

# IS31FL3193

## 3-CHANNEL FUN LED DRIVER

December 2014

### GENERAL DESCRIPTION

IS31FL3193 is a 3-channel fun LED driver which features two-dimensional auto breathing mode. It has One Shot Programming mode and PWM Control mode for RGB lighting effects. The maximum output current can be adjusted in 5 levels (5mA~42mA).

In PWM Control mode, the PWM duty cycle of each output can be independently programmed and controlled in 256 steps to simplify color mixing. In One Shot Programming mode, the timing characteristics for output current - current rising, holding, falling and off time, 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.

IS31FL3193 is available in DFN-10 (3mm × 3mm). It operates from 2.7V to 5.5V over the temperature range of -40°C to +85°C.

### FEATURES

- One group RGB, single color LED breathing system-free pre-established pattern
- 3 independently controlled automatic and semiautomatic breathing system-free pre-established pattern
- I2C interface, automatic address increment function
- 3 independently controlled outputs of 256 PWM steps
- 2.7V to 5.5V supply voltage
- 5 levels programmable output current
- Over-temperature protection
- Operating temperature  $T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$
- DFN-10 (3mm × 3mm) package

### APPLICATIONS

- Mobile phones and other hand-held devices for LED display
- LED in home appliances

### TYPICAL APPLICATION CIRCUIT

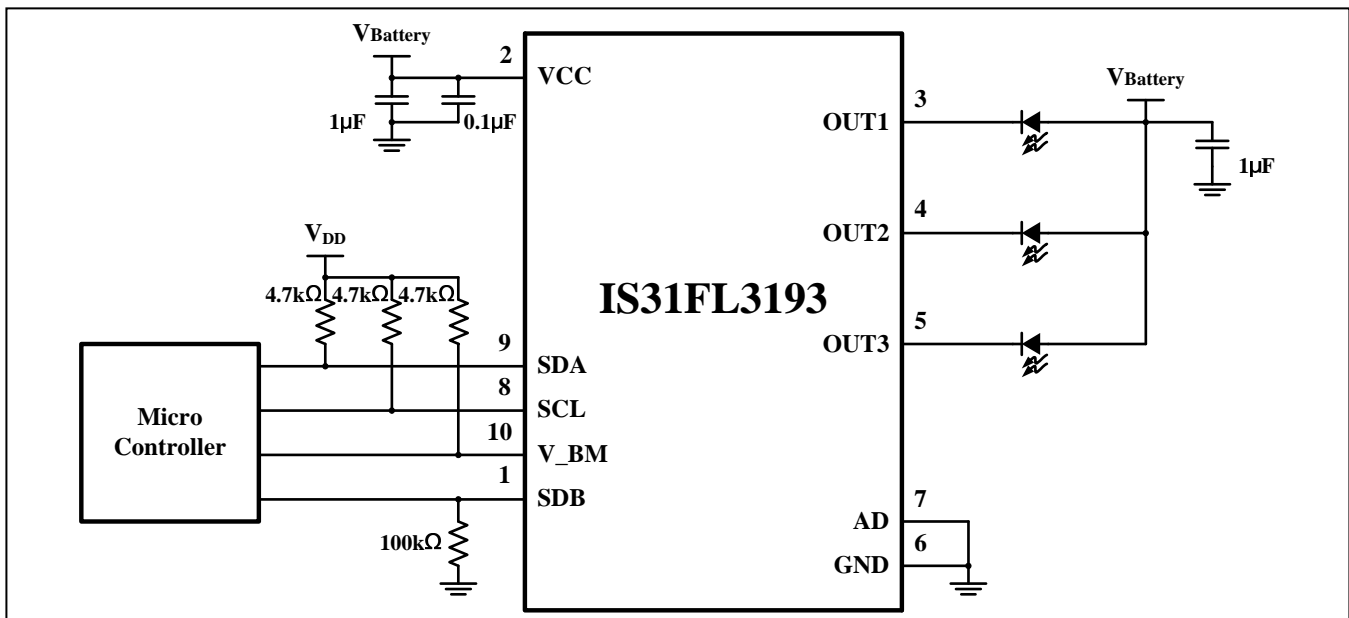
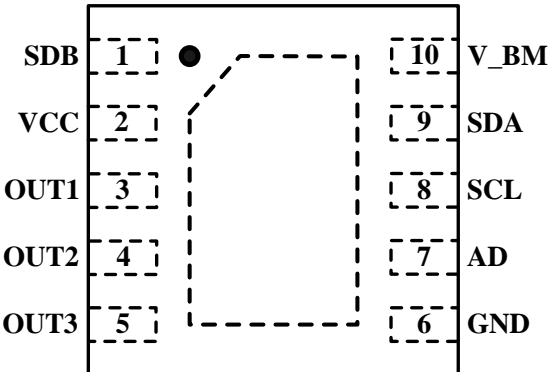


