

GENERAL DESCRIPTION

The IS31FL3099 is a 9 LED current sink LED driver with 1MHz I2C compatible programming interface. Each LED can be dimmed individually with 12-bit PWM data and color calibrated with 8-bit DC scaling data, which provides 4096 steps of linear PWM dimming and 256 steps of DC current adjustable levels. All channels output current can be further globally adjusted in 64 steps.

The IS31FL3099 operates from 2.7V to 5.5V and features a very low operational and shutdown current.

Each channel of IS31FL3099 can operate in “PWM mode” or “Pattern mode” or “Current Level mode”. In “PWM mode”, the output current is set by 12-bit PWM registers and 8-bit current level registers. In “Pattern mode”, the timing characteristics for RGB channels output can be individually adjusted to maintain a pre-established pattern sequence without requiring any additional MCU interaction, thus saving valuable system resources. In “Current Level mode”, the output current is set by 8-bit current level register.

IS31FL3099 is available in QFN-20 (3mm×3mm) package. It operates from 2.7V to 5.5V over the temperature range of -40°C to +125°C.

FEATURES

- Supply voltage range: 2.7V to 5.5V
- 9 current sinks, $I_{OUT} = 40\text{mA}$ (Max.)
- Ultra-low operational current (310 μA Typ. at $V_{CC} = 3.6\text{V}$)
- Sleep mode: 1 μA (Typ.) with SDB pulled high and all LEDs off
- Accurate color rendition
 - 12-bit/8+4-bit PWM/channel
 - 8-bit correction current/channel
 - 6-bit global current adjust
- SDB rising edge reset I2C module
- 1MHz I2C-compatible interface
- Auto breath function:
 - 4 patterns for auto breath.
 - Fade IN/ Fade OUT time up to 10s
 - 3 colors pre-configure registers for color breath
- 23kHz PWM frequency (8+4-bit PWM mode)
- QFN-20 (3mm×3mm) package
- RoHS & Halogen-Free Compliance
- TSCA Compliance

APPLICATIONS

- Hand-held devices for LED display
- Gaming device (Mouse, Mouse Pad etc.)
- IOT device (AI speaker etc.)
- Portable Medical Devices

TYPICAL APPLICATION CIRCUIT

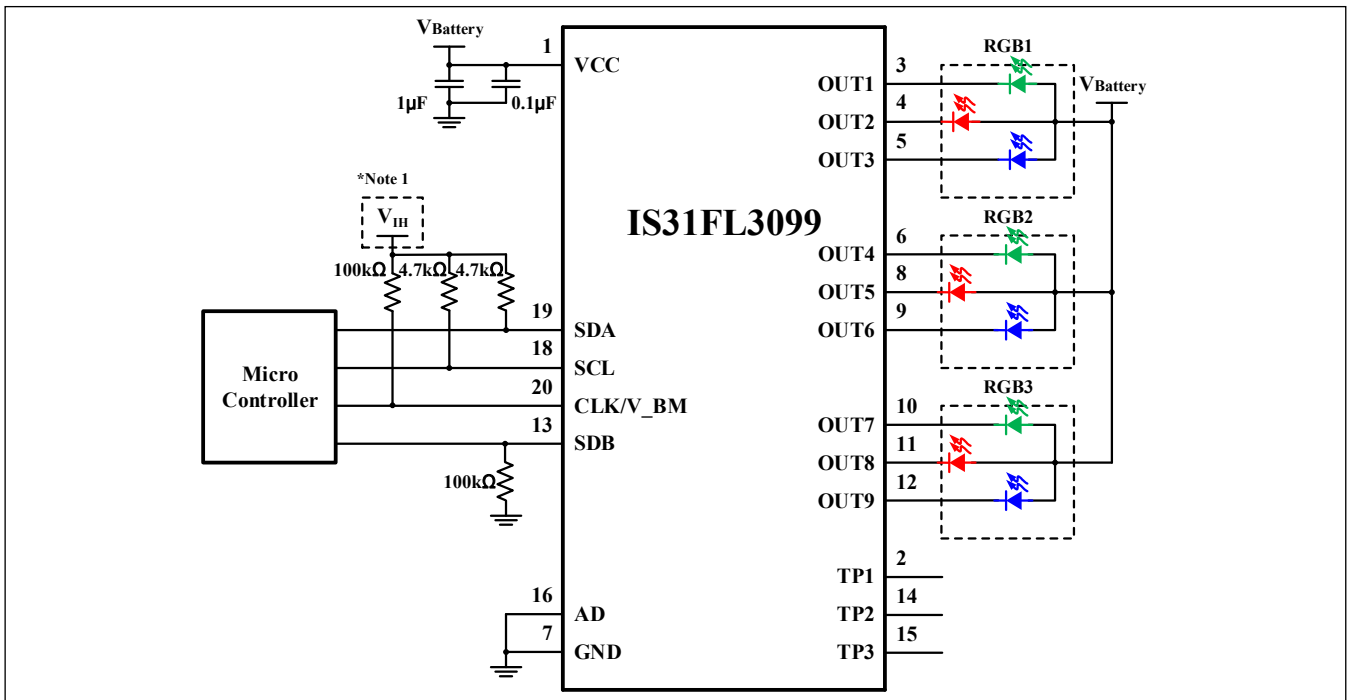


Figure 1 Typical Application Circuit: 3-RGBs

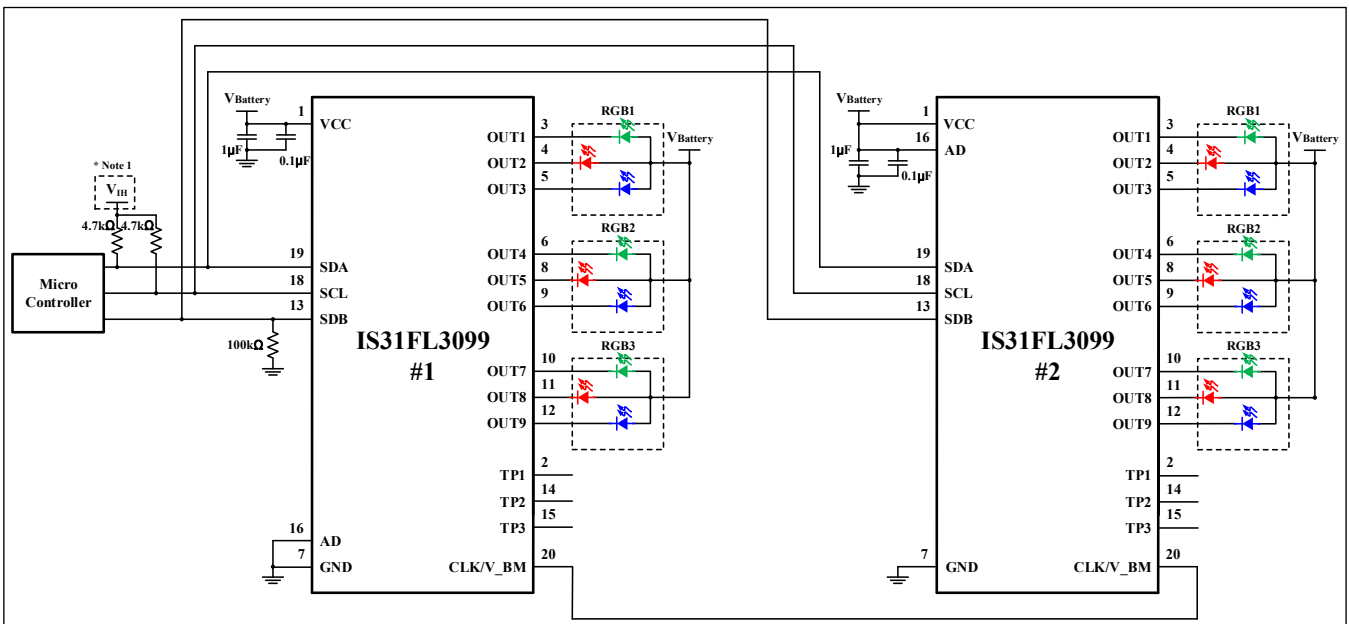
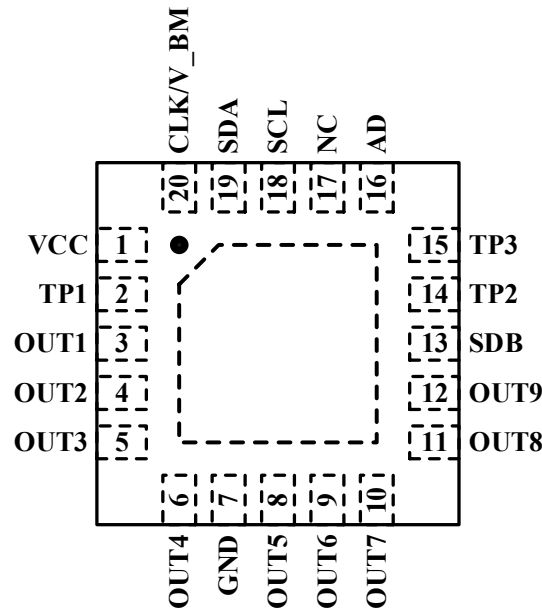


Figure 2 Typical Application Circuit (Cascade Mode)

Note 1: V_{DD} is the high-level voltage for IS31FL3099, which is usually same as VCC of Micro Controller, e.g. if V_{CC} of Micro Controller is 3.3V, V_{IH} = 3.3V. If V_{CC} = 5V and V_{IH} is lower than 2.8V, recommend to add level shift circuit.

