATION

Package	Pin Configuration (Top View)
QFN-16	
WLCSP-16	

PIN DESCRIPTION

No.		Pin	Description
QFN	WLCSP		
1~4	A3, A4, B4, C4	OUT1~OUT4	LED current sink pins, connect the corresponding LED cathode to this pin. The anode of the associated LED must to be connected to the VOUT pin. The unused channel can be float but need to shut down by 01h register.
5	D4	VOUT	Charge pump output supplies the LED current. In shutdown mode this pin is high impedance. Connect a 1 μ F capacitor from VOUT to GND.
6	D3	VCC	Power supply input, requires 1.0 μ F and 0.1 μ F capacitor between this pin and ground pin.
7,8	D1, D2	C1P, C1N	Stage 1 charge pump flying capacitor, C1N negative terminal, C1P positive terminal. (Note 1)
9,10	C2, C1	C2N, C2P	Stage 2 charge pump flying capacitor, C2N negative terminal, C2P positive terminal. (Note 1)
11	B1	GND	Ground reference signal for the charge pump and the output current control. A PCB ground plane strongly recommended.
12	A1	ISET	Connect external resistor R _{ISET} to ground to set global max current I _{GMAX} .
13	B2	SDB	Pull below 0.4V to activate low power shutdown mode.
14	C3	AD	I2C address setting.
15	A2	SDA	I2C data pin. The SDA byte is used to program the device operating mode.
16	B3	SCL	I2C serial clock associated with SDA signal.
		Thermal Pad	Connect to GND.

Note 1: The flying capacitors should be placed as close as possible to the IC and the signal trace between the capacitor and CP terminals kept as short as possible.

IS31FL3195



ORDERING INFORMATION

Industrial Range: -40°C to +85°C

Order Part No.	Package	QTY/Reel
IS31FL3195-QFLS2-TR	QFN-16, Lead-free	2500
IS31FL3195-CLS2-TR	WLCSP-16, Lead-free	3000

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ABSOLUTE MAXIMUM RATINGS

Supply voltage, V_{CC} , V_{OUT}	-0.3V ~ +6.0V
Voltage at any input pin	-0.3V ~ $V_{CC}+0.3V$
Maximum junction temperature, T_{JMAX}	+150°C
Operating temperature range, $T_A=T_J$	-40°C ~ +125°C
Storage temperature range, T_{STG}	-65°C ~ +150°C
Package thermal resistance, junction to ambient (4-layer standard test PCB based on JEDEC 51-2A standard), θ_{JA}	53.8°C/W (QFN) 71.41°C/W (WLCSP)
ESD (HBM)	±8kV
ESD (CDM)	±750V

Note 2: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

$T_A = -40^\circ\text{C} \sim +85^\circ\text{C}$, $V_{CC} = 3.6\text{V}$, unless otherwise noted. Typical value are $T_A = 25^\circ\text{C}$.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{CC}	Supply voltage		2.7		5.5	V
I_{CC}	Quiescent operating current	1x mode, all outputs disable		640		μA
		1.5x mode, all outputs disable		1.2		mA
		Sleep 1 Mode: CP stops, Bandgap working and all OUTx are off without any bias		38		μA
		Sleep 2 Mode: CP, Bandgap stop and all OUTx are off without any bias		1		μA
I_{SD}	Shutdown current	$V_{SDB} = 0V$		1		μA
		$V_{SDB} = V_{CC}$, software shutdown		1		μA
I_{OUT}	Total output current	Current Level Mode, CL Register= 0xFF Current set Register 20mA		80		mA
I_{LED}	Current per channel	Current Level Mode, CL Register= 0xFF Current set Register 20mA, $V_{OUT}=0.3V$		20		mA
I_{MAT}	Current matching	Any two outputs, $V_{CC} = 3.6V$, $I_{OUT} = 20mA$ $V_{OUT}=0.3V$	-5		5	%
		Any two outputs, $V_{CC} = 3.6V$, $I_{OUT} = 5mA$ $V_{OUT}=0.3V$	-6		6	%
I_{ACC}	Current accuracy	Any outputs, $V_{CC} = 3.6V$, $I_{OUT} = 20mA$	-8		8	%
		Any outputs, $V_{CC} = 3.6V$, $I_{OUT} = 5mA$	-10		10	%
V_{HR}	Current sink headroom voltage	$I_{OUT} = 15mA$		150		mV
E_T	Total operating efficiency	$V_{CC} = 3.4V$, $V_F = 3.2V$, $I_{LOAD} = 20mA \times 4$ channel		92		%
		$V_{CC} = 2.7V$, $V_F = 3.2V$, $I_{LOAD} = 20mA \times 4$ channel		77		%
V_{OVP}	Output voltage compliance (OVP)	Output voltage clamp	4.4		5.5	V
Charge Pump Characteristics						
t_{ST}	Soft-start time	DC/DC start time ($C_{OUT} = 1\mu F$) $3.0V < V_{CC} < 5.5V$		64		μs
f_{CLK}	Charge pump operating frequency		900	1000	1200	kHz

ELECTRICAL CHARACTERISTICS (CONTINUED)

$T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{CC} = 3.6\text{V}$, unless otherwise noted. Typical value are $T_A = 25^{\circ}\text{C}$.

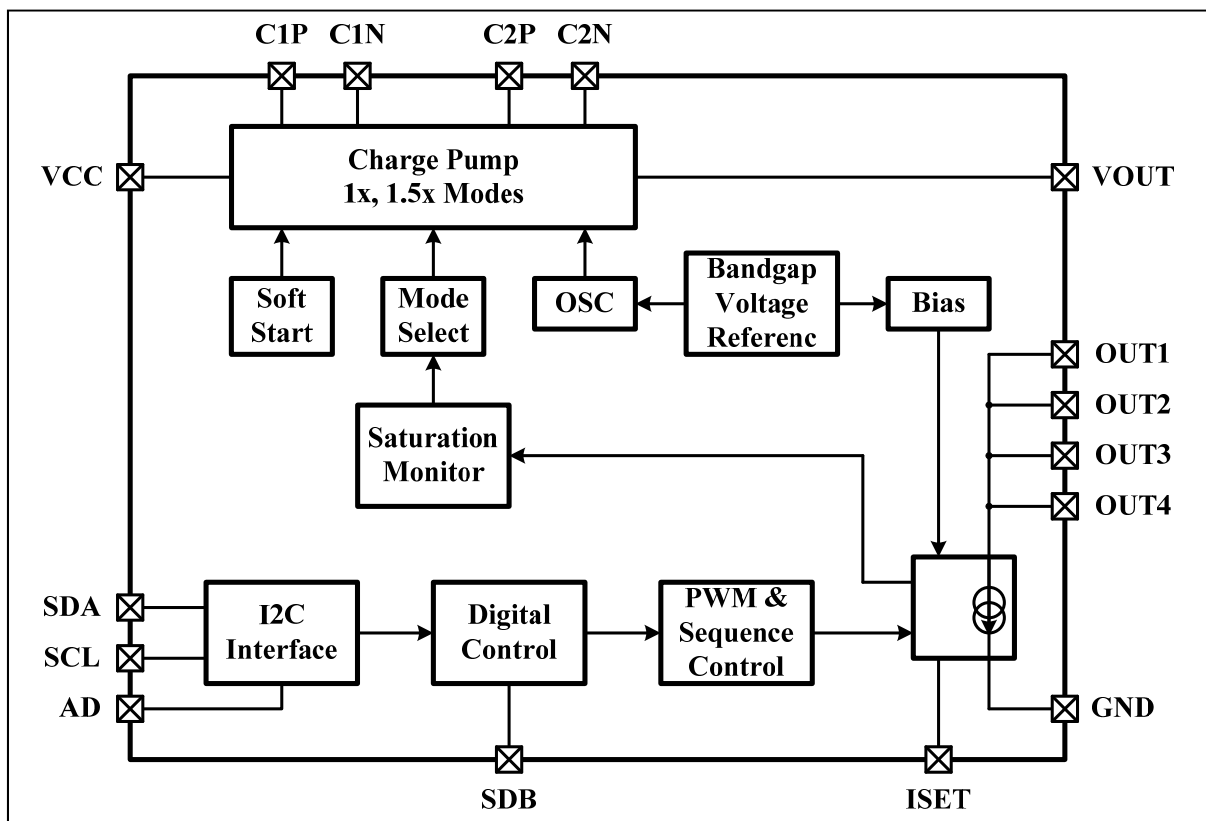
Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
Logic Electrical Characteristics (SDA, SCL, AD, SDB)						
V_{IL}	Logic "0" input voltage	$V_{CC} = 2.7\text{V} \sim 5.5\text{V}$	0		0.4	V
		$V_{CC} = 5\text{V}$, $T_A = 0^{\circ}\text{C} \sim +40^{\circ}\text{C}$ (SDA, SCL)	0		0.6	V
V_{IH}	Logic "1" input voltage	$V_{CC} = 2.7\text{V} \sim 5.5\text{V}$	1.4		V_{CC}	V
I_{IL}	Logic "0" input current	$V_{INPUT} = 0\text{V}$ (Note 3)		5		nA
I_{IH}	Logic "1" input current	$V_{INPUT} = V_{IO}$ (Note 3)		5		nA

DIGITAL INPUT SWITCHING CHARACTERISTICS (NOTE 3)

Symbol	Parameter	Fast Mode			Fast Mode Plus			Units
		Min.	Typ.	Max.	Min.	Typ.	Max.	
f_{SCL}	Serial-clock frequency	-		400	-		1000	kHz
t_{BUF}	Bus free time between a STOP and a START condition	1.3		-	0.5		-	μs
$t_{HD, STA}$	Hold time (repeated) START condition	0.6		-	0.26		-	μs
$t_{SU, STA}$	Repeated START condition setup time	0.6		-	0.26		-	μs
$t_{SU, STO}$	STOP condition setup time	0.6		-	0.26		-	μs
$t_{HD, DAT}$	Data hold time	-		-	-		-	μs
$t_{SU, DAT}$	Data setup time	100		-	50		-	ns
t_{LOW}	SCL clock low period	1.3		-	0.5		-	μs
t_{HIGH}	SCL clock high period	0.7		-	0.26		-	μs
t_R	Rise time of both SDA and SCL signals, receiving	-		300	-		120	ns
t_F	Fall time of both SDA and SCL signals, receiving	-		300	-		120	ns

Note 3: Guaranteed by design.