Figure 1 Typical Application Circuit

**Note:** The IC should be placed far away from the mobile antenna in order to prevent the EMI.

# IS31FL3193

## PIN CONFIGURATION

| Package | Pin Configuration (Top View)  |
|---------|---|
| DFN-10  |  <p>The diagram shows a top view of a DFN-10 package with 10 pins arranged in two rows of five. Pin 1 (SDB) is at the top left, pin 10 (V_BM) is at the top right. Pin 2 (VCC) is below pin 1, pin 9 (SDA) is below pin 10. Pin 3 (OUT1) is below pin 2, pin 8 (SCL) is below pin 9. Pin 4 (OUT2) is below pin 3, pin 7 (AD) is below pin 8. Pin 5 (OUT3) is at the bottom left, pin 6 (GND) is at the bottom right. A dashed line indicates the chip's footprint, and a solid dot is located between pins 1 and 2.</p> |

## PIN DESCRIPTION

| No. | Pin         | Description                           |
|-----|-------------|---------------------------------------|
| 1   | SDB         | Shutdown the chip when pulled to low. |
| 2   | VCC         | Power supply.                         |
| 3~5 | OUT1~OUT3   | Current source outputs.               |
| 6   | GND         | Ground.                               |
| 7   | AD          | I2C address setting.                  |
| 8   | SCL         | I2C serial clock.                     |
| 9   | SDA         | I2C serial data.                      |
| 10  | V_BM        | Breathing mark signal output.         |
|     | Thermal Pad | Connect to GND.                       |

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## ORDERING INFORMATION

Industrial Range: -40°C to +85°C

| Order Part No.     | Package           | QTY/Reel |
|--------------------|-------------------|----------|
| IS31FL3193-DLS2-TR | DFN-10, Lead-free | 2500     |

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# IS31FL3193

## 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                |
| Operating temperature range, $T_A$       | -40°C ~ +85°C         |
| Storage temperature range, $T_{STG}$     | -65°C ~ +150°C        |
| ESD (HBM)                                | ±7kV                  |
| ESD (CDM)                                | ±1kV                  |

**Note:** 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

$T_A = -40^\circ\text{C} \sim +85^\circ\text{C}$ ,  $V_{CC} = 5V$ , 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 power supply current | $V_{SDB} = V_{CC}$  |      | 0.8            |      | mA            |
| $I_{SD}$  | Shutdown current               | $V_{SDB} = 0V$  |      |                | 2.5  | $\mu\text{A}$ |
|           |                                | $V_{SDB} = V_{CC}$ , software shutdown  |      |                | 3.5  |               |
| $I_{OUT}$ | Output current                 | PWM Control mode, $V_{DS} = 0.5V$<br>PWM Register(04h~06h) = 0xFF<br>Current Register(03h) = 0x00 |      | 42<br>(Note 1) |      | mA            |
| $V_{HR}$  | Current sink headroom voltage  | $I_{OUT} = 42\text{mA}$   |      | 500            |      | mV            |

### Logic Electrical Characteristics (SDA, SCL, SDB, AD)

|          |                         |                 |     |               |     |    |
|----------|-------------------------|-----------------|-----|---------------|-----|----|
| $V_{IL}$ | Logic “0” input voltage | $V_{CC} = 2.7V$ |     |               | 0.4 | V  |
| $V_{IH}$ | Logic “1” input voltage | $V_{CC} = 5.5V$ | 1.4 |               |     | V  |
| $I_{IL}$ | Logic “0” input current |                 |     | 5<br>(Note 2) |     | nA |
| $I_{IH}$ | Logic “1” input current |                 |     | 5<br>(Note 2) |     | nA |

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## DIGITAL INPUT SWITCHING CHARACTERISTICS (Note 3)