PIN CONFIGURATION

Package	Pin Configuration (Top View)
QFN-20	

PIN DESCRIPTION

No.	Pin	Description
1	VCC	Power supply
2	TP1	Test pin, keep float
3~6	OUT1~OUT4	Current sink channels
7	GND	Ground
8~12	OUT5~OUT9	Current sink channels
13	SDB	Shutdown the chip when pulled to low
14,15	TP2, TP3	Test pin, keep float
16	AD	I2C address setting
17	NC	No connect
18	SCL	I2C serial clock
19	SDA	I2C serial data
20	CLK/V_BM	CLK input or output for cascade connection. When breathing mark function is enabled, this pin is V_BM pin.
	Thermal Pad	Connect to GND

IS31FL3099



ORDERING INFORMATION

Industrial Range: -40°C to +125°C

Order Part No.	Package	QTY/Reel
IS31FL3099-QFLS4-TR	QFN-20, Lead-free	2500

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ABSOLUTE MAXIMUM RATINGS

Supply voltage, V_{CC}	-0.3V ~ +6.0V
Voltage at any input pin	-0.3V ~ $V_{CC}+0.3V$
Maximum junction temperature, T_{JMAX}	+150°C
Storage temperature range, T_{STG}	-65°C ~ +150°C
Operating temperature range, $T_A=T_J$	-40°C ~ +125°C
Package thermal resistance, junction to ambient (4-layer standard test PCB based on JESD 51-2A), θ_{JA}	57.5°C/W
ESD (HBM)	±4kV
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

The following specifications apply for $V_{CC}=5V$, $T_A=25^\circ C$, unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{CC}	Supply voltage		2.7		5.5	V
I_{CC}	Quiescent power supply current	$V_{CC}=3.6V$, $V_{SDB}=V_{CC}$, all channels enable, PWM=0x00, 12-bit mode, PFS= 220Hz		0.31	0.35	
		$V_{CC}=5V$, $V_{SDB}=V_{CC}$, all channels enable, PWM=0x00, 12-bit mode, PFS= 220Hz		0.36	0.45	
		$V_{CC}=3.6V$, $V_{SDB}=V_{CC}$, all channels enable, PWM=0x00, 8+4-bit mode, PFS= 23kHz		0.76	0.95	
		$V_{CC}=5V$, $V_{SDB}=V_{CC}$, ALL channels enable, PWM=0x00, 8+4-bit mode, PFS= 23kHz		1	1.3	mA
I_{SD}	Shutdown current	$V_{CC}=5V$, $V_{SDB}=0V$		0.4	2	μA
		$V_{CC}=3.6V$, $V_{SDB}=0V$		0.3	1	
		$V_{SDB}=V_{CC}=5V$, Configuration Register written “0000 0000		0.4	2	
		$V_{SDB}=V_{CC}=3.6V$, Configuration Register written “0000 0000		0.3	1	
I_{OUT}	Constant current of channel	GCC=0x3F, CL=0xFF, IMAX=0	27.5	30	32.5	mA
		GCC=0x3F, CL=0xFF, IMAX=1		40		mA
f_{OUT}	PWM frequency of output	OSC= 1.8MHz, PFS=00, PWM Resolution= 12-bit	200	220	240	Hz
		OSC= 1.8MHz, PFS=01, PWM Resolution= 12-bit	400	440	480	Hz
		OSC= 6MHz, PFS=10, PWM Resolution= 8+4-bit	21	23	25.3	kHz
ΔI_{MAT}	Between channels	$I_{OUT}=30mA$ (Note 3)	-6.5		6.5	%
ΔI_{ACC}	Between device to device	$I_{OUT}=30mA$ (Note 4)	-6.5		6.5	%
ΔI_{MAT}	Between channels	$I_{OUT}=3mA$ (LCAI=1) (Note 3)	-7		7	%
ΔI_{ACC}	Between device to device	$I_{OUT}=3mA$ (LCAI=1) (Note 4)	-7		7	%

ELECTRICAL CHARACTERISTICS (CONTINUE)

The following specifications apply for $V_{CC}=5V$, $T_A=25^{\circ}C$, unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{HR}	Current sink headroom voltage	$I_{OUT}=30mA$		250	350	mV
T_{SD}	Thermal shutdown	(Note 5)		165		$^{\circ}C$
T_{SD_HY}	Thermal shutdown hysteresis	(Note 5)		18		$^{\circ}C$
Logic Electrical Characteristics (SDA, SCL, SDB, AD)						
V_{IL}	Logic "0" input voltage	$V_{CC}=2.7V\sim 5.5V$	GND		0.4	V
V_{IH}	Logic "1" input voltage	$V_{CC}=2.7V\sim 5.5V$	1.4		V_{CC}	V
I_{IL}	Logic "0" input current	$V_{INPUT}=0V$ (Note 5)		5		nA
I_{IH}	Logic "1" input current	$V_{INPUT}=V_{CC}$ (Note 5)		5		nA
V_{OL_SDA}	Low-level output voltage of SDA	$I_{LOAD}=5mA$			0.4	V
V_{OL_CLK}	Low-level output voltage of CLK/V _{BM}	$I_{LOAD}=-5mA$			0.4	V
V_{OH_CKL}	High-level output voltage of CLK/V _{BM}	$I_{LOAD}=5mA$	$V_{CC}-0.4$			V

DIGITAL INPUT I2C SWITCHING CHARACTERISTICS (NOTE 5)

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 (Note 6)	-		300	-		120	ns
t_F	Fall time of both SDA and SCL signals, receiving (Note 6)	-		300	-		120	ns

Note 3: I_{OUT} mismatch (bit to bit) ΔI_{MAT} is calculated:

$$\Delta I_{MAT} = \left(\frac{I_{OUTn}(n = 1 \sim 9)}{I_{OUT1}+I_{OUT2}+I_{OUT3}+I_{OUT4}+I_{OUT5}+I_{OUT6}+I_{OUT7}+I_{OUT8}+I_{OUT9}} - 1 \right) \times 100\%$$

Note 4: I_{OUT} accuracy (device to device) ΔI_{ACC} is calculated:

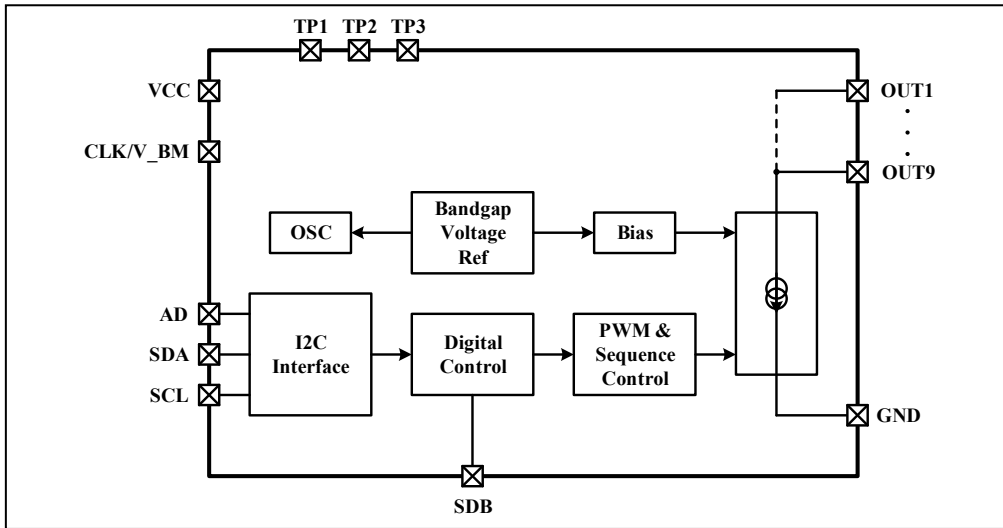
$$\Delta I_{ACC} = \left(\frac{I_{OUT1}+I_{OUT2}+I_{OUT3}+I_{OUT4}+I_{OUT5}+I_{OUT6}+I_{OUT7}+I_{OUT8}+I_{OUT9}}{9} - I_{OUT(IDEAL)} \right) \times 100\%$$

Where $I_{OUT(IDEAL)}=30mA$ or $3mA$.

Note 5: Guaranteed by design.

Note 6: t_R and t_F measured between $0.3 \times V_{CC}$ and $0.7 \times V_{CC}$.

FUNCTION BLOCK DIAGRAM



DETAILED DESCRIPTION

I2C INTERFACE

IS31FL3099 uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31FL3099 has a 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.

Table 1 Slave Address

AD	A7:A3	A2:A1	A0
GND	1001 1	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-drain) with a pull-up resistor (typically 2kΩ). The maximum clock frequency specified by the I2C standard is 1MHz. In this discussion, the master is the microcontroller and the slave is the IS31FL3099.

The timing diagram for the I2C is shown in Figure 3. 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 IS31FL3099's acknowledge. The master

releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the IS31FL3099 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 IS31FL3099, the register address byte is sent, most significant bit first. IS31FL3099 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 IS31FL3099 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 IS31FL3099, load the address of the data register that the first data byte is intended for. During the IS31FL3099 acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to IS31FL3099 will be placed in the new address, and so on. The auto increment of the address will continue as long as data continues to be written to IS31FL3099 (Figure 6).

READING OPERATION

Most of the registers can be read.

To read the register, after I2C start condition, the bus master must send the IS31FL3099 device address with the R/ bit set to "0", followed by the register address which determines which register is accessed. Then restart I2C, the bus master should send the IS31FL3099 device address with the R/ bit set to "1". Data from the register defined by the command byte is then sent from the IS31FL3099 to the master (Figure 7).