FUNCTION BLOCK DIAGRAM



DETAILED DESCRIPTION

I2C INTERFACE

The IS31FL3195 uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31FL3195 has a constant 7-bit slave address (A7:A1), followed by the R/W bit, A0. Set A0 to "0" for a write command and set A0 to "1" for a read command. The value of bits A1 and A2 are decided by the connection of the AD pin.

The complete slave address is:

Table 1 Slave Address:

AD	A7:A3	A2:A1	A0
GND	10101	00	0/1
SCL		01	
SDA		10	
VCC		11	

AD connected to GND, A2:A1=00;
 AD connected to VCC, A2:A1=11;
 AD connected to SCL, A2:A1=01;
 AD connected to SDA, A2:A1=10;

The SCL line is uni-directional. The SDA line is bi-directional (open-collector) with a pull-up resistor (typically 4.7kΩ when SCL frequency is 400kHz). The maximum clock frequency specified by the I2C standard is 400kHz. In this discussion, the master is the microcontroller and the slave is the IS31FL3195.

The timing diagram for the I2C is shown in Figure 2. The SDA is latched in on the stable high level of the SCL. When there is no interface activity, the SDA line should be held high.

The "START" signal is generated by lowering the SDA signal while the SCL signal is high. The start signal will alert all devices attached to the I2C bus to check the incoming address against their own chip address.

The 8-bit chip address is sent next, most significant bit first. Each address bit must be stable while the SCL level is high.

After the last bit of the chip address is sent, the master checks for the IS31FL3195's acknowledge. The master releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the IS31FL3195 has received the address correctly, then it holds the SDA line low during the SCL pulse. If the SDA line is not low, then the master should send a "STOP" signal (discussed later) and abort the transfer.

Following acknowledge of IS31FL3195, the register address byte is sent, most significant bit first. IS31FL3195 must generate another acknowledge indicating that the register address has been received.

Then 8-bit of data byte are sent next, most significant bit first. Each data bit should be valid while the SCL level is stable high. After the data byte is sent, the IS31FL3195 must generate another acknowledge to indicate that the data was received.

The "STOP" signal ends the transfer. To signal "STOP", the SDA signal goes high while the SCL signal is high.

ADDRESS AUTO INCREMENT

To write multiple bytes of data into IS31FL3195, load the address of the data register that the first data byte is intended for. During the IS31FL3195 acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to IS31FL3195 will be placed in the new address, and so on (Figure 5).

READING PORT REGISTERS

To read the device data, the bus master must first send the IS31FL3195 address with the R/W bit set to "0", followed by the command byte, which determines which register is accessed. After a restart, the bus master must then send the IS31FL3195 address with the R/W bit set to "1". Data from the register defined by the command byte is then sent from the IS31FL3195 to the master (Figure 6).

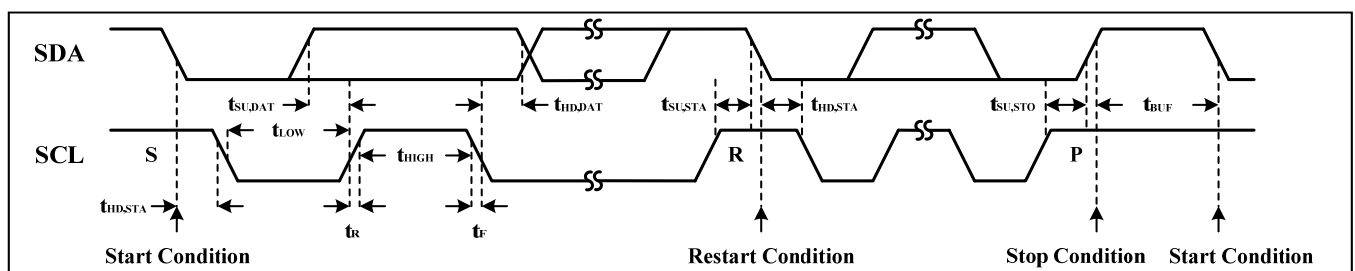


Figure 2 Interface Timing

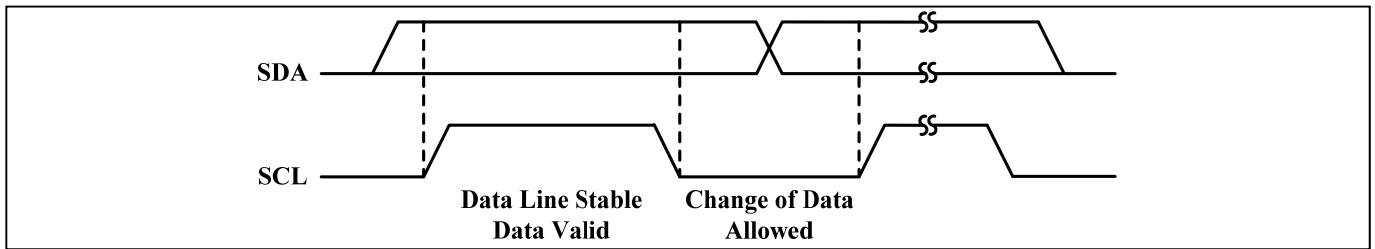


Figure 3 Bit Transfer

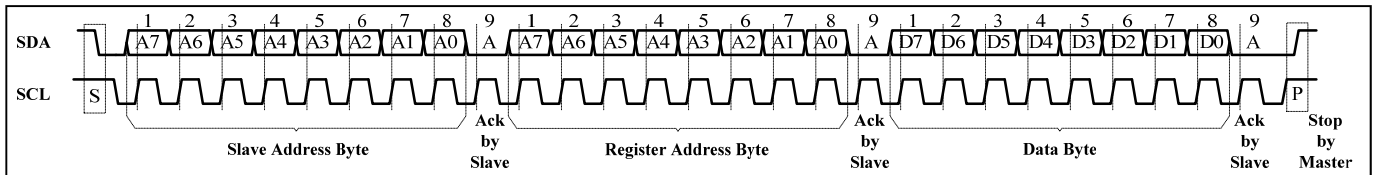


Figure 4 Writing to IS31FL3195 (Typical)

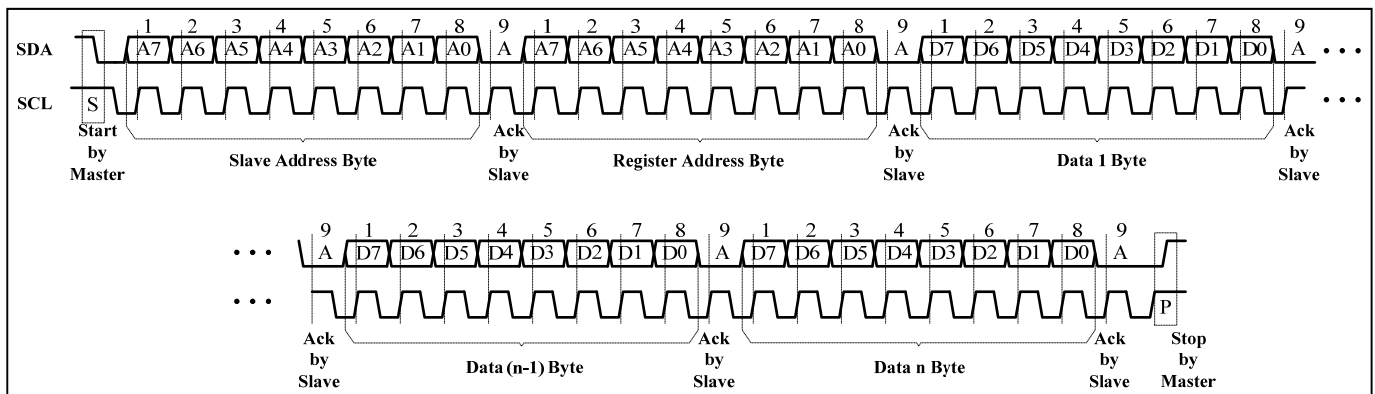


Figure 5 Writing to IS31FL3195 (Automatic Address Increment)