| Symbol        | Parameter  | Condition | Min. | Typ.        | Max. | Unit    |
|---------------|--|-----------|------|-------------|------|---------|
| $f_{SCL}$     | Serial-Clock frequency                             |           |      |             | 400  | kHz     |
| $t_{BUF}$     | Bus free time between a STOP and a START condition |           | 1.3  |             |      | $\mu$ s |
| $t_{HD, STA}$ | Hold time (repeated) START condition               |           | 0.6  |             |      | $\mu$ s |
| $t_{SU, STA}$ | Repeated START condition setup time                |           | 0.6  |             |      | $\mu$ s |
| $t_{SU, STO}$ | STOP condition setup time                          |           | 0.6  |             |      | $\mu$ s |
| $t_{HD, DAT}$ | Data hold time                                     |           |      |             | 0.9  | $\mu$ s |
| $t_{SU, DAT}$ | Data setup time                                    |           | 100  |             |      | ns      |
| $t_{LOW}$     | SCL clock low period                               |           | 1.3  |             |      | $\mu$ s |
| $t_{HIGH}$    | SCL clock high period                              |           | 0.7  |             |      | $\mu$ s |
| $t_R$         | Rise time of both SDA and SCL signals, receiving   | (Note 4)  |      | $20+0.1C_b$ | 300  | ns      |
| $t_F$         | Fall time of both SDA and SCL signals, receiving   | (Note 4)  |      | $20+0.1C_b$ | 300  | ns      |

**Note 1:**  $I_{OUT}$  represents the average output current of each individual output. See PWM Register, Table 7.

**Note 2:** All LEDs are on.

**Note 3:** Guaranteed by design.

**Note 4:**  $C_b$  = total capacitance of one bus line in pF.  $I_{SINK} \leq 6mA$ .  $t_R$  and  $t_F$  measured between  $0.3 \times V_{CC}$  and  $0.7 \times V_{CC}$ .

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## DETAILED DESCRIPTION

### I2C INTERFACE

The IS31FL3193 uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31FL3193 has a 7-bit slave address (A7:A1), followed by the R/W bit, A0. Since IS31FL3193 only supports write operations, A0 must always be "0". 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 (Write Only):**

| Bit   | A7:A3 | A2:A1 | A0 |
|-------|-------|-------|----|
| Value | 11010 | AD    | 0  |

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

The SCL line is uni-directional. The SDA line is bi-directional (open-collector) with a pull-up resistor (typically 4.7kΩ). The maximum clock frequency specified by the I2C standard is 400kHz. In this discussion, the master is the microcontroller and the slave is the IS31FL3193.

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 IS31FL3193's acknowledge. The master releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the IS31FL3193 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 IS31FL3193, the register address byte is sent, most significant bit first. IS31FL3193 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 IS31FL3193 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 IS31FL3193, load the address of the data register that the first data byte is intended for. During the IS31FL3193 acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to IS31FL3193 will be placed in the new address, and so on (Figure 5).