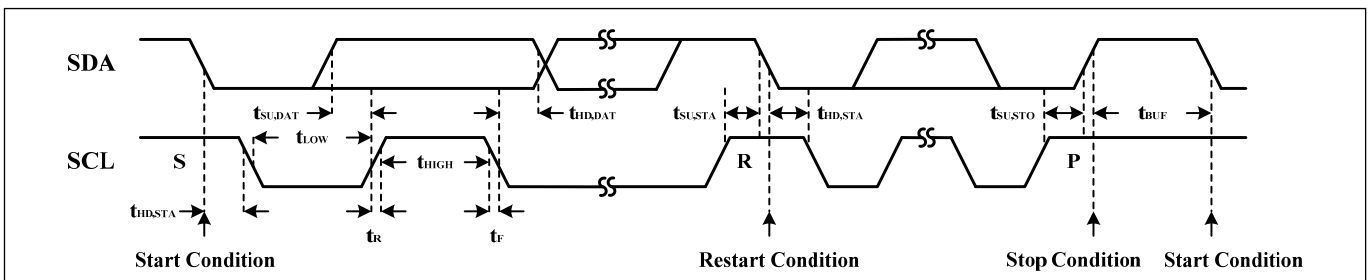


Figure 3 I2C Interface Timing

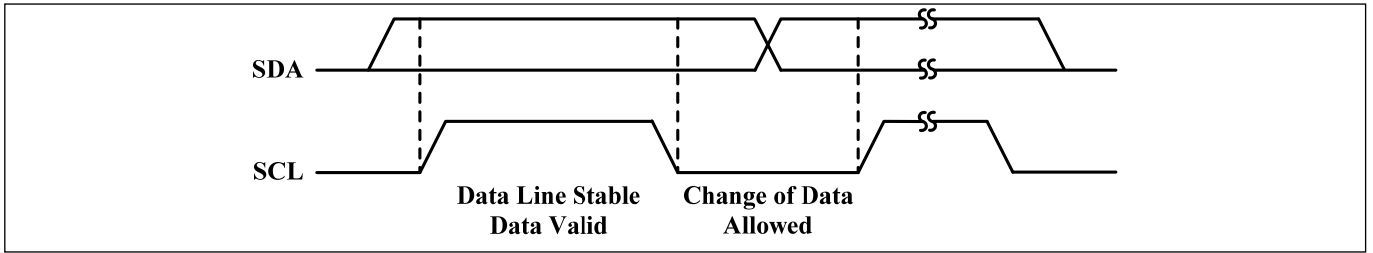


Figure 4 I2C Bit Transfer

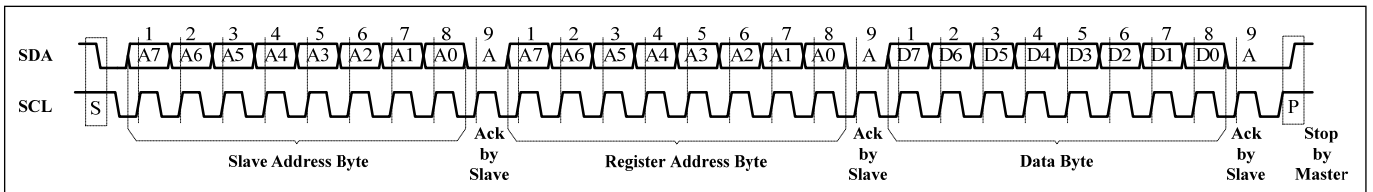


Figure 5 I2C Writing to IS31FL3099 (Typical)

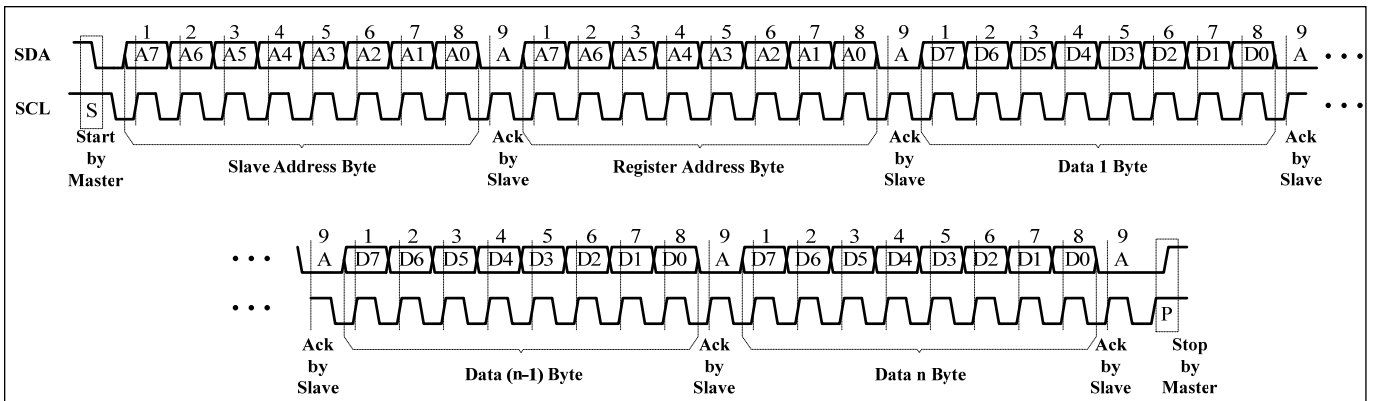


Figure 6 I2C Writing to IS31FL3099 (Automatic Address Increment)

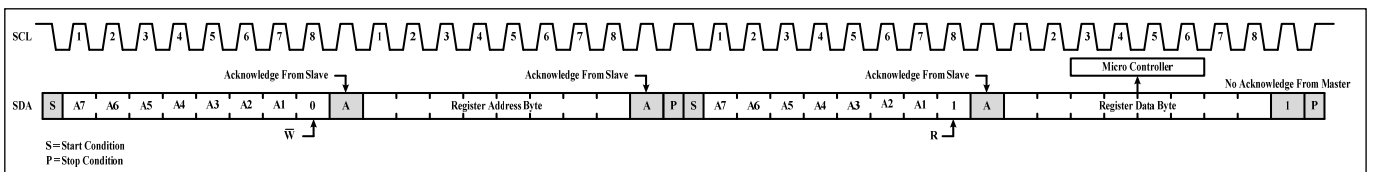


Figure 7 I2C Reading from IS31FL3099

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	R/W	3	0010 0000
02h	Output Enable Register 1	Enable output 1~8	R/W	4	1111 1111
03h	Output Enable Register 2	Enable output 9	R/W	5	0000 1111
04h	Operation Configure Register 1	Set output 1~4 operation mode	R/W	6	0000 0000
05h	Operation Configure Register 2	Set output 5~8 operation mode	R/W	7	0000 0000
06h	Operation Configure Register 3	Set output 9 operation mode	R/W	8	0000 0000
07h	Global Current Control Register	Set global current	R/W	9	0011 1111
08h	Hold Function Register	Set the hold function of each Output	R/W	10	0000 0000
09h	V_BM Function Register	Clock and V_BM mark	R/W	11	0000 0000
0Ah	PWM Frequency Adjust Unlock Register	Unlock the 0Ch	W	-	0000 0000
0Bh	PWM Frequency Adjust and Spread Spectrum Register	Adjust the PWM Frequency	R/W	12	0000 0000
0C~0Fh	3 Pattern State Registers	For reading the pattern running state	R	13	0000 0000
10h~18h	OUT1~OUT9 Current Level Register	Output current level data register	R/W	14	0000 0000
10h~18h	Color 1 Setting Register of Pattern	Output current level data register-Color 1	R/W	15	0000 0000
20h~28h	Color 2 Setting Register of Pattern	Output current level data register-Color 2	R/W		0000 0000
30h~38h	Color 3 Setting Register of Pattern	Output current level data register-Color 3	R/W		0000 0000
40h~51h	PWM Register	Set PWM data	R/W	16	0000 0000
60h/70h/80h/90h	Pattern TS &T1 Setting Register	Set the TS~T1 time	R/W	18	0000 0000
61h/71h/81h/91h	Pattern T2 &T3 Setting Register	Set the T2~T3 time	R/W	19	0000 0000
62h/72h/82h/92h	Pattern TP &T4 Setting Register	Set the TP~T4 time	R/W	20	0000 0000
63h/73h/83h/93h	Pattern Color Enable Register	Set the color enable/disable	R/W	21	0000 0001
64h/74h/84h/94h	Pattern Color Cycle Times Register	Set color repeat time	R/W	22	0000 0000
65h/75h/85h/95h	Pattern Register	Set next step and Gamma of each pattern	R/W	23	0000 0001
66h/76h/86h/96h	Pattern Loop Times Register	Set the loop time of Pattern	R/W	24	0000 0000
99h	Color Update Register	Update color data	R/W	-	0000 0000
9Ah	PWM Update Register	Update PWM data	R/W	-	0000 0000
9Bh/9Ch/9D/9Eh	Pattern Update Register	Update the time data and start to run pattern	R/W	-	0000 0000
9Fh	Reset Register	Reset the registers value to default	W	-	0000 0000

Table 3 01h Shutdown Control Register

Bit	D7	D6	D5	D4	D3:D2	D1	D0
Name	LCAI	IMAX	MS	SYNC	PFS	SLE	SSD
Default	0	0	1	0	00	0	0

The Shutdown Control Register sets software shutdown and sleep modes of IS31FL3099.

When the SLE bit is set to "1", the IS31FL3099 enters Sleep Mode if all OUTx outputs are off for >40s. All OUTx are off without any bias. I_SLEEP = 1µA (Typ.). When the IS31FL3099 is in sleep mode, the SLE bit needs to be set to "0" so that the IS31FL3099 will wake up and disable the sleep mode.

The PFS bit sets the PWM resolution. PWM mode can operate at 220Hz (12-bit, 8+4-bit mode), 440Hz (12-bit, 8+4-bit mode) and 23kHz (8+4-bit mode).