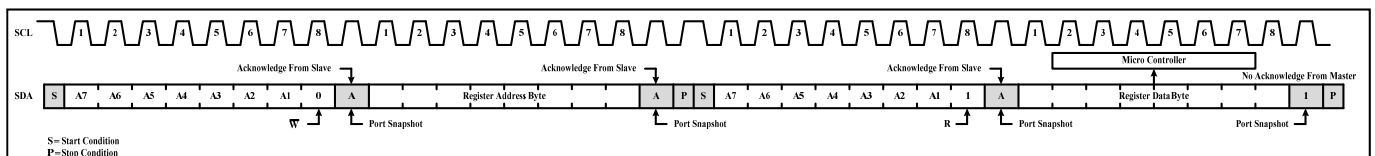


Figure 6 Reading from IS31FL3195

Table 2 Registers Definitions

Address	Name	Function	R/W	Table	Default
00h	Product ID	For read only, read result is Slave address	R	-	-
01h	Shutdown Control Register	Set power down mode and outputs shutdown control	W	3	1111 0000
02h	Operation Mode Configure Register	Set output operation mode	W	4	0000 0000
03h	Charge Pump Setting-1	Set charge pump parameters	W	5	0010 0000
04h	Charge Pump Setting-2	Set charge pump parameters	W	6	0011 0000
05h	Current Band Register	Set current band of each Output	W	7	0101 0101
06h	Hold Function Register	Set the hold function of each Output	W	8	0000 0000
07h	Phase Delay Register	Phase delay mode setting	W	9	0000 0001
0Ch/0Dh/0Eh/0Fh	P1/P2/P3/P4 State Register	For reading the pattern running state	R	10	0000 0000
10h/21h/32h/40h	OUT1/OUT2/OUT3/OUT4 Current Level Register	Output current level data register	W	11	0000 0000
10h~12h/20h~22h/30h~32h/40h~42h	Color 1 Setting Register of P1/P2/P3/P4	Output current level data register-Color 1	W	12~15	0000 0000
13h~15h/23h~25h/33h~35h/43h~45h	Color 2 Setting Register of P1/P2/P3/P4	Output current level data register-Color 2	W	12~15	0000 0000
16h~18h/26h~28h/36h~38h/46h~48h	Color 3 Setting Register of P1/P2/P3/P4	Output current level data register-Color 3	W	12~15	0000 0000
19h/29h/39h/49h	P1/P2/P3/P4 TS &T1 Setting Register	Set the TS~T1 time	W	16	0000 0000
1Ah/2Ah/3Ah/4Ah	P1/P2/P3/P4 T2 &T3 Setting Register	Set the T2~T3 time	W	17	0000 0000
1Bh/2Bh/3Bh/4Bh	P1/P2/P3/P4 TP &T4 Setting Register	Set the TP~T4 time	W	18	0000 0000
1Ch/2Ch/3Ch/4Ch	P1/P2/P3/P4 Color Enable Register	Set the color enable/disable	W	19	0000 0001
1Dh/2Dh/3Dh/4Dh	P1/P2/P3/P4 Color Cycle Times Register	Set color repeat time	W	20	0000 0000
1Eh/2Eh/3Eh/4Eh	P1/P2/P3/P4 NXT Register	Set next step and Gamma of each pattern	W	21~24	0000 0001
1Fh/2Fh/3Fh/4Fh	P1/P2/P3/P4 Loop Times Register	Set the loop time of P1~P4	W	25	0000 0000
50h	Color Update Register	Update color data	W	-	0000 0000
51h/52h/53h/54h	P1/P2/P3/P4 Update Register	Update the time data and start to run pattern	W	-	0000 0000
5Fh	Reset Register	Reset the registers value to default	W	-	0000 0000

Note: When T1 or T3= 0.03s, GAM will be set to 10 (Linearity).

Table 3 01h Shutdown Control Register

Bit	D7:D4	D3	D2:D1	D0
Name	EN4:EN1	CPPM	SLE	SSD
Default	1111	0	00	0

The Shutdown Control Register sets software shutdown and sleep modes of IS31FL3195.

The Output Enable Register enables/disables the outputs independently. The ENx is only effective when SSD= "1".

Sleep 1 (power saving standby 1) Mode: CP in 1x mode and all OUTx are off without any bias. I_SLEEP1=35μA (Typ.)

Sleep 2 (power saving standby 2) Mode: CP off and all OUTx are off without any bias. I_SLEEP2=1μA (Typ.)

When SLE bits are set to "01" or "10", IS31FL3195 puts itself in Sleep 1 or Sleep 2 Modes if all OUTx outputs are off for >30s. MCU command to the IS31FL3195 will wake it up and disable the sleep mode.

The CPPM bit selects the default charge pump power up mode. When CPPM= "0", the default power up mode is 1x mode, otherwise it will run in 1.5x mode to ensure the LEDs can work with enough forward voltage.

SSD Software Shutdown Enable

0	Software shutdown mode
1	Normal operation

SLE Sleep Mode Enable

00/11	Sleep mode disable
01	Sleep1 mode enable
10	Sleep2 mode enable

CPPM Charge Pump Power Up Mode

0	1x
1	1.5x

ENx Output Enable Control

0	Output disable
1	Output enable

Table 4 02h Operating Configure Register

Bit	D7:D4	D3:D1	D1:D0
Name	OUT4:OUT1	-	LM
Default	0000	00	00

The Operating Configure Register sets operation modes of IS31FL3195.

When LM= "00/11", the OUTx can be "0" current level mode or "1" pattern mode, when LM= "01", the OUT4 can be "0" current level mode or "1" pattern mode, OUT1~3 are not needed to set. When LM= "10", OUT1~4 are not needed to set.

LM LED Mode

00/11	Single mode
01	RGB + W mode, OUT1, OUT2 and OUT3 work together, OUT4 work independent
10	RGBY mode, OUT1, OUT2, OUT3 and OUT4 work together thru Pattern 1-3

OUTx Output Operating Mode

0	Current Level Mode
1	Pattern Mode

Table 5 03h Charge Pump Setting-1

Bit	D7:D2	D1:D0
Name	-	CPM
Default	0010 00	00

The Charge Pump Setting Register-1 sets the charge pump working mode.

CPM Charge Pump Working Mode

00	Auto mode
01	1x mode
10	1.5x mode

Table 6 04h Charge Pump Setting-2

Bit	D7	D6:D4	D3:D0
Name	-	HRT	CPDE4:CPDE1
Default	0	011	0000

The Charge Pump Setting Register-2 sets headroom detect threshold voltage and enables OUTx charge pump detection. Disable charge pump detection on OUTx if LED anode not connected to VOUT or OUTx floating.

CPDEx Charge Pump Detection Enable of OUTx

0	Enable
1	Disable

HRT	Headroom Threshold Voltage
000	50mV
001	100mV
010	125mV
011	150mV
100	175mV
101	200mV
110	250mV
111	300mV

Table 7 05h Current Band Register

Bit	D7:D6	D5:D4	D3:D2	D1:D0
Name	CB4	CB3	CB2	CB1
Default	01	01	01	01

The Current Band Register stores the current band of each LED output.

$I_{GMAX}=20mA$ when $R_{SET}=12k\Omega$. When current level register is 0xFF and CBx is "01", $I_{BAND}= I_{GMAX} \times 2/4=10mA$, when current level register is 0x00, $I_{OUT}=0mA$.

CBx Current Band Setting

00	Band 1: $0mA \sim I_{GMAX} \times 1/4$, $I_{BAND}= I_{GMAX} \times 1/4$
01	Band 2: $0mA \sim I_{GMAX} \times 1/2$, $I_{BAND}= I_{GMAX} \times 1/2$
10	Band 3: $0mA \sim I_{GMAX} \times 3/4$, $I_{BAND}= I_{GMAX} \times 3/4$
11	Band 4: $0mA \sim I_{GMAX}$, $I_{BAND}= I_{GMAX}$

Table 8 06h Hold Function Register

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	HF4	HT4	HF3	HT3	HF2	HT2	HF1	HT1
Default	0	0	0	0	0	0	0	0

The Hold Function Register configures hold time for each output in Pattern Mode.

HTx Hold Time Selection

0	Hold at end of T4 when pattern loop done (always off)
1	Hold at end of T2 when pattern loop done (always on)

HFx Hold Function Enable

0	Hold function disable
1	Hold function enable

Table 9 07h Phase Delay Register

Bit	D7:D0	D1:D0
Name	-	PD
Default	0000 00	01

IS31FL3195 features the output current phase delay function, default is mode 1

PD Phase Delay Mode

01	Phase delay mode 1
11	Phase delay mode 2

Table 10 0Ch/0Dh/0Eh/0Fh P1/P2/P3/P4 State Register (Read Only)

Bit	D7	D6	D5	D4	D3	D2:D0
Name	PSx	CS3x	CS2x	CS1x	-	TXx
Default	0	0	0	0	0	000

The Pattern State Registers store the four patterns. PS is the pattern enable or not, CSX is the color enable or not, TX will show the running position of Pattern 1.

0Dh, 0Eh and 0Fh store the state of Pattern 2, 3 and 4.

TXx Time State

000	Running at TS
001	Running at T1
010	Running at T2
011	Running at T3
100	Running at TP
101	Running at T4

CSXx Color State

0	Not running at Color x
1	Running at Color x

PSx Pattern State

0	Not running at Pattern x
1	Running at Pattern x

**Table 11 10h/21h/32h/40h
OUT1/OUT2/OUT3/OUT4 Current Level Register**

Bit	D7:D0
Name	CL
Default	0000 0000

When IS31FL3195 operates in Current Level Mode, the value of Current Level Registers will decide the output current of OUTx in 256 levels.

The output current may be computed using the Formula (1):

$$I_{OUT} = \frac{I_{BAND}}{256} \sum_{n=0}^7 D[n] \times 2^n \quad (1)$$

Where D[n] stands for the individual bit value, 1 or 0, in location n.

For example: if D7:D0 = 10110101,

$$I_{OUT} = I_{BAND} (2^7 + 2^5 + 2^4 + 2^2 + 2^0) / 256$$

I_{BAND} is defined in Table 7.

**Table 12
10h ~12h Color 1 Setting Register of P1**

Bit	D7:D0
Name	P1COL1_Ox
Default	0000 0000

13h~15h Color 2 Setting Register of P1

Bit	D7:D0
Name	P1COL2_Ox
Default	0000 0000

16h~18h Color 3 Setting Register of P1

Bit	D7:D0
Name	P2COL3_Ox
Default	0000 0000

**Table 13
20h~22h Color 1 Setting Register of P2**

Bit	D7:D0
Name	P2COL1_Ox
Default	0000 0000

23h~25h Color 2 Setting Register of P2

Bit	D7:D0
Name	P2COL2_Ox
Default	0000 0000

26h~28h Color 3 Setting Register of P2

Bit	D7:D0
Name	P2COL3_Ox
Default	0000 0000

**Table 14
30h~32h Color 1 Setting Register of P3**

Bit	D7:D0
Name	P3COL1_Ox
Default	0000 0000

33h~35h Color 2 Setting Register of P3

Bit	D7:D0
Name	P3COL2_Ox
Default	0000 0000

36h~38h Color 3 Setting Register of P3

Bit	D7:D0
Name	P3COL3_Ox
Default	0000 0000

Table 15 40h~42h COL1/2/3 Setting Register of P4

Bit	D7:D0
Name	P4COL1_Ox
Default	0000 0000

Color Setting Registers store the color setting for each output in Pattern Mode. Check Pattern Color Setting section for more information about the color setting registers.