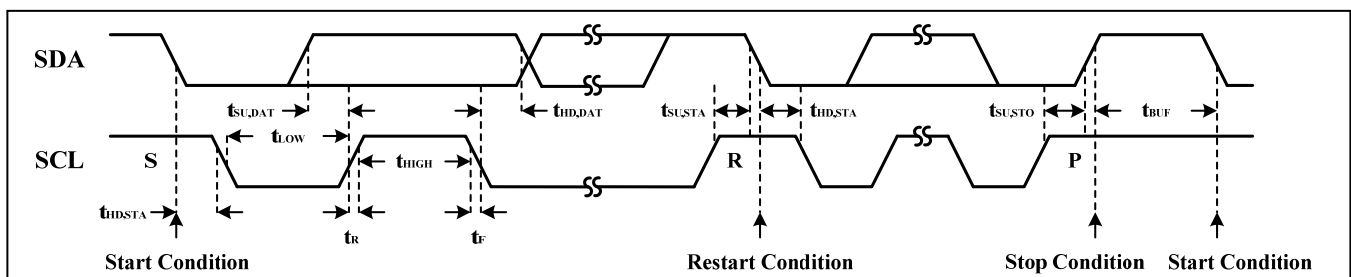


Figure 2 Interface Timing

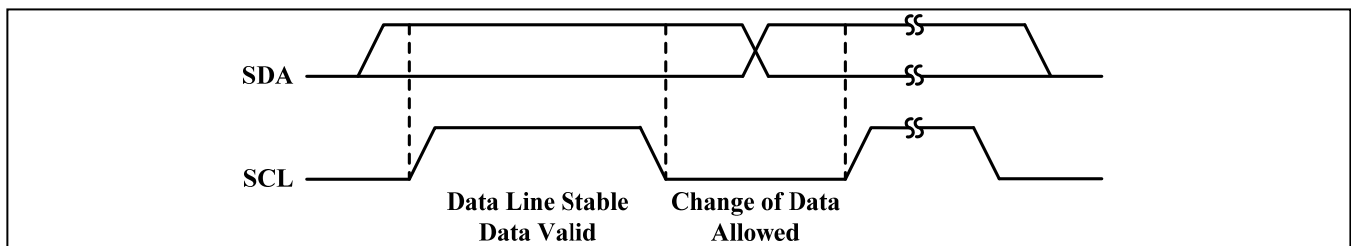


Figure 3 Bit Transfer

# IS31FL3193

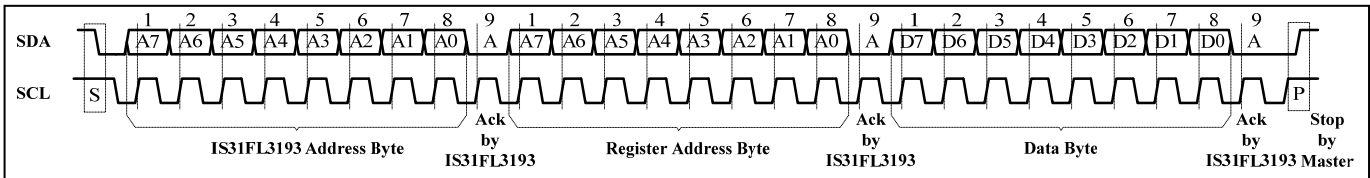


Figure 4 Writing to IS31FL3193 (Typical)

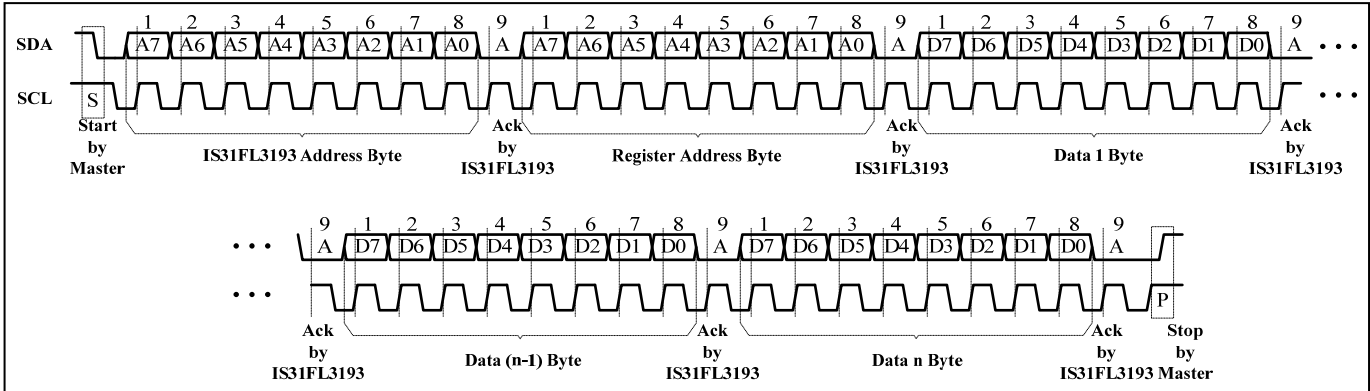


Figure 5 Writing to IS31FL3193 (Automatic Address Increment)

## REGISTERS DEFINITIONS

Table 2 Register Function

| Address   | Name                       | Function  | R/W | Table | Default   |
|-----------|----------------------------|---|-----|-------|-----------|
| 00h       | Shutdown Register          | Set software shutdown mode                        | W   | 3     | 0000 0001 |
| 01h       | Breathing Control Register | Set the breathing function                        |     | 4     | 0000 0000 |
| 02h       | LED Mode Register          | Set operation mode                                |     | 5     |           |
| 03h       | Current Setting Register   | Set output current                                |     | 6     |           |
| 04h~06h   | PWM Register               | 3 channels PWM duty cycle data                    |     | 7     |           |
| 07h       | Data Update Register       | Load PWM Registers and LED Control Register' data |     | -     | xxxx xxxx |
| 0Ah ~ 0Ch | T0 Register                | Set the T0 time                                   |     | 8     | 0000 0000 |
| 10h ~ 12h | T1&T2 Register             | Set the T1&T2 time                                |     | 9     |           |
| 16h ~18h  | T3&T4 Register             | Set the T3&T4 time                                |     | 10    | xxxx xxxx |
| 1Ch       | Time Update Register       | Load time registers' data                         |     | -     |           |
| 1Dh       | LED Control Register       | OUT1~ OUT3 enable bit                             |     | 11    | 0000 0111 |
| 2Fh       | Reset Register             | Reset all registers to default value              |     | -     | xxxx xxxx |

Table 3 00h Shutdown Register

| Bit     | D7:D6 | D5 | D4:D1 | D0  |
|---------|-------|----|-------|-----|
| Name    | -     | EN | -     | SSD |
| Default | 00    | 0  | 0000  | 1   |

The Shutdown Register sets software shutdown mode of IS31FL3193.