MS and SYNC bit control the CLK pin status. When MS and SYNC are both set to "1", the CLK pin will have a clock output to support cascade connection between 2 or more IS31FL3099.

SSD Software Shutdown Enable

- 0 Software shutdown mode
- 1 Normal operation

SLE Sleep Mode Enable

- 0 Sleep mode disable
- 1 Sleep mode enable (40s after no output current)

PFS PWM Frequency Select

- 00 220Hz (Force 220Hz in Pattern Mode or PWM mode)
- 01 440Hz (12-bit PWM mode)
- 1x 23kHz (8+4-bit PWM mode, 23kHz)

SYNC Enable Synchronization Clock

- 0 Disable, CLK pin is Hi-Z status
- 1 Enable, CLK is clock output.

MS Master Slave

- 0 Slave, CLK is input
- 1 Master, CLK is clock output or Hi-Z status

IMAX Enable I_{OUT(MAX)}=40mA

- 0 Default 30mA
- 1 I_{OUT(MAX)}=40mA

LCAI Low Current Accuracy Improve

- 0 Default maximum 30mA
- 1 1/3 output current, and improve low current accuracy

Table 4 02h Output Enable Register 1

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	EN8	EN7	EN6	EN5	EN4	EN3	EN2	EN1
Default	1	1	1	1	1	1	1	1

Table 5 03h Output Enable Register 2

Bit	D7:D6	D5:D4	D3:D1	D0
Name	-	RGMS	-	EN9
Default	00	00	111	1

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

The RGMS bit is used to select RGB group mode. When the RGMS is not set to "00", the MODx (x=1~9) bits in 04h/05h/06h are invalid, and three outputs in one RGB group run synchronously in pattern loop for color mixture. All 9 outputs can be divided into 3 RGB groups. OUT1, OUT2, OUT3 in RGB group 1. OUT4, OUT5, OUT6 in RGB group 2. OUT7, OUT8, OUT9 in RGB group 3.

ENx Output Enable Control

- 0 Output disable
- 1 Output enable

RGMS RGB Group Mode Select

- 00 Mode 1, 9 Outputs running individual.
- 01 Mode 2, RGB Group 1/2/3 run in Pattern 1 to 4

Table 6 04h Operating Configure Register 1

Bit	D7:D6	D5:D4	D3:D2	D1:D0
Name	MOD4	MOD3	MOD2	MOD1
Default	00	00	00	00

Table 7 05h Operating Configure Register 2

Bit	D7:D6	D5:D4	D3:D2	D1:D0
Name	MOD8	MOD7	MOD6	MOD5
Default	00	00	00	00

Table 8 06h Operating Configure Register 3

Bit	D7:D2	D1:D0
Name	-	MOD9
Default	000000	00

The MODx (x=1~9) bits set output operation modes of IS31FL3099 when output not in RGB Group Mode.

MODx OUT1~OUT9 LED Mode

- 00 PWM Mode
- 01 Pattern Mode
- 10 Current Level Mode (No PWM)

When the OUTx works in PWM Mode, means the output current is controlled by PWM Registers (40h~51h).

When the OUTx works in Pattern Mode, it means the output current is controlled by Color Setting Registers (10h~18h, 20h~28h and 30h~38h).

When the OUTx works in Current Level Mode, it means the output current is controlled by Current Level Register (10h~18h).

Table 9 07h Global Current Control Register

Bit	D7:D6	D5:D0
Name	-	GCC
Default	00	11 1111

The Global Current Control Register modulates all OUTx (x=1~9). DC current which is noted as IO_{UT} in 64 steps.

IO_{UT} is computed by as shown in Formula (1).

If GCC=0x3F, CL=0xFF, IO_{UT}=IO_{UT(MAX)}

$$I_{OUT} = 30mA \times \frac{GCC}{64} \times \frac{CL}{256} \quad (1)$$

$$GCC = \sum_{n=0}^7 D[n] \cdot 2^n \quad (2)$$

When I_{MAX}=“1”, the 30mA will become 40mA.

Table 10 08h Hold Function Register

Bit	D7	D6	D5	D4	D3	D2	D1	D0
Name	HFE4	HTS4	HFE3	HTS3	HFE2	HTS2	HFE1	HTS1
Default	0	0	0	0	0	0	0	0

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

HTS Hold Time Selection

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

HFE Hold Function Enable

- 0 Hold function disable
- 1 Hold function enable

Table 11 09h V_{BM} Function Register

Bit	D7	D6	D5:D4	D3:D2	D1:D0
Name	VPE	BME	PAMF	CMF	TMP
Default	0	0	00	00	00

The V_{BM} function register stores the V_{BM} pin function, PAMF selects the pattern and TMP selects the time point to have interrupt.

Note 7: When only one color is enabled in the Pattern Color Enable Register (63h/73h/83h/93h = 0x01, 0x02, or 0x04), the TMP bits can be set to “00” or “1x”.

VPE V_{BM} Pull High EN

- 0 Disable, V_{BM} is open drain
- 1 Enable, V_{BM} is pull to VCC by 100kΩ

BME Breath Mark function enable

- 0 Disable, CLK/V_{BM} is clock function
- 1 Enable, CLK/V_{BM} is V_{BM} function

CMF Color Mark Function

- 00 Color 1
- 01 Color 2
- 10 Color 3

PAMF Pattern Mark Function

- 00 Pattern 1
- 01 Pattern 2
- 10 Pattern 3
- 11 Pattern 4

TMP Time Point

- 00 Start of T2
- 01 Start of TP
- 1x Start of T4

0Ah PWM Frequency Adjust Unlock Register

Write “0xA5” to 0Ah to unlock the PWM Frequency Adjust Register (0Bh).

Table 12 0Bh PWM Frequency Adjust and Spread Spectrum Register

Bit	D7:D6	D5:D4	D3	D2:D0
Name	CLT	RNG	SSP	PFA
Default	00	00	0	000

Before access to 0Bh, the 0Ah needs to be written with 0xA5 to unlock it.

The PFA bits adjust the PWM Frequency, for example, if PWM frequency is 23kHz at 8+4-bit PWM mode, if PFA is “000”, the PWM frequency is 23kHz, if PFA is “001”, the PWM frequency is 25.806kHz (+12.2%).

SSP bit enables the spread spectrum function, RNG bits adjust the range and CLT bits select the cycle time. The spread spectrum function only takes effect in 8+4-bit PWM mode (PFS bit is '1x' in 01h).

Note 8: It is recommended to use SSP=1 only when PWM frequency is 23kHz.

PFA PWM Frequency Adjust

000	0%
001	+12.2%
010	+29%
011	+52.7%
100	-53%
101	-39.8%
110	-31.8%
111	-21%

SSP Spread Spectrum Enable

0	Disable
1	Enable

CLT Spread Spectrum Cycle Time

00	512ms
01	256ms
10	2ms
11	1ms

RNG Spread Spectrum Range

00	+3.2%
01	+7.2%
10	+12.2%
11	+27.2%

Table 13 0Ch~0Fh Pattern State Register (Read Only)

Bit	D7	D6	D5	D4	D3	D2:D0
Name	PS	CS3	CS2	CS1	-	TS
Default	0	0	0	0	0	000

The Pattern State Register stores the pattern status. 0Ch register is used for pattern 1, 0Dh for pattern 2, 0Eh for pattern 3, similarly 0Fh for pattern 4.

Below table shows the pattern running state.

Note 9: These reading results are only applicable for the condition: the color 1, color 2 and color 3 in one pattern are all enabled (63h/73h/83h/93h = 0x07).

Read Result	D7:D0	Pattern State	Color	Time
0x90	1001 0000	Running	-	TS
0x91	1001 0001	Running	Color1	T1
0x92	1001 0010	Running	Color1	T2
0x93	1001 0011	Running	Color1	T3
0xA4	1010 0100	Running	Color1	TP
0xA1	1010 0001	Running	Color2	T1
0xA2	1010 0010	Running	Color2	T2
0xA3	1010 0011	Running	Color2	T3
0xC4	1100 0100	Running	Color2	TP
0xC1	1100 0001	Running	Color3	T1
0xC2	1100 0010	Running	Color3	T2
0xC3	1100 0011	Running	Color3	T3
0x94	1001 0100	Running	Color3	TP
0x95	1001 0101	Running	-	T4
0x00	0000 0000	Not running	-	-

Table 14 10h~18h OUT1~OUT9 Current Level Register

Bit	D7:D0
Name	CL
Default	0000 0000

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

$$I_{OUT} = 30mA \times \frac{GCC}{64} \times \frac{CL}{256} \quad (1)$$

$$CL = \sum_{n=0}^7 D[n] \cdot 2^n \quad (3)$$

$$I_{LED} = 30mA \times \frac{GCC}{64} \times \frac{CL}{256} \times \frac{PWM}{4096} \quad (4)$$

Where D[n] stands for the individual bit value, 1 or 0, in location n, PWM is the value in 40h~51h, I_{OUT} is the peak current of the outputs. I_{LED} is the average current of the outputs.

When IMAX= "1", the 30mA will become 40mA.

When IS31FL3099 operates in Current Level Mode, PWM = 4096 in the above equation.

For example: in Current Level node only, if D7:D0 = 10110101,

$$I_{OUT} = 30mA \times (2^7 + 2^5 + 2^4 + 2^2 + 2^0) / 256$$

When IS31FL3099 operates in PWM & Current Level Mode, the value of CL and PWM will decide the output current together.