Need to write Color Update Register (50h) to update the data.

Table 16 19h/29h/39h/49h P1/P2/P3/P4 TS & T1 Setting Register

Bit	D7:D3	D4:D0
Name	T1	TS
Default	0000	0000

The TS & T1 Setting Registers set the TS and T1 time in Pattern Mode.

TS Pattern Start Time Selection

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

T1 Rise Time Selection

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

Table 17 1Ah/2Ah/3A/4Ah P1/P2/P3/P4 T2 & T3 Setting Register

Bit	D7:D3	D4:D0
Name	T3	T2
Default	0000	0000

The T2 & T3 Setting Registers set the T2 and T3 time in Pattern Mode.

T2 Hold Time Selection

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

T3 Fall Time Selection

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

Table 18 1Bh/3Bh/3Bh/4Bh P1/P2/P3/P4 TP & T4 Setting Register

Bit	D7:D3	D4:D0
Name	T4	TP
Default	0000	0000

The TP & T4 Setting Registers set the TP and T4 time in Pattern Mode.

TP Time between Pulses

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

T4 Off Time Selection

0000	0.03s
0001	0.13s
0010	0.26s
0011	0.38s
0100	0.51s
0101	0.77s
0110	1.04s
0111	1.60s
1000	2.10s
1001	2.60s
1010	3.10s
1011	4.20s
1100	5.20s
1101	6.20s
1110	7.30s
1111	8.30s

Table 19 1Ch/2Ch/3Ch/4Ch P1/P2/P3/P4 Color Enable Register

Bit	D7:D3	D2	D1	D0
Name	-	CE3	CE2	CE1
Default	00000	0	0	1

Color Enable Register enables the color function for each color in Pattern Mode.

CEx Color Enable Selection

0	Color x disable
1	Color x enable

Table 20 1Dh/2Dh/3Dh/4Dh P1/P2/P3/P4 Color Cycle Times Register

Bit	D7:D6	D5:D4	D3:D2	D1:D0
Name	-	CCT3	CCT2	CCT1
Default	00	00	00	00

Color Cycle Times Register sets Color loop times for each color.

CCTx Color Cycle Times Selection

00	Endless
01	1 time
10	2 times
11	3 times

Table 21 1Eh P1 NXT Register

Bit	D7:D4	D3:D2	D1:D0
Name	MTPLT1	GAM1	NXT1
Default	0000	00	01

NXT1 defines next operation when Pattern 1 is done. GAM1 controls the gamma of Pattern 1. MTPLT1 controls the loop of Pattern 1.

NXT1 Pattern 1 Next

00/10/11	Just stop
01	Go to Pattern 2 (Only effective in RGB & RG+W Mode)

GAM1 Gamma Selection

00/11	Gamma=2.4
01	Gamma=3.5
10	Linearity

MTPLT1 Multy-Pulse Loop Time

0000	Endless
0001	1 time
...	
1111	15 times

Table 22 2Eh P2 NXT Register

Bit	D7:D4	D3:D2	D1:D0
Name	MTPLT2	GAM2	NXT2
Default	0000	00	01

NXT2 defines next operation when Pattern 2 is done. GAM2 controls the gamma of Pattern 2. MTPLT2 controls the loop of Pattern 2.

NXT2 Pattern 2 Next

00/11	Just stop
01	Go to Pattern 1 (Only effective in RGB mode)
10	Go to Pattern 3 (Only effective in RGB mode)

GAM2 Gamma Selection

00/11	Gamma=2.4
01	Gamma=3.5
10	Linearity

MTPLT2 Multy-Pulse Loop Time

0000	Endless
0001	1 time
...	
1111	15 times

Table 23 3Eh P3 NXT Register

Bit	D7:D4	D3:D2	D1:D0
Name	MTPLT3	GAM3	NXT3
Default	0000	00	01

NXT3 defines next operation when Pattern 3 is done. GAM3 controls the gamma of Pattern 3. MTPLT3 controls the loop of Pattern 3.

NXT3 Pattern 3 Next

00/11	Just stop
01	Go to Pattern 1 (Only effective in RGB mode)
10	Go to Pattern 2 (Only effective in RGB Mode)

GAM3 Gamma Selection

00/11	Gamma=2.4
01	Gamma=3.5
10	Linearity

MTPLT3 Multy-Pulse Loop Time

0000	Endless
0001	1 time
...	
1111	15 times

Table 24 4Eh P4 NXT Register

Bit	D7:D4	D3:D2	D1:D0
Name	MTPLT4	GAM4	-
Default	0000	00	01

NXT4 defines next operation when Pattern 4 is done. GAM4 controls the gamma of Pattern 4. MTPLT4 controls the loop of Pattern 4.

GAM4 Gamma Selection

00/11	Gamma=2.4
01	Gamma=3.5
10	Linearity

MTPLT4 Multy-Pulse Loop Time

0000	Endless
0001	1 time
...	
1111	15 times

Table 25 1Fh/2Fh/3Fh/4Fh P1/P2/P3/P4 Loop Times Register

Bit	D7	D6:D0
Name	PLTx_H	PLTx_L
Default	0	000 0000

If PLTx_H(D7)=0, PLTx_L!=0

Pattern loop times:

$$Looptime = \sum_{n=0}^6 D[n] \times 2^n \quad (3)$$

If PLTx_H(D7)=0, PLTx_L=0, endless

If PLTx_H(D7)=1, PLTx_L!=0

Pattern loop times:

$$Looptime = 16 \times \sum_{n=0}^6 D[n] \times 2^n \quad (4)$$

If PLTx_H(D7)=1, PLTx_L=0, endless

Where D[n] stands for the individual bit value.

50h Color Update Register

Write 0xC5 to 50h will update the data of 10h~18h/20h~28h/30h~38h

51h/52h/53h/54h P1/P2/P3/P4 Update Register

Write 0xC5 to these registers will update the time parameters of Pattern x, and start to run Pattern x.

5Fh Reset Register

Once user writes "0xC5" to the Reset Register, IS31FL3195 will reset all registers to their default value. On initial power-up, the IS31FL3195 registers are reset to their default values for a blank display.

TYPICAL APPLICATION INFORMATION

GENERAL DESCRIPTION

IS31FL3195 is a 4-channel LED driver which features two-dimensional auto breathing mode. It has Pattern Mode and Current Level Mode for RGB+W lighting effects.

The IS31FL3195 LED driver integrates a switched capacitor charge pump to power four LEDs with a programmable regulated current, up to 20mA (max) per channel.

Upon power up, the built-in charge pump converter will initialize base on CPPM bit of 01h register. To prevent a large in-rush current; the IS31FL3195 will first charge the C1P/N, C2P/N capacitors to near VIN. The 1x mode provides maximum efficiency and minimum noise. The IS31FL3195 will remain in this mode until one of the LED current source drivers begins to drop out of regulation.

The current delivered through the LED load is controlled by an internal configurable low dropout (135mV Typ.) current source. The current is set by the value of the Current Setting Resistor.

CHARGE PUMP

The converter is based on a charge pump technique to efficiently generate a DC voltage to supply the RGBW or RGBY LED current. The system regulates the current flowing into each LED, not the DC VOUT value. The built-in OVP circuit continuously monitors the VOUT voltage and in 1.5x charge pump mode, IS31FL3195 continuously calculates the expected current sink headroom if it exits 1.5x charge pump mode and enters 1x mode. It exits the 1.5x mode if the expected headroom is sufficient. The IS31FL3195 can operate under no load conditions.

The integrated capacitive charge pump is designed for $V_{OUT} = V_{CC} \times \text{Mode}$, where Mode= 1, or 1.5. The charge pump converter only needs four external components: supply decoupling capacitor, output bypass capacitor and two flying capacitors.

To maintain the lowest output resistance and highest efficiency, use capacitors with low ESR (Equivalent Series Resistance). The charge-pump output resistance is a function of CP and C_{OUT}'s ESR and the internal switch resistance. Minimizing the charge-pump capacitor's ESR minimizes the total resistance.

Using larger flying capacitors for the Charge Pump (CP) reduces the output impedance and improves efficiency however, above a certain point, increasing CP's capacitance has a negligible effect because the output resistance becomes dominated by the internal switch resistance and capacitor ESR. But when space is a constraint, it may be necessary to sacrifice low output resistance for the sake of small capacitor size.

Increasing the output capacitance (C_{OUT}) reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Smaller capacitance values can be used with light loads. Use the following equation to calculate the peak-to-peak ripple:

$$V_{RIPPLE} = \frac{I_{OUT}}{f_{OSC} \times C_{OUT}} + 2 \times I_{OUT} \times ESR_{C_{OUT}} \quad (1)$$

A bypass capacitor on the incoming supply will reduce its AC impedance and the impact of the charge pump switching noise. A 0.1μF bypass capacitor is sufficient, place this next to the VIN pin.

POWER ON SEQUENCE

IS31FL3195 provides a power-on reset feature that is controlled by VCC supply voltage. When the VIN supply voltage exceeds 2.6V (Typ.), the internal circuit starts to work. The reset signal will be generated to perform a power-on reset (POR) operation, which will reset all control circuits and configuration registers until the internal power voltage becomes stable.

I2C operation is allowed before SDB is pulled to high, the rising edge of SDB will reset the I2C bus.