**EN** Channel Control  
 0 All channel disable  
 1 All channel enable

**SSD** Software Shutdown Enable  
 0 Normal operation  
 1 Software shutdown mode

# IS31FL3193

**Table 4 01h Breathing Control Register**

| Bit     | D7:D6 | D5 | D4 | D3 | D2  | D1:D0 |
|---------|-------|----|----|----|-----|-------|
| Name    | -     | RM | HT | -  | BME | CSS   |
| Default | 00    | 0  | 0  | 0  | 0   | 00    |

The Breathing Control Register sets the breathing function.

**RM** Ramping Mode Enable  
 0 Disable  
 1 Enable

**HT** Hold Time Selection  
 0 Hold on T2  
 1 Hold on T4

**BME** Breathing Mark Enable  
 0 Disable  
 1 Enable

**CSS** Channel Selection  
 00 OUT1  
 01 OUT2  
 10 OUT3  
 Others Unavailable

**Table 5 02h LED Mode Register**

| Bit     | D7:D6 | D5  | D4:D0 |
|---------|-------|-----|-------|
| Name    | -     | RGB | -     |
| Default | 00    | 0   | 00000 |

The LED Mode Register sets operation mode of IS31FL3193.

**RGB** RGB Mode Selection  
 0 PWM Control Mode  
 1 One Shot Programming Mode

**Table 6 03h Current Setting Register**

| Bit     | D7:D5 | D4:D2 | D1:D0 |
|---------|-------|-------|-------|
| Name    | -     | CS    | -     |
| Default | 000   | 000   | 00    |

The Current Setting Register stores the maximum current setting,  $I_{MAX}$ , for all of the LED output channels.

**CS** Current Setting  
 000 42mA  
 001 10mA  
 010 5mA  
 011 30mA  
 1xx 17.5mA

**Table 7 04h~06h PWM Register(OUT1~OUT3)**

| Bit     | D7:D0     |
|---------|-----------|
| Name    | PWM       |
| Default | 0000 0000 |

The value in the PWM Registers modulate the RGB LEDs in 256 steps.

The value of the PWM Registers decide the average output current of OUT1~OUT3. The average output current may be computed using the Formula (1):

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

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

For example: if D7:D0 = 10110101,

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

$I_{MAX}$  is set by Current Setting Register.

### 07h PWM Update Register

The data sent to the PWM Registers and the LED Control Registers will be stored in temporary registers. A write operation of "0000 0000" to the Update Register is required to update the registers (04h~06h, 1Dh).

**Table 8 0Ah~0Ch T0 Register (OUT1~OUT3)**

| Bit     | D7:D4 | D3:D0 |
|---------|-------|-------|
| Name    | T0    | -     |
| Default | 0000  | 0000  |

The T0 Registers set the T0 time in One Shot Programming mode.

**T0** T0 Setting  
 0000 0s  
 0001 0.13s  
 0010 0.26s  
 0011 0.52s  
 0100 1.04s  
 0101 2.08s  
 0110 4.16s  
 0111 8.32s  
 1000 16.64s  
 1001 33.28s  
 1010 66.56s  
 Others Unavailable



# IS31FL3193

**Table 9 10h~12h T1&T2 Register (OUT1~OUT3)**

| Bit     | D7:D5 | D4:D1 | D0 |
|---------|-------|-------|----|
| Name    | T1    | T2    | -  |
| Default | 000   | 0000  | 0  |

The T1&T2 Registers set the T1&T2 time in One Shot Programming mode.

**T1** T1 Setting

|     |        |
|-----|--------|
| 000 | 0.13s  |
| 001 | 0.26s  |
| 010 | 0.52s  |
| 011 | 1.04s  |
| 100 | 2.08s  |
| 101 | 4.16s  |
| 110 | 8.32s  |
| 111 | 16.64s |

**T2** T2 Setting

|        |             |
|--------|-------------|
| 0000   | 0s          |
| 0001   | 0.13s       |
| 0010   | 0.26s       |
| 0011   | 0.52s       |
| 0100   | 1.04s       |
| 0101   | 2.08s       |
| 0110   | 4.16s       |
| 0111   | 8.32s       |
| 1000   | 16.64s      |
| Others | Unavailable |

**Table 10 16h~18h T3&T4 Register (OUT1~OUT3)**

| Bit     | D7:D5 | D4:D1 | D0 |
|---------|-------|-------|----|
| Name    | T3    | T4    | -  |
| Default | 000   | 0000  | 0  |

The T3&T4 Registers set the T3&T4 time in One Shot Programming mode.