Table 15-1 10h~18h Color 1 Setting Register of Pattern (OUT1~OUT9)

Bit	D7:D0
Name	COL1_Oy
Default	0000 0000

Table 15-2 20h~28h Color 2 Setting Register of Pattern (OUT1~OUT9)

Bit	D7:D0
Name	COL2_Oy
Default	0000 0000

Table 15-3 30h~38h Color 3 Setting Register of Pattern (OUT1~OUT9)

Bit	D7:D0
Name	COL3_Oy
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.

When IS31FL3099 operates in Pattern Mode, the value of Color Registers will decide the output current of each output in 256 levels.

The output current may be computed using the Formula (4):

$$I_{OUT} = 30\text{ mA} \times \frac{COLx_Oy}{256} \quad (5)$$

$$COLx_Oy = \sum_{n=0}^7 D[n] \cdot 2^n \quad (6)$$

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

For example: if D7:D0 = 10110101,

$$I_{OUT} = 30\text{mA} \times (2^7 + 2^5 + 2^4 + 2^2 + 2^0) / 256$$

I_{OUT} is the peak current of the outputs.

Need to write Color Update Register (99h) to update the data.

Table 16 40h~51h PWM Register

Reg	41h (43h, 45h...)		40h (42h, 44h...)
Bit	D7:D4	D3:D0	D7:D0
Name	-	PWM_H	PWM_L
Default	0000	0000	0000 0000

When IS31FL3099 operates in PWM Mode, each output has 2 bytes to modulate the PWM duty as below Table 17 in 4096 steps, in Pattern Mode, the PWM cannot be accessed.

The value of the PWM Registers decides the average current of each LED noted I_{LED} .

I_{LED} computed by Formula (1):

$$I_{LED} = 30\text{mA} \times \frac{GCC}{64} \times \frac{CL}{256} \times \frac{PWM}{4096} \quad (7)$$

Where I_{OUT} is the peak current of the outputs. I_{LED} is the average current of the outputs.

$$PWM = \sum_{n=0}^{11} D[n] \cdot 2^n$$

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

For example: if PWM_H = 00001001, PWM_L = 10110101, N=4096, GCC=63, CL=255,

$$I_{LED} = 30\text{mA} \times (2^{11} + 2^8 + 2^7 + 2^5 + 2^4 + 2^2 + 2^0) / 4096.$$

Need to write PWM Update Register (9Ah) to update the data.

Table 17 Register of PWM Mode

Mode	Register	OUT1	OUT2	OUT3
PWM	PWM_H	41h	43h	45h
	PWM_L	40h	42h	44h
	CL	10h	11h	12h
	Register	OUT4	OUT5	OUT6
	PWM_H	47h	49h	4Bh
	PWM_L	46h	48h	4Ah
	CL	13h	14h	15h
	Register	OUT7	OUT8	OUT9
	PWM_H	4Dh	4Fh	51h
	PWM_L	4Ch	4Eh	50h
	CL	16h	17h	18h

Table 18 60/70/80/90h Pattern 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. 60h register is used for pattern 1, 70h for pattern 2, 80h for pattern 3, similarly 90h for pattern 4.

TS Pattern Start Time Selection

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

T1 Rise Time Selection

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

Table 19 61/71/81/91h Pattern 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. 61h register is used for pattern 1, 71h for pattern 2, 81h for pattern 3, similarly 91h for pattern 4.

T2 Hold Time Selection

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

T3 Fall Time Selection

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

Table 20 62/72/82/92h Pattern TP &T4 Setting Register

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

The TP & T4 Setting Registers set the TP and T4 time in Pattern Mode. 62h register is used for pattern 1, 72h for pattern 2, 82h for pattern 3, similarly 92h for pattern 4.

It should be noted that the sleep mode effective time is 40s, it starts at the end of T3. If T4+TP is too long, pattern loop will stop. When sleep mode is enabled, T4 & TP do not last longer than 4.20s.

TP Time between Pulses

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

T4 Off Time Selection

0000	0.04s
0001	0.16s
0010	0.31s
0011	0.46s
0100	0.61s
0101	0.92s
0110	1.25s
0111	1.92s
1000	2.52s
1001	3.12s
1010	3.72s
1011	5.04s
1100	6.24s
1101	7.44s
1110	8.76s
1111	9.96s

Table 21 63/73/83/93h Pattern Color Enable Register

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

Pattern Color Enable Register enables/disables color function for each color in Pattern Mode. 63h register is used for pattern 1, 73h for pattern 2, 83h for pattern 3, similarly 93h for pattern 4.

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 22 64/74/84/94h Pattern Color Cycle Times Register

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

Pattern Color Cycle Times Register Sets Color loop time for each color in pattern mode. 64h register is used for pattern 1, 74h for pattern 2, 84h for pattern 3, similarly 94h for pattern 4.

CCTx Color Cycle Times Selection

00	Endless
01	1 time
10	2 times
11	3 times

Table 23-1 65h Pattern Register 1

Bit	D7:D4	D3	D2	D1:D0
Name	MTPLT1	GAM1	-	NXT1
Default	0000	0	0	01

GAM controls the gamma of pattern. MTPLT controls the loop of Pattern. NXT1 Only effective in RGB Group Mode.

GAM1 Gamma Selection

0	Gamma=2.4
1	Linearity

MTPLT1 Multi-Pulse Loop Time

0000	endless
0001	1 time
1111	15 times

NXT1 Pattern 1 Next

01 Go to Pattern 2
00/10/11 Just stop

Table 23-2 75h Pattern Register 2

Bit	D7:D4	D3	D2	D1:D0
Name	MTPLT2	GAM2	-	NXT2
Default	0000	0	0	01

GAM controls the gamma of pattern. MTPLT controls the loop of Pattern. NXT2 Only effective in RGB Group Mode.

GAM2 Gamma Selection

0 Gamma=2.4
1 Linearity

MTPLT2 Multi-Pulse Loop Time

0000 Endless
0001 1 time
...
1111 15 times

NXT2 Pattern 2 Next

01 Go to Pattern 1
10 Go to Pattern 3
00/11 Just stop

Table 23-3 85h Pattern Register 3

Bit	D7:D4	D3	D2	D1:D0
Name	MTPLT3	GAM3	-	NXT3
Default	0000	0	0	01

GAM controls the gamma of pattern. MTPLT controls the loop of Pattern. NXT3 Only effective in RGB Group Mode.

GAM3 Gamma Selection

0 Gamma=2.4
1 Linearity

MTPLT3 Multi-Pulse Loop Time

0000 endless
0001 1 time
...
1111 15 times

NXT3 Pattern 3 Next

01 Go to Pattern 1
10 Go to Pattern 2
11 Go to Pattern 4
00 Just stop

Table 23-4 95h Pattern Register 4

Bit	D7:D4	D3	D2	D1:D0
Name	MTPLT4	GAM4	-	NXT4
Default	0000	0	0	01

GAM controls the gamma of pattern. MTPLT controls the loop of Pattern. NXT4 Only effective in RGB Group Mode.

GAM3 Gamma Selection

0 Gamma=2.4
1 Linearity

MTPLT3 Multi-Pulse Loop Time

0000 endless
0001 1 time
...
1111 15 times

NXT3 Pattern 4 Next

01 Go to Pattern 1
10 Go to Pattern 2
11 Go to Pattern 3
00 Just stop

Table 24 66/76/86/96h Pattern Loop Times Register

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

Pattern loop Times register sets the loop time of the pattern. 66h register is used for pattern 1, 76h for pattern 2, 86h for pattern 3, similarly 96h for pattern 4.

If PLT_H(D7)=0, PLT_L!=0

Pattern loop times:

$$Looptime = \sum_{n=0}^6 D[n] \times 2^n \quad (8)$$

If PLT_H(D7)=0, PLT_L=0, endless

If PLT_H(D7)=1, PLT_L!=0

Pattern loop times:

$$Looptime = 16 \times \sum_{n=0}^6 D[n] \times 2^n \quad (9)$$

If PLT_H(D7)=1, PLT_L=0, endless

99h Color Update Register

Write "0xC5" to 99h will update the data of 10h~18h/20h~28h/30h~38h.

9Ah PWM Update Register

Write "0xC5" to 9Ah will update the data of 40~51h.

9B/9C/9D/9Eh Pattern time Update Register

Write "0xC5" to 9B/9C/9D/9Eh will update the data of 60h~66h/70h~76h/80h~86h/90h~96h.

9Fh Reset Register

Once user writes "0xC5" to the Reset Register, IS31FL3099 will reset all registers to their default value. On initial power-up, the IS31FL3099 registers are reset to their default values for a blank display.

TYPICAL APPLICATION INFORMATION

GENERAL DESCRIPTION

IS31FL3099 is a 9-channel fun LED driver with auto breathing function. It has PWM Mode and Pattern Mode and Current Level Mode for RGB lighting effects.

CURRENT SETTING

The maximum output current is 30mA. When $I_{MAX}="1"$, the 30mA will become 40mA. The Global Current Control register GCC can be used to set a lower current. The 8-bit CL registers (10h~18h) control the individual currents for each of the outputs.

For example, OUT1, OUT2 and OUT3 drive an RGB LED, OUT1 is Red LED, OUT2 is Green LED and OUT 3 is Blue LED. If GCC and CL bits are the same, then the RGB LED may appear slightly pink, or not so white. The CL bits can be used to adjust the IOUTx current so the RGB LED appears closer to a pure white color. We call this CL bit adjustment by another name: white balance register.

PWM FREQUENCY SELECT

The IS31FL3099 output channels operate with a default 12-bit PWM resolution and the PWM frequency of 220Hz. Because all the OUTx channels are synchronized, the DC power supply will experience large instantaneous current surges when the OUTx channels turn ON. These current surges will generate an AC ripple on the power supply which cause stress to the decoupling capacitors. When the AC ripple is applied to a monolithic ceramic capacitor chip (MLCC) it will expand and contract causing the PCB to flex and generate audible hum in the range of between 20Hz to 20kHz, to avoid this hum, there are many countermeasures, such as selecting the capacitor type and value which will not cause the PCB to flex and contract.