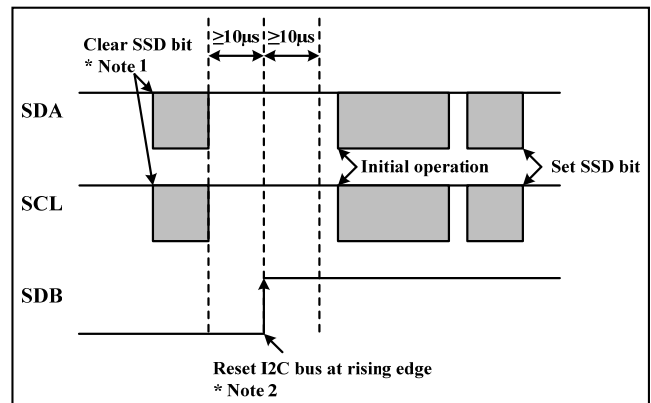


Figure 7 SDB Pin Sequence

Note 1: I2C operation is allowed when SDB is low.

Note 2: There should be no I2C operation 10μs before or after SDB rising edge.

SET MAX CURRENT

The maximum output current of OUT1~OUT4 can be adjusted by the external resistor, R_{SET}, as described in Formula (2).

$$I_{GMAX} = \frac{240}{R_{SET}} \quad (2)$$

The recommended value of R_{SET} is 12kΩ, when R_{SET}=12kΩ, I_{GMAX}=20mA.

The minimum I_{OUT} of each out is 2.5mA and to achieve this, when minimum CBx of 04h is "11" (I_{BAND}=1/4

I_{GMAX}), maximum R_{ISET} is 96k Ω , when minimum CBx of 04h is "10" ($I_{BAND}=2/4 I_{GMAX}$), maximum R_{ISET} is 72k Ω , when minimum CBx of 04h is "01" ($I_{BAND}=3/4 I_{GMAX}$), maximum R_{ISET} is 48k Ω , when minimum CBx of 04h is "00" ($I_{BAND}=4/4 I_{GMAX}$), maximum R_{ISET} is 24k Ω .

If R_{ISET} is smaller than 12k Ω , the output current will increase according the Formula 2, recommend absolute minimum R_{ISET} is 10k Ω ($I_{GMAX}=25mA$).

CURRENT LEVEL MODE

There are four programmed current bands which can be set by the Current Band Register (03h). It is used to set the global maximum of each output current, I_{GMAX} .

By setting the OUTx bits of the Operating Configure Register to "0", the corresponding OUTx will operate in Current Level Mode. The Current Level Registers are active and can modulate LED brightness of each output with 256 steps independently. For example, if the data in Current Level Register is "0000 0100", then the current level is the fourth step, with a current level of 4/256.

In Current Level Mode, the user doesn't need to turn on the CEx, a new value must be written to the Current Level registers to change the output current. Writing new data continuously to the registers can modulate the brightness of the LEDs to achieve breathing, blinking, or any other effects that the user defines.

PATTERN MODE

By setting the OUTx bits of the Operating Configure Register (01h) to "1", the corresponding OUTx will operate in Pattern Mode. In Pattern Mode, the timing characteristics for output current – current rising (T1), holding (T2), falling (T3) and off time (TS, TP, T4), can be adjusted individually so that each output can independently maintain a pre-established pattern. Thus, achieving mixing color breathing or a single color breathing without requiring any additional interface activity which will save valuable system resources. The IS31FL3195 will continuously cycle through the pre-programmed patterns; the system including the micro can be powered off to significantly save battery power.

PATTERN COLOR SETTING

In Pattern Mode, the LED color is defined by PxCOLy_Oz (x,y,z= 1,2,3,4) bits in Color Setting Registers. There are 3 RGBW current combinations to generate 3 pre-defined colors for display. More than one of the 3 pre-defined colors can be chosen by setting CEx bits in Color Enable Register (1Ch/2Ch/3Ch/4Ch). When CEx is set, the color x is allowed to be displayed in current pattern.

Table 26, 27 show the registers for each mode, for example, in the Current Level Mode, the current level

register is 10H for OUT1, 21H for OUT2, 32H for OUT3, 40H for OUT4, in Single mode and pattern mode, Pattern 1 has 3 current level registers and enabled/disabled by CEx.

Table 26 Color Register of Single Mode

Mode		Color EN	P1 OUT1	P2 OUT2	P3 OUT3	P4 OUT4
Single Mode	Pattern Mode	CE1	10H	21H	32H	40H
		CE2	13H	24H	35H	41H
		CE3	16H	27H	38H	42H
	Current Level Mode		10H	21H	32H	40H

Table 27 Color Register of RGB/RGBY Mode

RGB Mode	Color EN	P1 OUT1	P2 OUT2	P3 OUT3	P4 OUT4
Pattern 1	CE1(1Ch)	10H	11H	12H	40h
	CE2(1Ch)	13H	14H	15H	41h
	CE3(1Ch)	16H	17H	18H	42h
Pattern 2	CE1(2Ch)	20H	21H	22H	43H
	CE2(2Ch)	23H	24H	25H	44H
	CE3(2Ch)	26H	27H	28H	45H
Pattern 3	CE1(3Ch)	30H	31H	32H	46H
	CE2(3Ch)	33H	34H	35H	47H
	CE3(3Ch)	36H	37H	38H	48H

PATTERN TIME SETTING

User should configure the related pattern time setting registers according to actual timing requirements via I2C interface before starting pattern. There are three groups of pattern time that can be set for P1~P4, including TS, T1~T4 and TP. And each pattern has three continue lighting cycle as Color 1~Color 3.

PHASE DELAY

The outputs automatically delay the phase to minimize audible ceramic hum EMI.

Phase Delay Mode 1

By setting PD (Phase delay mode) bits to "01", the 4 outputs work in Phase Delay mode 1, each output will have a 125 μ s delay compare to previous channel, for example, OUT2 has 125 μ s delay than OUT1, OUT3 has 125 μ s delay than OUT2.

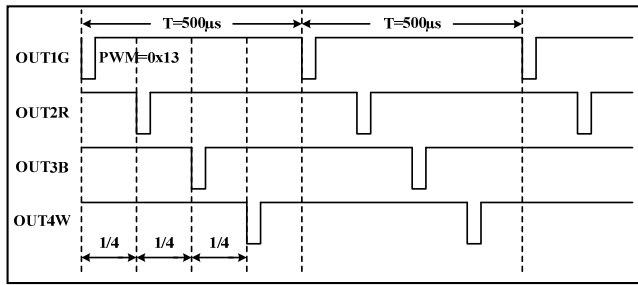


Figure 8 Phase Delay Mode 1 Timing

Phase Delay Mode 2

By setting PD (Phase delay mode) bits to “11”, the 4 outputs work in Phase Delay mode 2, each output will have a 62.5µs delay compare to previous channel, which is half of mode 1.

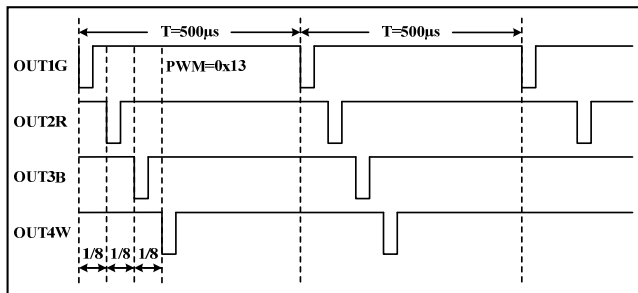


Figure 9 Phase Delay Mode 2 Timing

GAMMA CORRECTION

In order to perform a better visual LED breathing effect, the device integrates gamma correction to the Pattern Mode. The gamma correction function causes the change in intensity to appear more linear to the human eye.

Gamma correction, also known as gamma compression or encoding, is used to encode linear luminance to match the non-linear characteristics of LED brightness. Since the IS31FL3195 can modulate the brightness of the LEDs with 256 steps, a gamma correction function can be applied when computing each subsequent LED intensity setting such that the changes in brightness matches the human eye's brightness curve.

The IS31FL3195 provides three gamma corrections which can be set by GAM bits of NXT Registers (1Eh/2Eh/3Eh/4Eh) for each pattern. The gamma correction is shown as below.

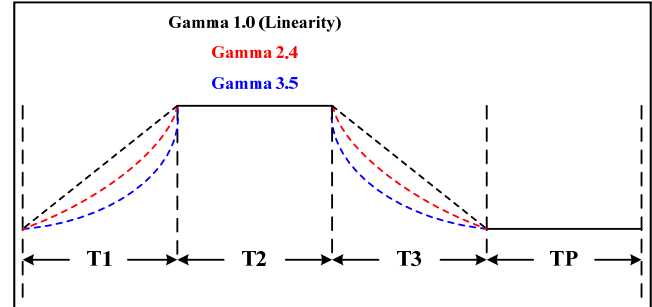


Figure 10 Gamma Correction

SHUTDOWN MODE

Shutdown mode can either be used as a means of reducing power consumption or generating a flashing display (repeatedly entering and leaving shutdown mode). During shutdown mode all registers retain their data.

Software Shutdown

By setting SSD bit of the Shutdown Register (01h) to “0”, the IS31FL3195 will operate in software shutdown mode, wherein it will consume only 1.0µA (Typ.) current. When the IS31FL3195 is in software shutdown mode, all current sources are switched off.

Hardware Shutdown

The chip enters hardware shutdown mode when the SDB pin is pulled low, wherein it will consume only 1.0µA (Typ.) current. When set SDB high, the rising edge will reset the I2C module, but the registers retain their data.

Sleep 1 Mode

When SLE bits is set to “01”, the chip will enter sleep 1 mode whenever the OUTx outputs are off for >30s, wherein they consume only 38µA (Typ.) current. In sleep 1 mode, CP stops, Bandgap working and all OUTx are off without any bias. MCU command to the IS31FL3195 will wake it up and disable the sleep mode.