**T3** T3 Setting

|     |        |
|-----|--------|
| 000 | 0.13s  |
| 001 | 0.26s  |
| 010 | 0.52s  |
| 011 | 1.04s  |
| 100 | 2.08s  |
| 101 | 4.16s  |
| 110 | 8.32s  |
| 111 | 16.64s |

**T4** T4 Setting

|        |             |
|--------|-------------|
| 0000   | 0s          |
| 0001   | 0.13s       |
| 0010   | 0.26s       |
| 0011   | 0.52s       |
| 0100   | 1.04s       |
| 0101   | 2.08s       |
| 0110   | 4.16s       |
| 0111   | 8.32s       |
| 1000   | 16.64s      |
| 1001   | 33.28s      |
| 1010   | 66.56s      |
| Others | Unavailable |

**1Ch Time Update Register**

The data sent to the PWM Registers and the LED Control Register will be stored in temporary registers. A write operation of "0000 0000" to the Update Register is required to update the registers (0Ah~0Ch, 10h~12h, 16h~18h).

**Table 11 1Dh LED Control Register (OUT1~OUT3)**

| Bit     | D7:D3 | D2:D0     |
|---------|-------|-----------|
| Name    | -     | OUT3:OUT1 |
| Default | 00000 | 111       |

The LED Control Registers store the on or off state of each channel LED.

**OUTx** LED State

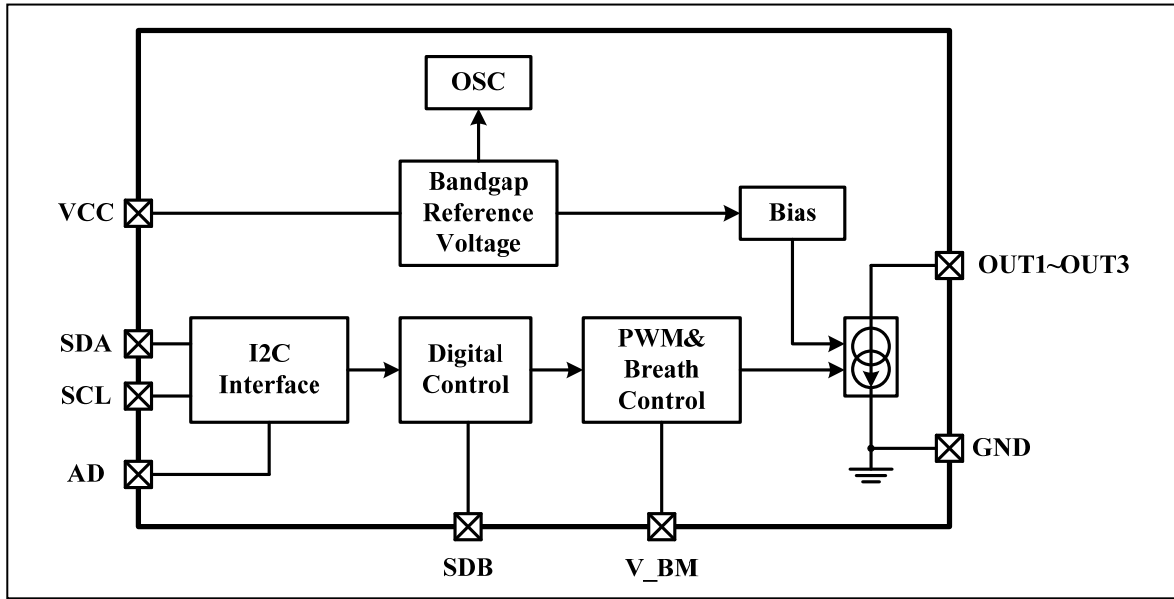
|   |         |
|---|---------|
| 0 | LED off |
| 1 | LED on  |

**2Fh Reset Register**

Once user writes "0000 0000" to the Reset Register, IS31FL3193 will reset all registers to their default value. On initial power-up, the IS31FL3193 registers are reset to their default values for a blank display.

# IS31FL3193

## FUNCTIONAL BLOCK DIAGRAM



# IS31FL3193

## TYPICAL APPLICATION INFORMATION

### GENERAL DESCRIPTION

IS31FL3193 is a 3-channel LED driver with two-dimensional auto breathing and PWM Control mode. It can drive three individual LEDs or one group of RGB.

### PWM CONTROL

By setting the RGB bit of the LED Mode Register (02h) to "0", the IS31FL3193 will operate in PWM Control mode. The PWM Registers (04h~06h) can modulate LED brightness of 3 channels with 256 steps. For example, if the data in PWM Register is "0000 0100", then the PWM is the fourth step, with a duty cycle of 4/256.

In PWM control mode, a new value must be written to the PWM registers to change the output PWM duty cycle. Writing new data continuously to the registers can modulate the brightness of the LEDs to achieve a breathing effect, blinking, or any other effects that the user defines.