An additional option for avoiding audible hum is to set the IS31FL3099's output PWM frequency above the audible frequency range. The Shutdown Control Register (01h) can be used to set the switching frequency to 220Hz/440Hz/23KHz. Combination settings of the PFS bits will result in different PWM frequency, select a value higher than 20kHz to avoid the audible frequency range.

PWM CONTROL

The PWM Registers (40h~51h) can modulate LED brightness of each channels with 4096 steps. For example, if the data in PWM_H Register is "0000 0000" and in PWM_L Register is "0000 0100", then the PWM is 4/4096.

Writing new data continuously to the registers can modulate the brightness of the LEDs to achieve a breathing effect.

CURRENT LEVEL MODE

The Current Level Registers (10h~18h) are active and can modulate LED peak current IOUT of each output with 256 steps independently. For example, if the data in Current Lever Register is "0000 0100", then the current level is the fourth step, with a current level of 4/256.

In Current Level Mode, 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.

In Current Level Mode, the output current (OUT1~OUT9) is configured by the Current Level Register (10h~18h).

PWM MODE

PWM Mode is the combination of PWM and Current Level Mode. In this mode, the Current Level Registers (10h~18h) adjust the peak current (I_{OUT}) of the outputs, the PWM Registers (40h~51h) adjust the duty cycle of the output current, the final result is the output average current ILED.

Table 17 Register of PWM Mode

Mode	Register	OUT1	OUT2	OUT3
PWM	PWM_H	41h	43h	45h
	PWM_L	40h	42h	44h
	CL	10h	11h	12h
	Register	OUT4	OUT5	OUT6
	PWM_H	47h	49h	4Bh
	PWM_L	46h	48h	4Ah
	CL	13h	14h	15h
	Register	OUT7	OUT8	OUT9
	PWM_H	4Dh	4Fh	51h
	PWM_L	4Ch	4Eh	50h
	CL	16h	17h	18h

RGB GROUP MODE

By setting the RGMS bits of the Operating Configure Register 3 (03h) to "01" "10" or "11", the IS31FL3099 will operate in RGB Group Mode. In this mode 9 channels can be modulated breathing cycle independently by TS~TP (Figure 11). Setting different TS~T4 can achieve RGB breathing with auto color changing. All 9 outputs can be divided into 3 RGB groups. OUT1, OUT2, OUT3 in RGB group 1. OUT4, OUT5, OUT6 in RGB group 2. OUT7, OUT8, OUT9 in

RGB group 3. When RGMS bits is “01”, RGB Group 1/2/3 run in Pattern 1 to 4. The maximum intensity of each LED can be adjusted independently by the Color Setting Registers (10h~18h/20h~28h/30h~38h) (Table 28/29/30).

Note 10: If IS31FL3099 operates in the RGB Group Mode and then enters into sleep mode, the SLE bit needs to set as “0”, that the IS31FL3099 will wake up and disable the sleep mode.

PATTERN MODE

By setting the MOD1~MOD9 bits of the Operating Configure Register (04h/05h/06h) to “01” and the RGMS bits of the Operating Configure Register 3 (03h) to “00”, the corresponding output 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) (Figure 10), can be adjusted individually so that each output can independently maintain a pre-established pattern achieving mixing color breathing or a single-color breathing without requiring any additional interface activity, thus saving valuable system resources. OUT1~OUT3 running in Pattern 1, OUT4~OUT6 running in Pattern 2, and OUT7~OUT9 running in Pattern 3.

PATTERN COLOR SETTING

In Pattern Mode, the LED color is defined by COLx_Oy (x, y= 1, 2, 3) bits in Color Setting Registers (10h~18h/20h~28h/30h~38h). There are 3 RGB 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 (63h/73h/83h). When CEx is set, the color x is allowed to be displayed in current pattern.

In Pattern Mode, the output current (OUT1~OUT9) is configured by the Color Setting Register of Pattern as Table 25.

Table 25 Color Register of Pattern Mode

Pattern Mode	Color Enable	OUT1	OUT2	OUT3
Pattern 1	CE1(63h)	10h	11h	12h
	CE2(63h)	20h	21h	22h
	CE3(63h)	30h	31h	32h
Pattern Mode	Color Enable	OUT4	OUT5	OUT6
Pattern 2	CE1(73h)	13h	14h	15h
	CE2(73h)	23h	24h	25h
	CE3(73h)	33h	34h	35h
Pattern Mode	Color Enable	OUT7	OUT8	OUT9
Pattern 3	CE1(83h)	16h	17h	18h
	CE2(83h)	26h	27h	28h
	CE3(83h)	36h	37h	38h

PATTERN TIME SETTING

User should configure the related pattern time setting registers according to actual timing requirements via I2C interface before starting pattern. The pattern time is including TS, T1~T4 and TP. And the pattern has three continue lighting cycle as Color 1~Color 3. Please check the LED OPERATING MODE section for more about the time setting.

GAMMA CORRECTION

In order to perform a better visual LED breathing effect, the device integrates gamma correction to the Pattern Mode. The gamma correction 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 display. Since the IS31FL3099 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 IS31FL3099 provides three gamma corrections which can be set by GAM bits of Pattern Registers (65h/75h/85h/95h) for each pattern. The gamma correction is shown as below.

BREATHING MARK FUNCTION

In RGB Group Mode or Pattern Mode, by setting the BME bit of the Breathing Mark Register (09h) to “1”, the breathing mark function is enabled. If the BME bit sets to “0”, the breathing mark function disabled. The CLK/V_{BM} pin is used as CLK. V_{BM} is an output pin. The breathing mark function is useful as a signal to notify the MCU when and where the pattern or color is running.

Note 11: When only one color is enabled in Pattern Color Enable Register (63/h73h/83h/93h = 0x01 or 0x02 or 0x04), the TMP bit can set as “00” and “1x”.

After selecting the PAMF (Pattern Mark Function) and CMF (Color Mark Function),

When you choose start of T2 (TMP=00): At the start time T2, V_{BM} will induce a falling edge and hold logic low, at the end of time period T2, V_{BM} will induce a rising edge.

When you choose start of TP (TMP=01): At the start time TP, V_{BM} will induce a falling edge and hold logic low, at the end of time period TP, V_{BM} will induce a rising edge.

When you choose start of T4 (TMP=1x): At the start time T4, V_{BM} will induce a falling edge and hold logic low, at the end of time period T4, V_{BM} will induce a rising edge.

The VPE bit of 09h sets the pull up of the V_{BM} pin, when VPE=“0”, the V_{BM} is open drain and it needs external pull up resistor.

When VPE=“1”, the V_{BM} is pulled to internal VCC by 100kΩ.

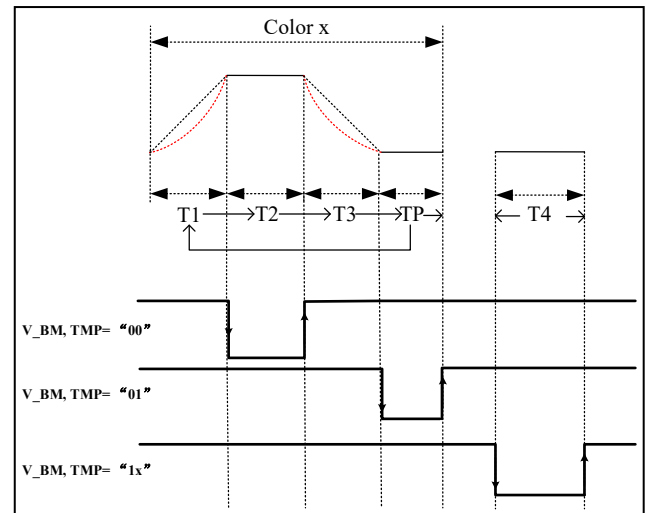


Figure 8 V_{BM} function

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 control Register (01h) to “0”, the IS31FL3099 will operate in software shutdown mode, wherein it will consume only 0.4μA (Typ.) current. When the IS31FL3099 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 they consume only 0.4μA (Typ.) current. When set SDB high, the rising edge will reset the I2C module, but the register information retains.

LED OPERATING MODE

When the RGMS = 00, 9 Outputs running individual. There have three operating modes which can be chosen by the MODx bits of Operating Configure Register (04h/05h/06h). When the RGMS = 01, All 9 outputs can be divided into 3 RGB groups, and running in RGB Group mode.