Sleep 2 Mode

When SLE bits is set to “10”, the chip will enter sleep 2 mode whenever the OUTx outputs are off for >30s, wherein they consume only 1.0µA (Typ.) current. In sleep 2 mode, CP, Bandgap stop and all OUTx are off without any bias. MCU command to the IS31FL3195 will wake it up and disable the sleep mode.

LED OPERATING MODE

The IS31FL3195 has three operating modes which can be chosen by the RGBW bits of Operating Configure Register (01h).

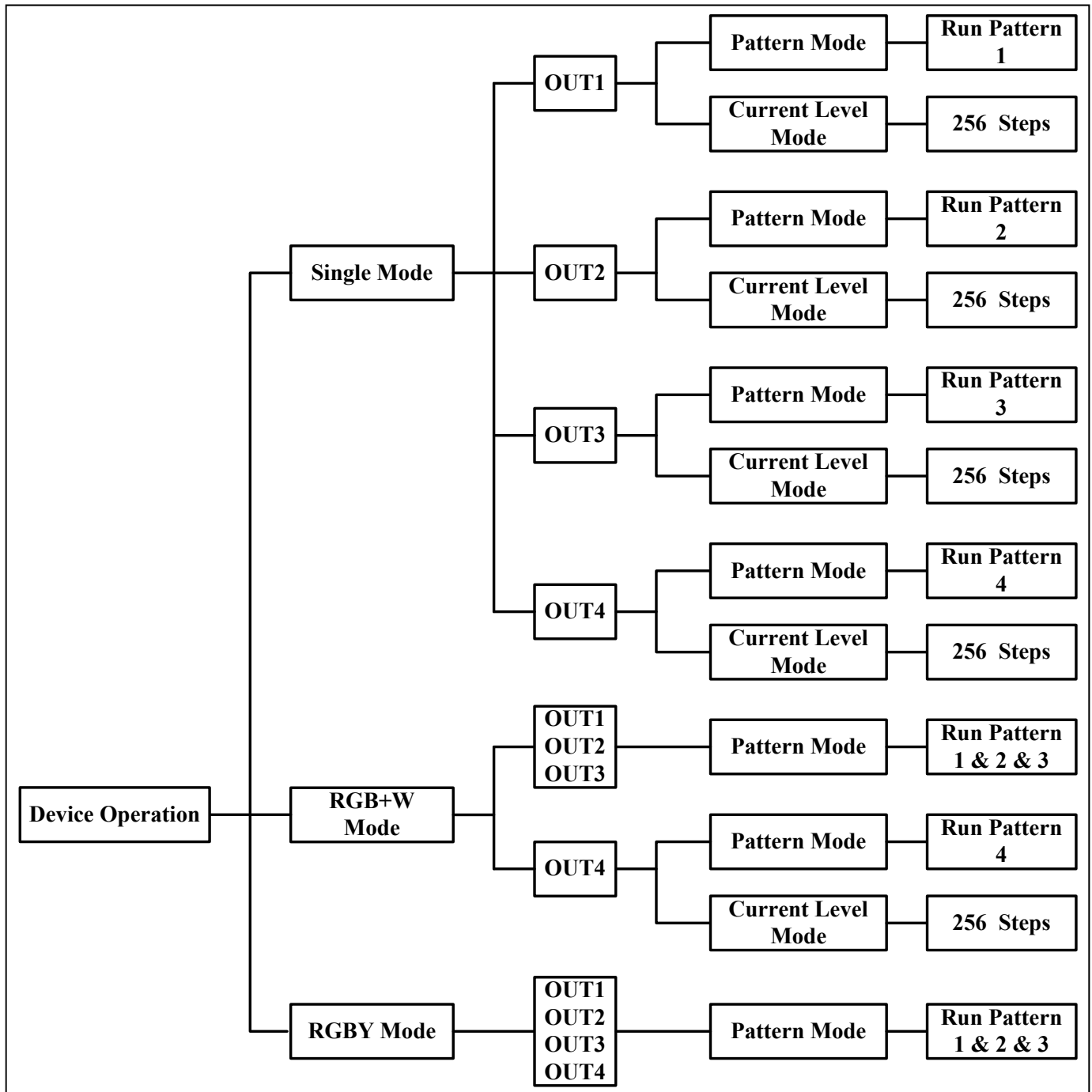


Figure 11 Operating Mode Map

Single Mode

If RGB=00/11 (Single Mode), OUTx runs Px independently in Pattern Mode or operates in Current Level Mode.

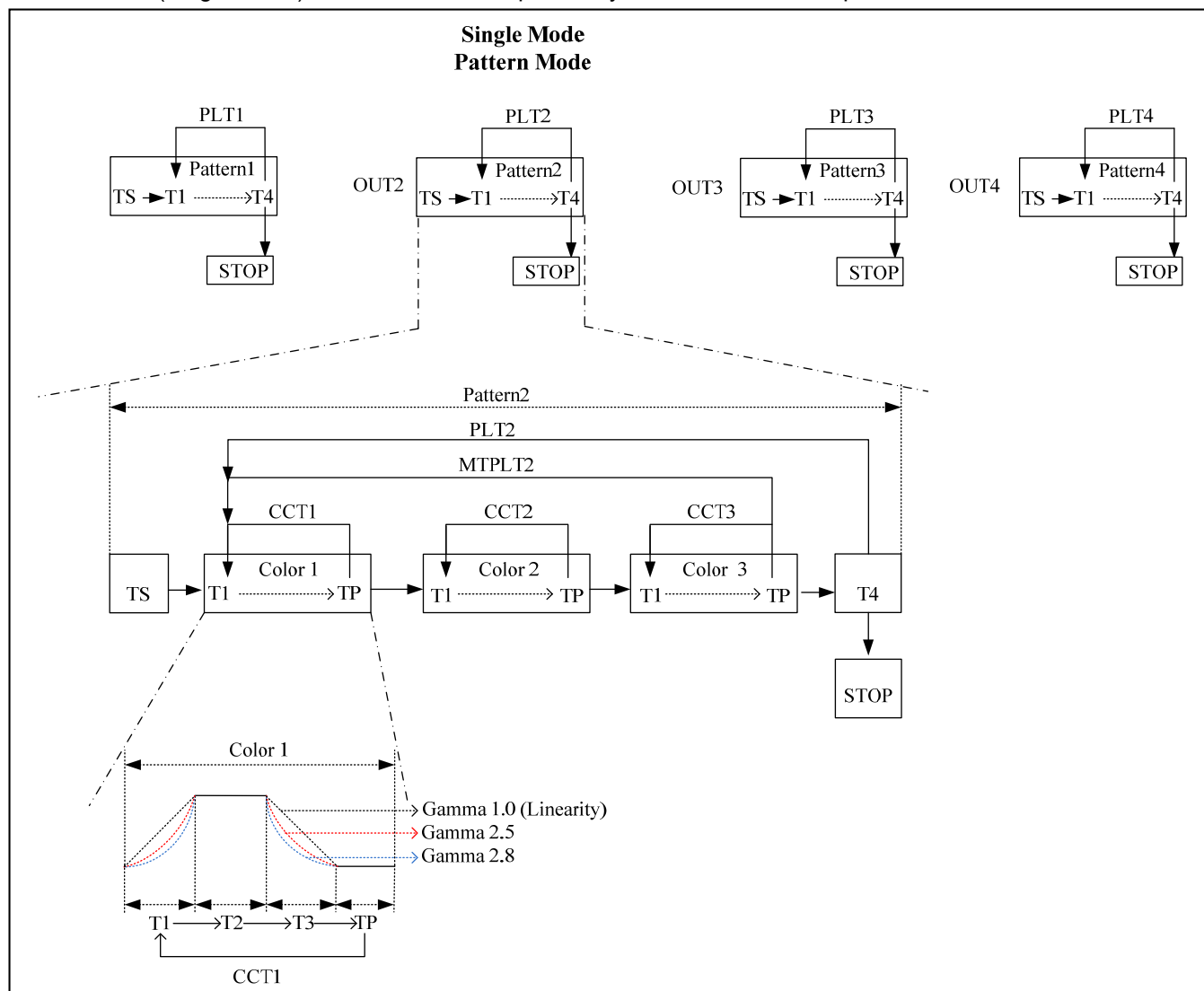
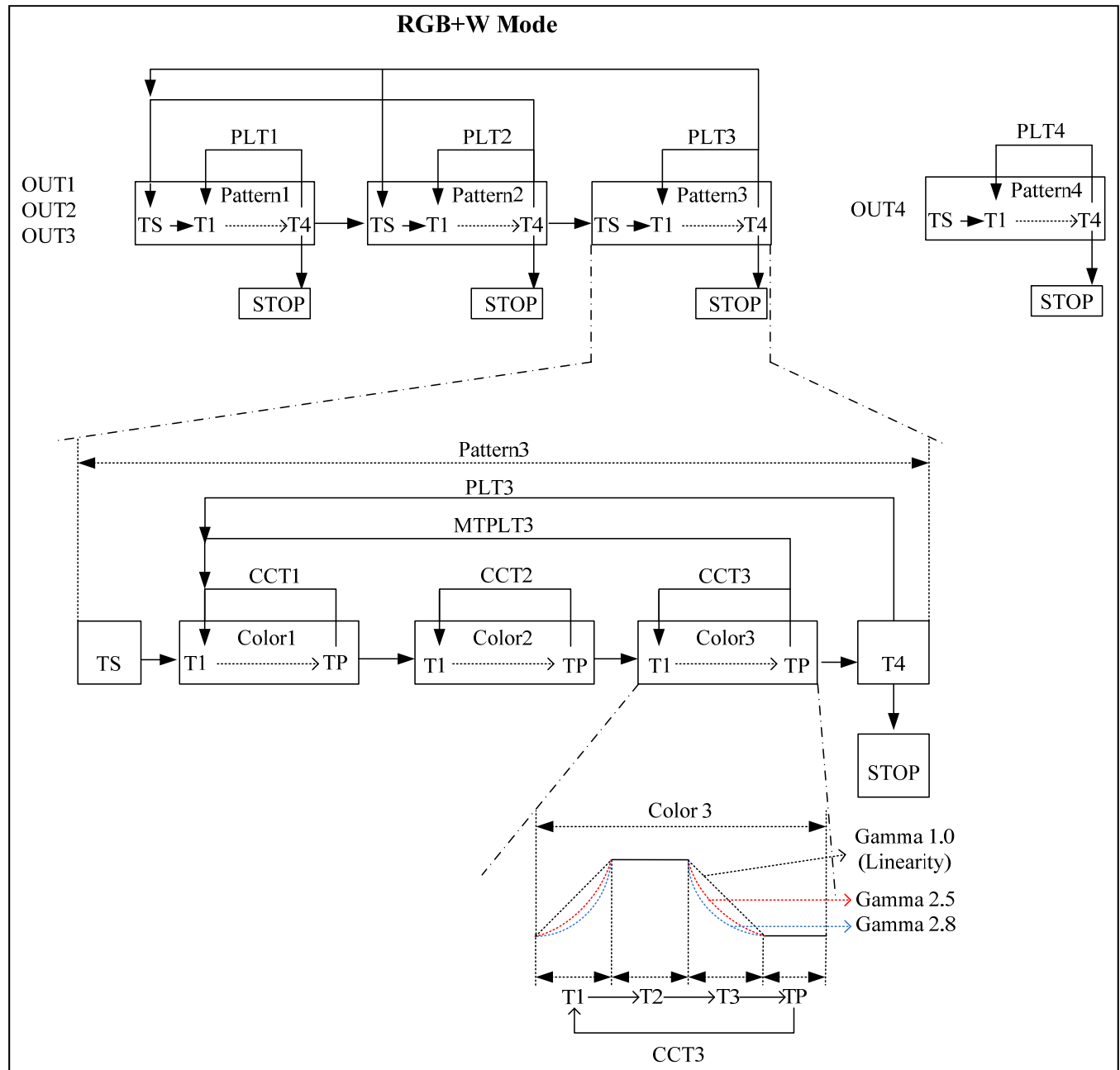