### RGB BREATHING CONTROL WITH AUTO COLOR CHANGING

By setting the RGB bit of the LED Mode Register (02h) to "1", the IS31FL3193 will operate in One Shot Programming mode. In this mode, the RGB intensity is automatically modulated in a breathing cycle, independently controlled by T0~T4. T0 is an offset time period which runs only once at the start of the cycle. The full cycle is T1 to T4 (Figure 6). Setting different T0~T4 can achieve RGB breathing with auto color changing. The maximum intensity of each RGB is adjusted independently by the PWM Registers (04h~06h).

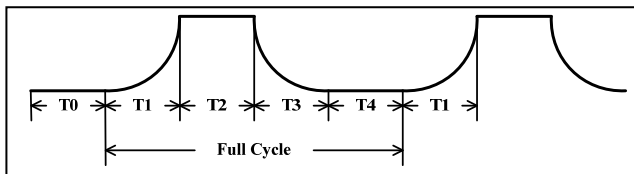


Figure 6 Breathing Timing

### RGB AUTO BREATHING CONTROL WITH COLOR SETTING

IS31FL3193 can pre-establish pattern achieving mixing color breathing. There is one group RGB. The RGB consists of three channels. Every channel has an 8-bit PWM data register. The color can be set by the PWM data register. By adjusting the individual intensity of the red, green and blue LED, different colors are perceived. For example, the three PWM data: 20h, 80h, C8h, will determine one particular color.

After setting the color, T0~T4 time register will be set to control the LED breathing panel. And T0~T4 time

should be same for each of the RGB LEDs, otherwise the pre-established color will change.

### SEMIAUTOMATIC BREATHING

By setting the RGB bit of the LED Mode Register (02h) to "1" and the RM bit of the Breathing Control Register (01h) to "1", the ramping function is enabled. HT is the time select bit. When HT bit is set to "0", T2 will be held forever, and the LED will remain at the programmed maximum intensity. When HT bit is set to "1", T3 will continue and T4 will be held, causing the LED to complete one breathing cycle and then remain off.

### BREATHING MARK FUNCTION

By setting the BME bit of the Breathing Control Register (01h) to "1", the breathing mark function is enabled. V<sub>BM</sub> is an output pin. The breathing mark function is useful as a signal to notify the MCU when to update the color data. At the end of time period T1, V<sub>BM</sub> will induce a falling edge and hold logic low, so the new data can be sent by MCU at this time. At the end of T3, V<sub>BM</sub> will induce a rising edge and the MCU can send an update command to update all data simultaneously (Figure 7). The marking channel (OUT1~OUT3) is selected by the CSS bits of the Breathing Control Register (01h).

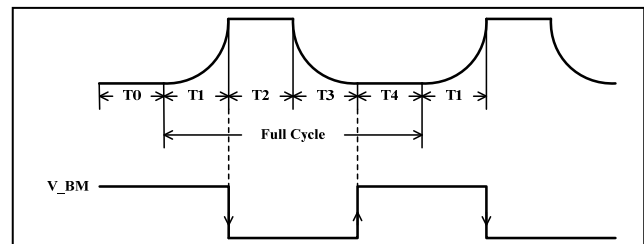


Figure 7 V<sub>BM</sub> Signal

### 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 (00h) to "1", the IS31FL3193 will operate in software shutdown mode, wherein they consume only 2µA (typ.) current. When the IS31FL3193 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.

# IS31FL3193

## CLASSIFICATION REFLOW PROFILES

| Profile Feature  | Pb-Free Assembly                 |
|--|----------------------------------|
| Preheat & Soak<br>Temperature min (T <sub>smin</sub> )<br>Temperature max (T <sub>smax</sub> )<br>Time (T <sub>smin</sub> to T <sub>smax</sub> ) (t <sub>s</sub> ) | 150°C<br>200°C<br>60-120 seconds |
| Average ramp-up rate (T <sub>smax</sub> to T <sub>p</sub> )  | 3°C/second max.                  |
| Liquidous temperature (T <sub>L</sub> )<br>Time at liquidous (t <sub>L</sub> )   | 217°C<br>60-150 seconds          |
| Peak package body temperature (T <sub>p</sub> )*   | Max 260°C                        |
| Time (t <sub>p</sub> )** within 5°C of the specified classification temperature (T <sub>c</sub> )  | Max 30 seconds                   |
| Average ramp-down rate (T <sub>p</sub> to T <sub>smax</sub> )  | 6°C/second max.                  |
| Time 25°C to peak temperature  | 8 minutes max.                   |