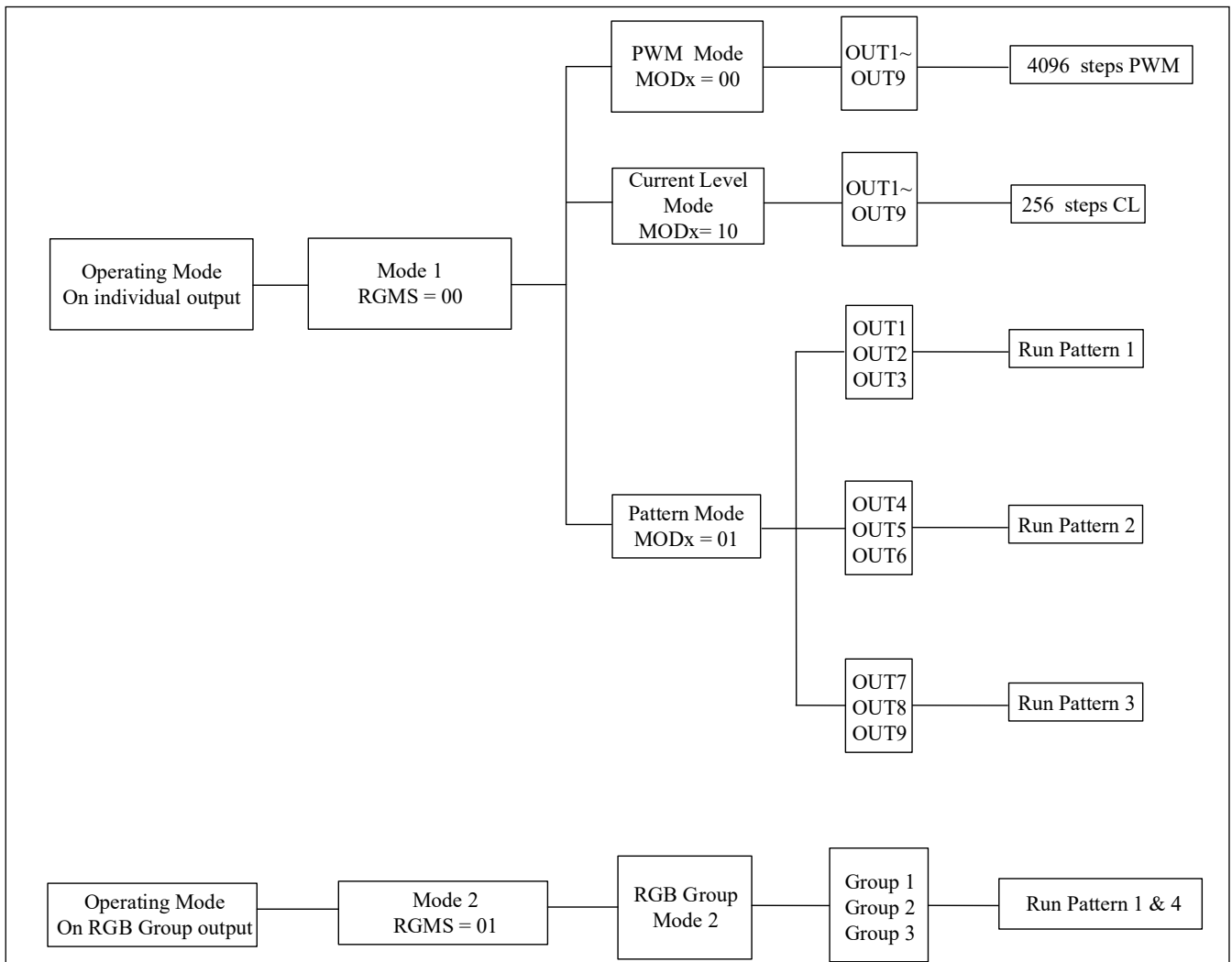


Figure 9 Operating Mode Map

Table 26 Pattern Select in RGB Group Mode

			OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8	OUT9
RGMS	RGB Group Mode	MODx	RGB Group 1			RGB Group 2			RGB Group 3		
00	Mode 1	00	Not run in Pattern								
		01	Pattern 1			Pattern 2			Pattern 3		
		10	Not run in Pattern								
01	Mode 2	xx	Pattern 1 & Pattern 2 & Pattern 3 & Pattern 4								

Pattern Mode

If RGMS="00", and MODx=01 (Pattern Mode), OUT1~OUT3 can operate in Pattern Mode only and run the pattern 1, OUT4~OUT6 run the pattern 2, OUT7~OUT9 run the pattern 3.

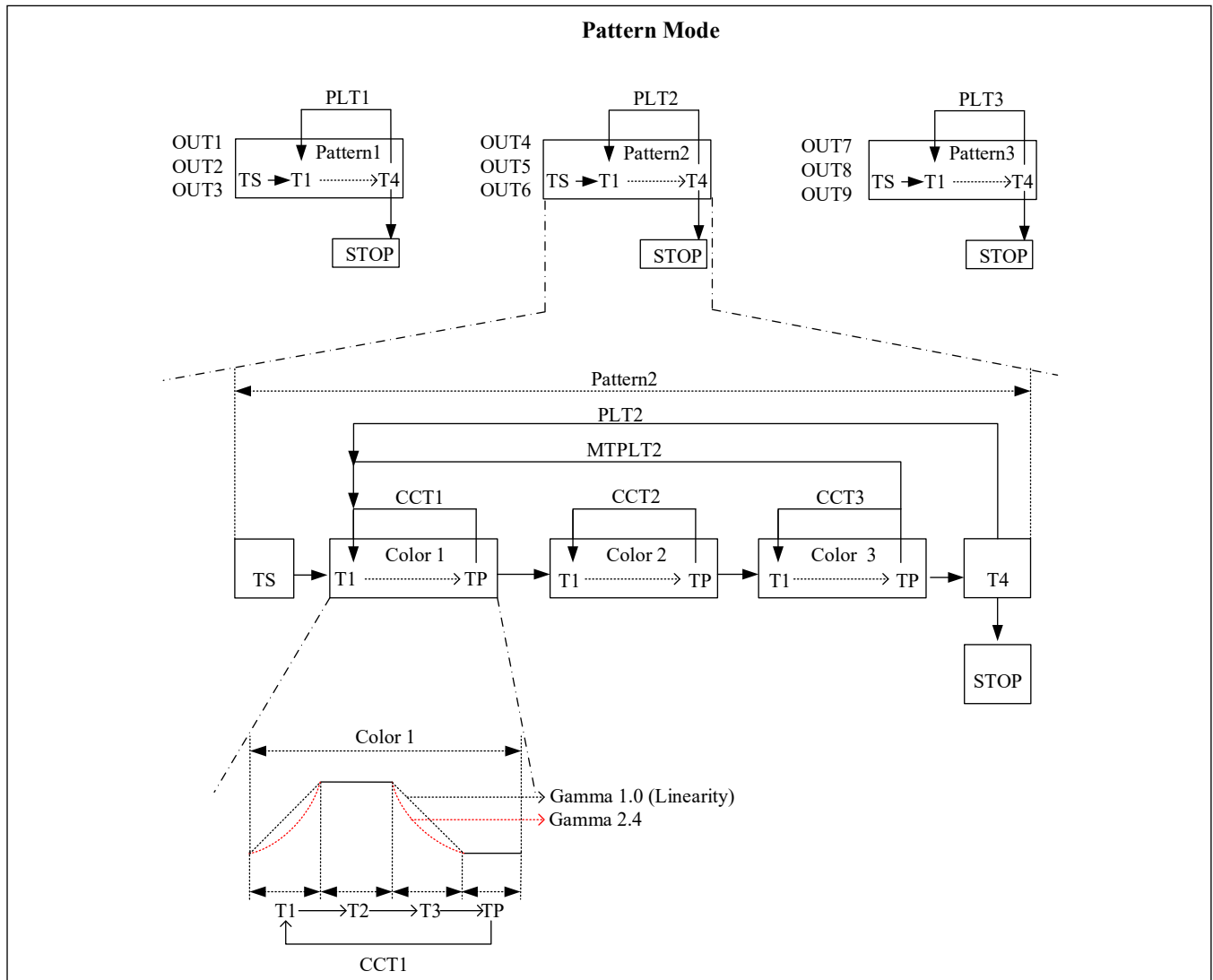


Figure 10 Pattern Mode

Table 27 Color Register of Pattern Mode

Pattern	Color Enable	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8	OUT9
Pattern 1	CE1(63h)	10h	11h	12h						
	CE2(63h)	20h	21h	22h						
	CE3(63h)	30h	31h	32h						
Pattern 2	CE1(73h)				13h	14h	15h			
	CE2(73h)				23h	24h	25h			
	CE3(73h)				33h	34h	35h			
Pattern 3	CE1(83h)							16h	17h	18h
	CE2(83h)							26h	27h	28h
	CE3(83h)							36h	37h	38h

RGB Group Mode

If RGMS="01", All 9 outputs can be divided into 3 RGB groups, and running in RGB Group mode.