Figure 12 Single Mode

If RGB=01 (RGB+W Mode), OUT1, OUT2 and OUT3 can operate in Pattern Mode only and run in the same pattern (P1~P3). OUT4 can be both mode and run in Pattern 4 independently. OUT1, OUT2 and OUT3 bits can't be set.



RGBY Mode

If LM=10 (RGBY Mode), OUT1, OUT2, OUT3 and OUT4 can operate in Pattern Mode only and run in the same pattern (P1~P3). OUT1, OUT2 and OUT3 bits can't be set.

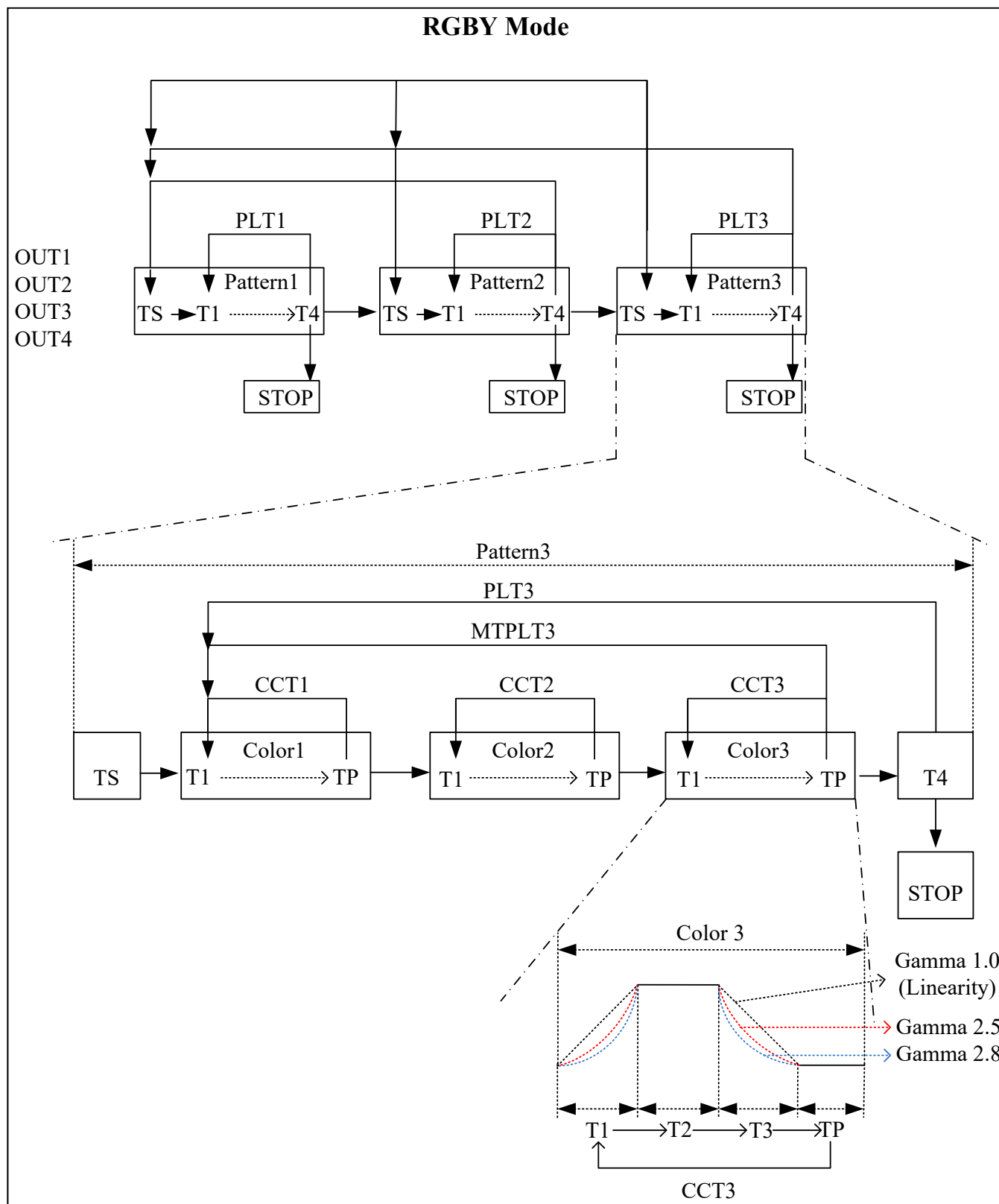


Figure 14 RGBY Mode

CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature min (T_{smin}) Temperature max (T_{smax}) Time (T_{smin} to T_{smax}) (t_s)	150°C 200°C 60-120 seconds
Average ramp-up rate (T_{smax} to T_p)	3°C/second max.
Liquidous temperature (T_L) Time at liquidous (t_L)	217°C 60-150 seconds
Peak package body temperature (T_p)*	Max 260°C
Time (t_p)** within 5°C of the specified classification temperature (T_c)	Max 30 seconds
Average ramp-down rate (T_p to T_{smax})	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

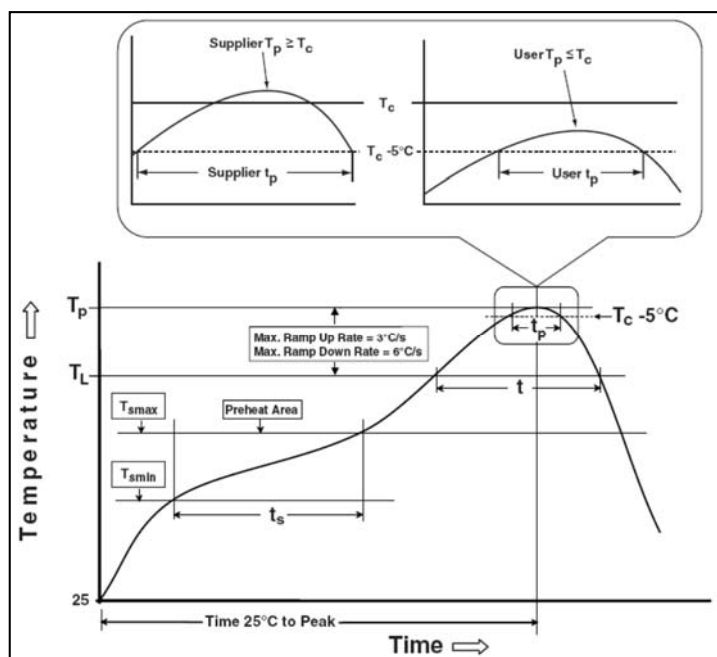
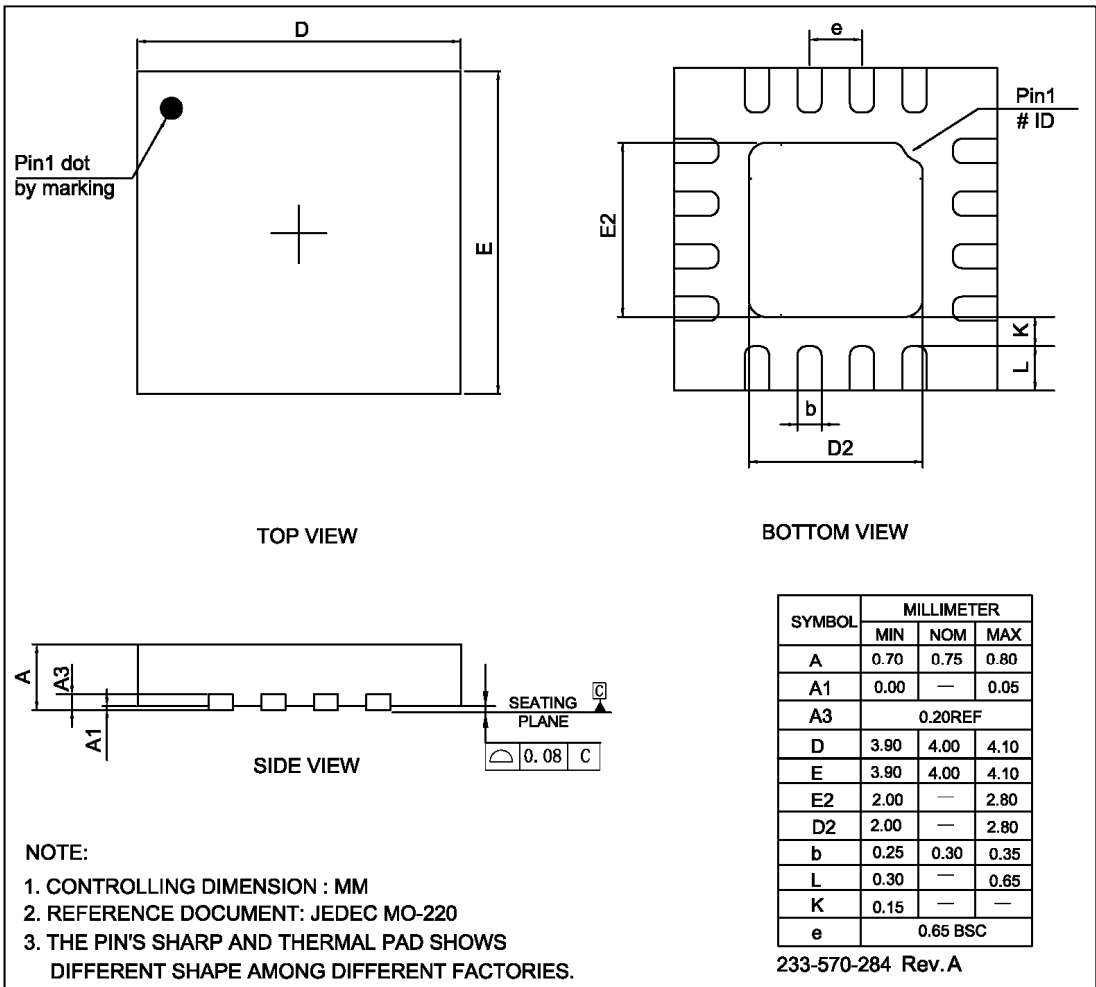