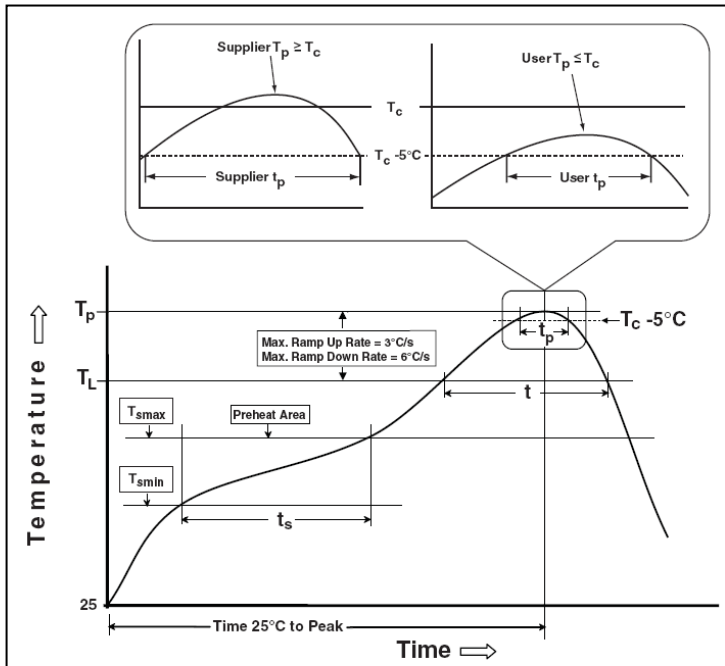
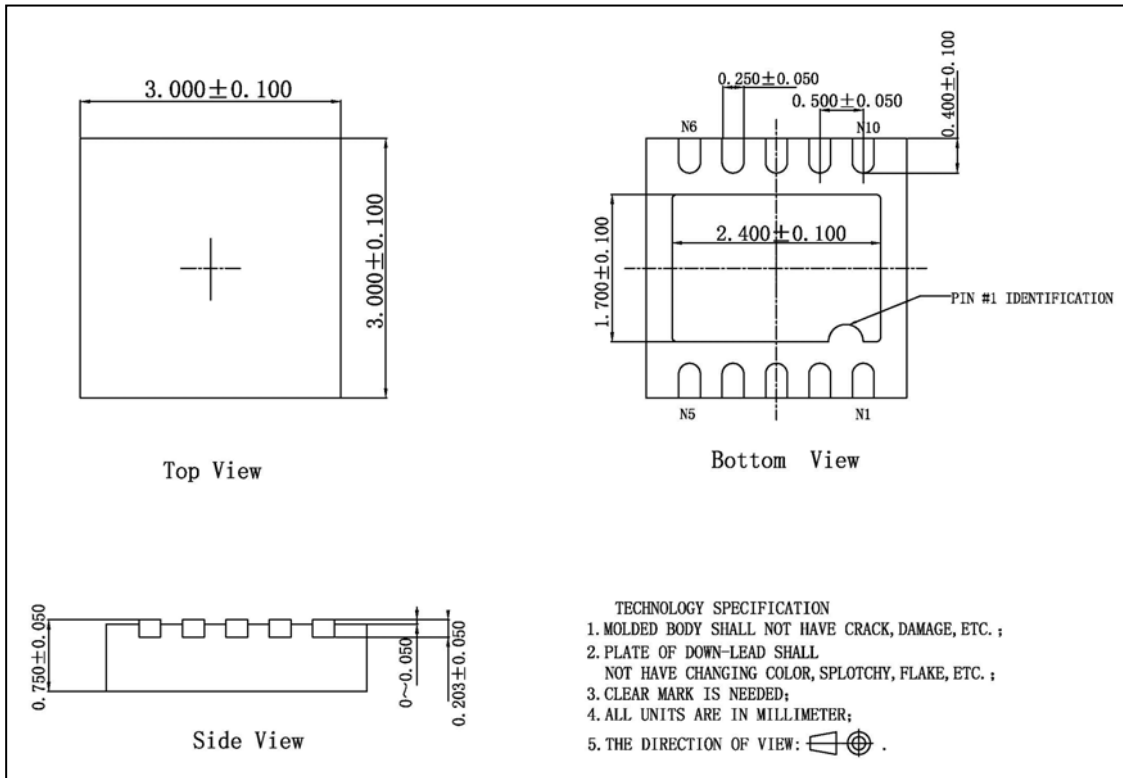


Figure 8 Classification Profile

# IS31FL3193

## PACKAGE INFORMATION

### DFN-10



**Note:** All dimensions in millimeters unless otherwise stated.

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