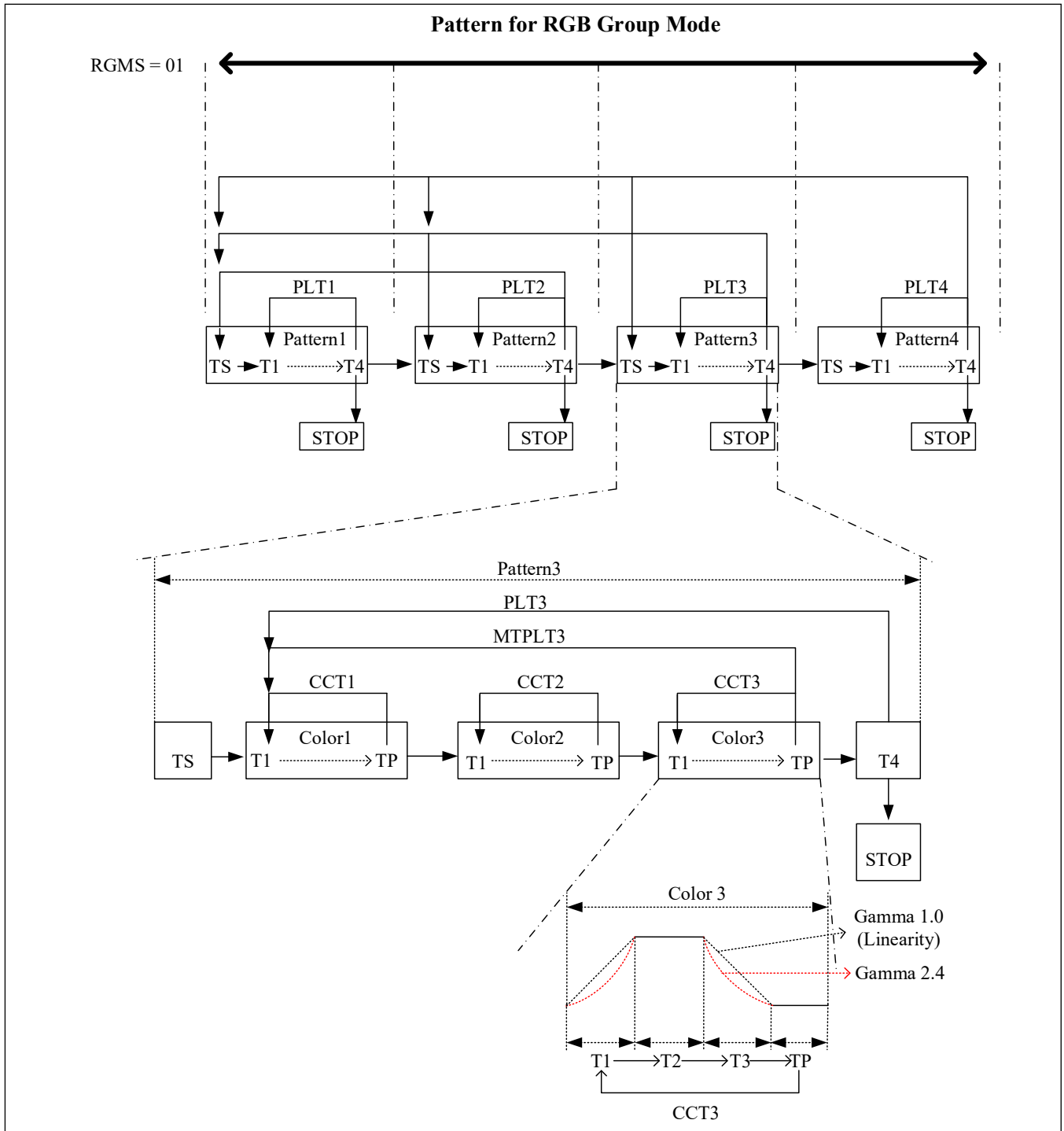


Figure 11 RGB Group Mode

Table 28 Color Register of RGB Group Mode 2

Pattern	Color Enable	OUT1	OUT2	OUT3	OUT4	OUT5	OUT6	OUT7	OUT8	OUT9
		RGB1			RGB2			RGB3		
Pattern 1	CE1(63h)	10h	11h	12h	13h	14h	15h	16h	17h	18h
	CE2(63h)	20h	21h	22h	23h	24h	25h	26h	27h	28h
	CE3(63h)	30h	31h	32h	33h	34h	35h	36h	37h	38h
Pattern 2	CE1(73h)	10h	11h	12h	13h	14h	15h	16h	17h	18h
	CE2(73h)	20h	21h	22h	23h	24h	25h	26h	27h	28h
	CE3(73h)	30h	31h	32h	33h	34h	35h	36h	37h	38h
Pattern 3	CE1(83h)	10h	11h	12h	13h	14h	15h	16h	17h	18h
	CE2(83h)	20h	21h	22h	23h	24h	25h	26h	27h	28h
	CE3(83h)	30h	31h	32h	33h	34h	35h	36h	37h	38h
Pattern 4	CE1(93h)	10h	11h	12h	13h	14h	15h	16h	17h	18h
	CE2(93h)	20h	21h	22h	23h	24h	25h	26h	27h	28h
	CE3(93h)	30h	31h	32h	33h	34h	35h	36h	37h	38h

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.

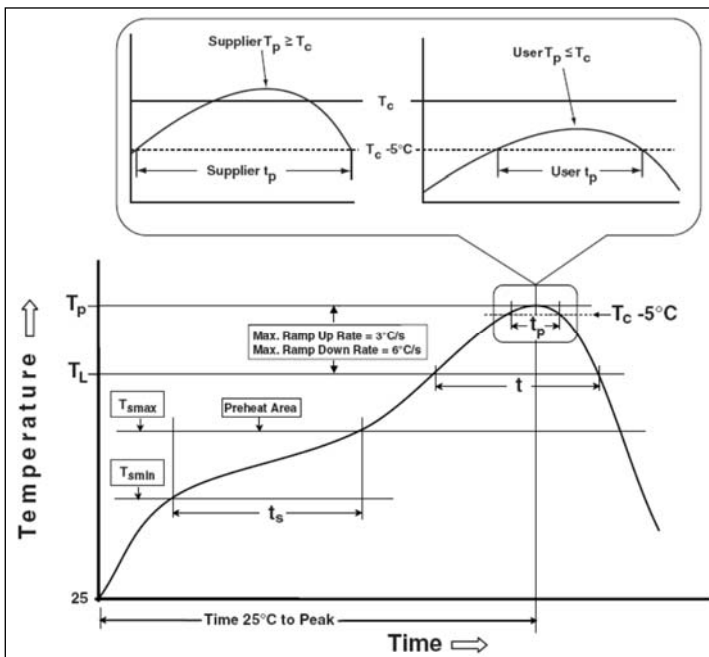
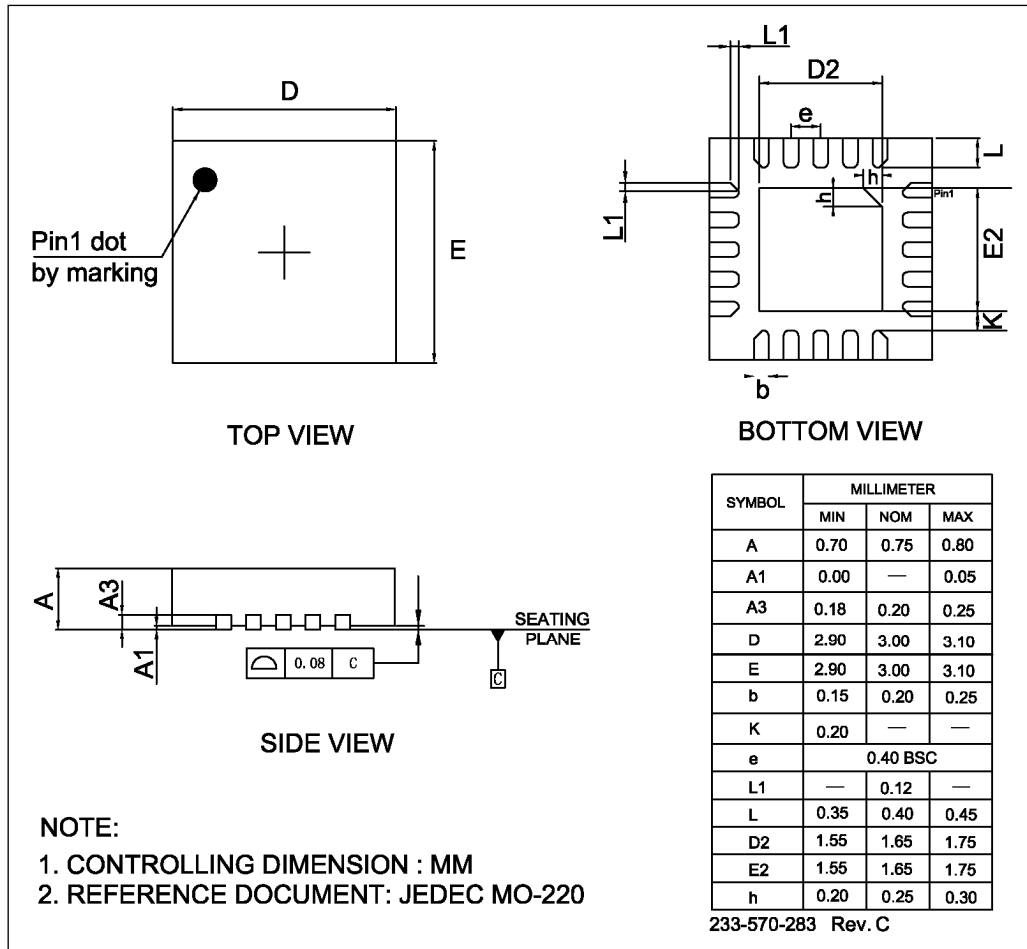


Figure 12 Classification Profile

PACKAGE INFORMATION

QFN-20

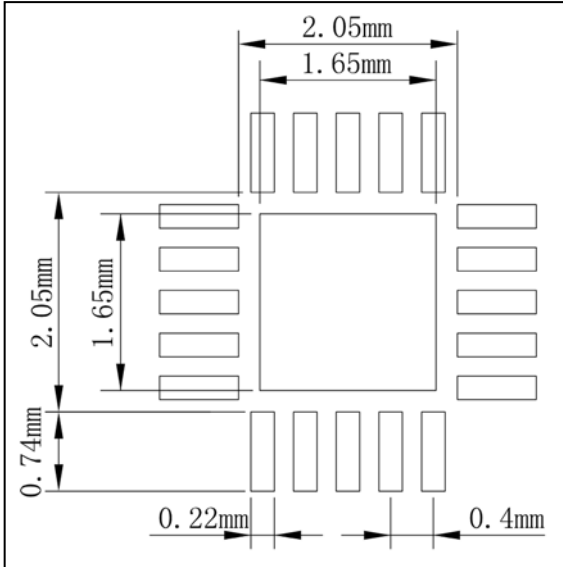


NOTE:

1. CONTROLLING DIMENSION : MM
2. REFERENCE DOCUMENT: JEDEC MO-220

RECOMMENDED LAND PATTERN

QFN-20



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 (e.g. User's board manufacturing specs), user must determine suitability for use.

REVISION HISTORY

Revision	Detail Information	Date
A	Initial Release	2024.05.24
B	Figure 10 description update	2024.09.04