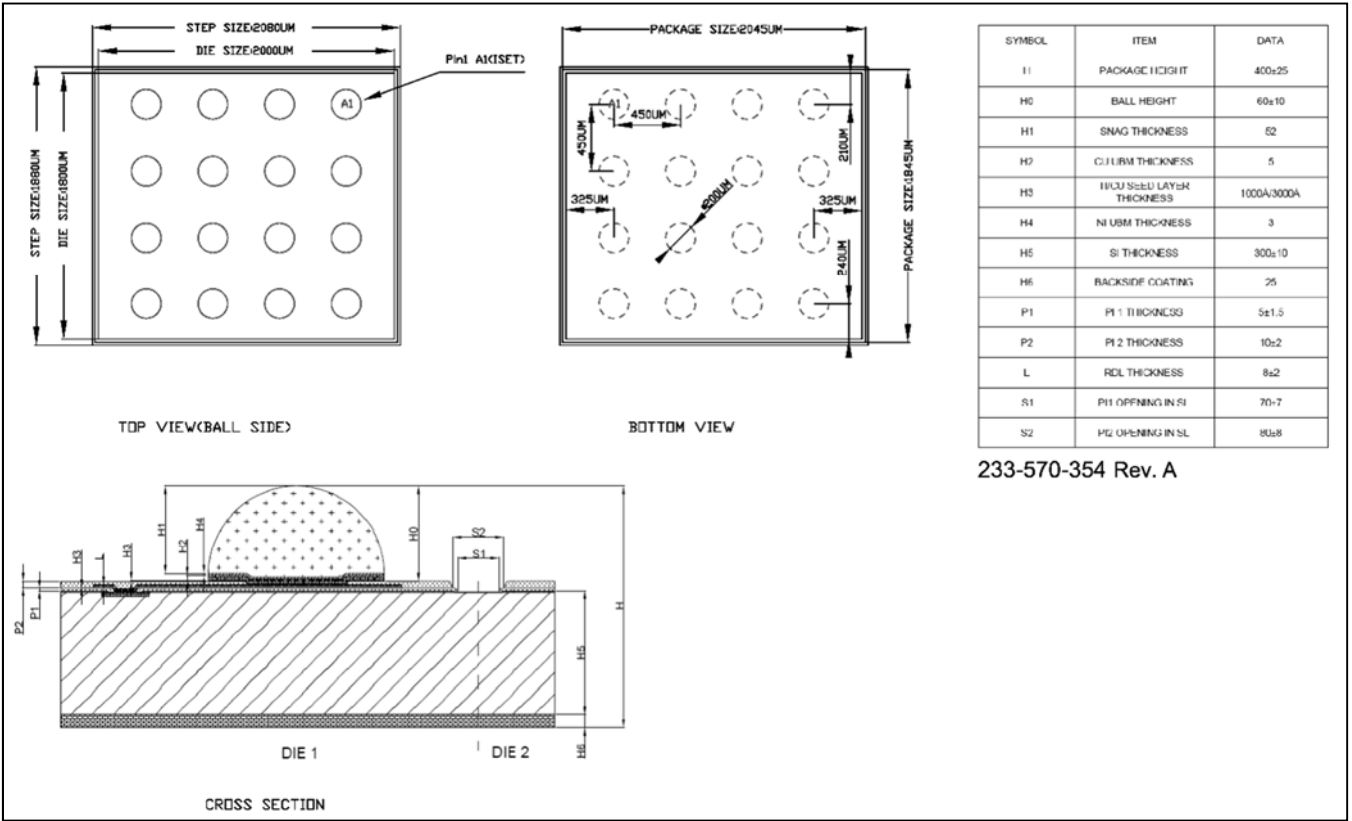
Figure 15 Classification Profile

PACKAGE INFORMATION

QFN-16

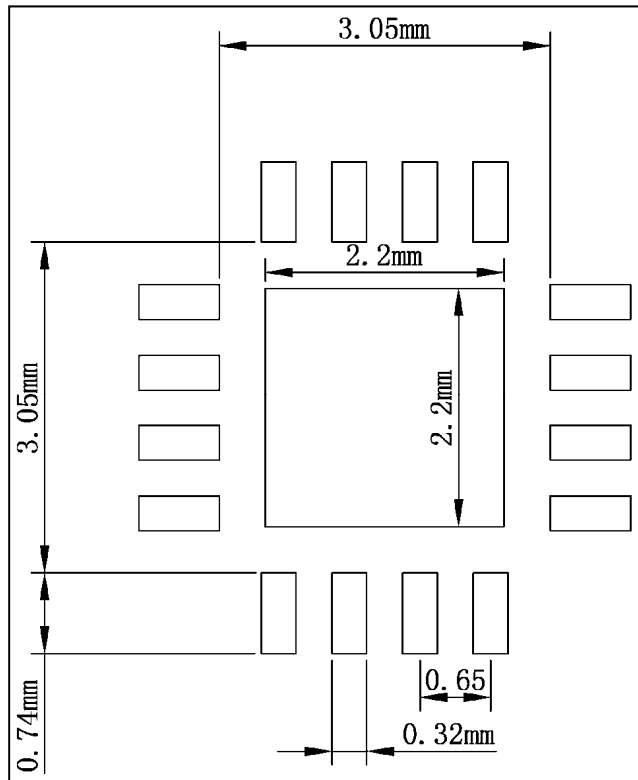


WLCSP-16

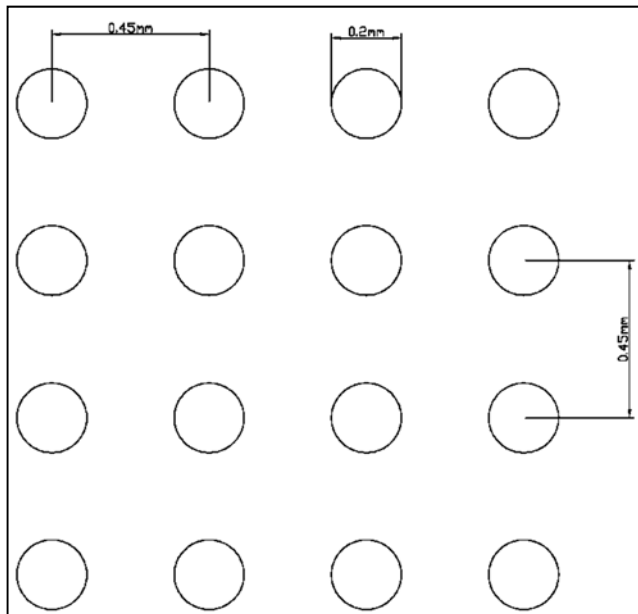


RECOMMENDED LAND PATTERN

QFN-16



WLCSP-16



Note:

1. Land pattern complies to IPC-7351.
2. All dimensions in MM.
3. This document (including dimensions, notes & specs) is a recommendation based on typical circuit board manufacturing parameters. Since land pattern design depends on many factors unknown (eg. User's board manufacturing specs), user must determine suitability for use.

REVISION HISTORY

Revision	Detail Information	Date
0A	Initial release	2018.12.07
A	Update to final version	2019.04.18
B	Update the Typical Application Information and Package Information	2022.05.25
C	Update Operating temperature range: -40°C ~ +125°C in ABS table	2023.01.05
D	1.Update Logic "0" input voltage at $V_{CC} = 5V$, $T_A = 0^{\circ}C \sim +40^{\circ}C$ (SDA, SCL) 2.Update to new Lumissil logo	2024.03.28