# IS31FL3719

## 16×8/15×9 MATRIX LED DRIVER

**May 2022**

### GENERAL DESCRIPTION

The IS31FL3719 is a general purpose 15×9 or 16×8 LED Matrix driver programmable via 1MHz I2C compatible interface. All LED can be turned on and off individually, and 9×7 or 8×8 of the matrix's LED can be dimmed individually with 8-bit PWM data. All LED has a global 7-bit current control (GCC) data which allowing 128 steps of linear DC current adjustable levels.

Additionally, each LED open and short state can be detected. IS31FL3719 store the open or short information in Open-Short Registers which can be read out by MCU via I2C compatible interface, inform MCU whether there are LEDs open or short and the locations of such open or short LEDs.

The IS31FL3719 operates from 2.7V to 5.5V and features a very low shutdown and operational current.

IS31FL3719 is available in QFN-32 (4mm×4mm) and eTQFP-32 packages. It operates over the temperature range of -40°C to +125°C.

### FEATURES

- Supply voltage range: 2.7V to 5.5V
- 16 current sinks
- Support 16×n (n=1~8) or 15×9 LED matrix configurations
- Individual on/off control steps for all LEDs
- Individual 256 PWM control steps for 9×7/8×8 LEDs
- 128 global current steps
- SDB rising edge reset I2C module
- 256kHz PWM frequency or 28.4kHz scanning rate when n=9
- 1MHz I2C-compatible interface
- Individual open and short error detect function
- PWM 180-degree phase shift
- De-ghost - reduced inactive LED reverse bias to improve LED reliability
- QFN-32 (4mm×4mm) and eTQFP-32 packages

### APPLICATIONS

- White goods LED display panel
- Gaming device
- IOT device

### TYPICAL APPLICATION CIRCUIT

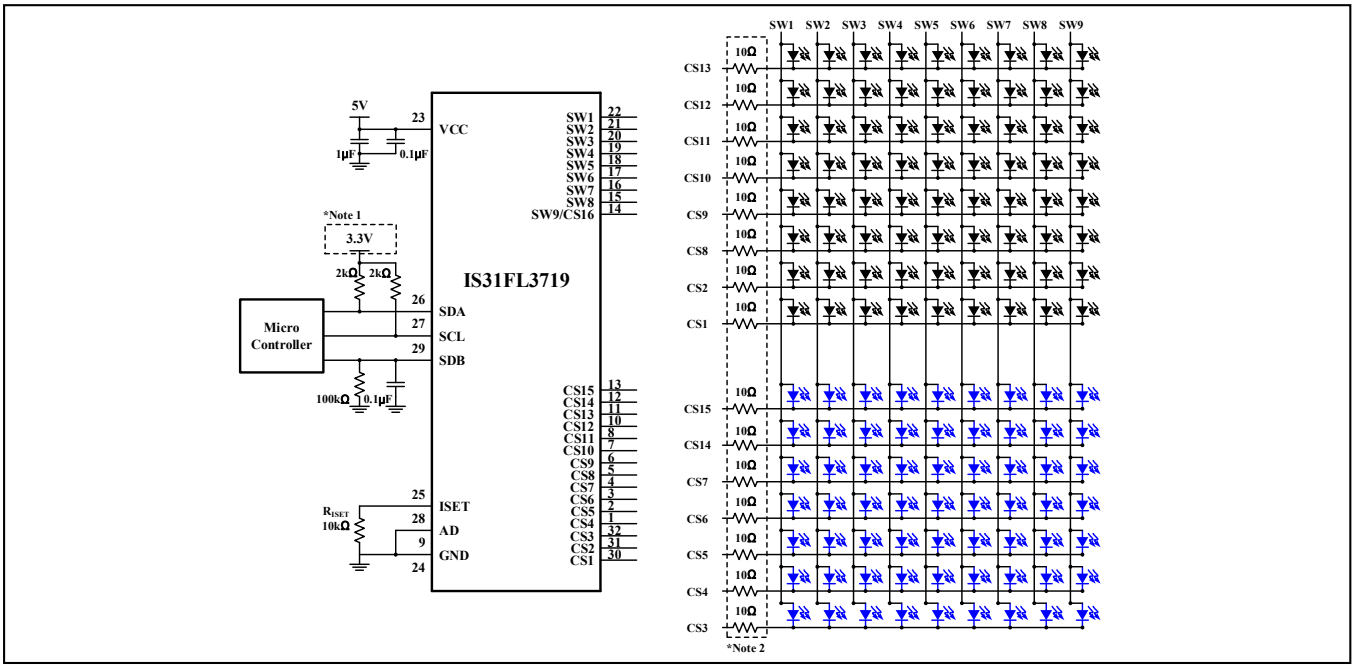



**Figure 1** Typical Application Circuit (15×9)

**Note 1:** The VIH of I2C bus should be not higher than VCC. And if VIH is lower than 3.0V, it is recommended add a level shift circuit to avoid extra shutdown current.

**Note 2**: These optional resistors are for offloading the thermal dissipation ($P=I^2R$) away from the IS31FL3719, for mono red/yellow/orange LED, if $PV_{CC}=V_{CC}=3.3V$, don't need these resistors.

## TYPICAL APPLICATION CIRCUIT (CONTINUED)

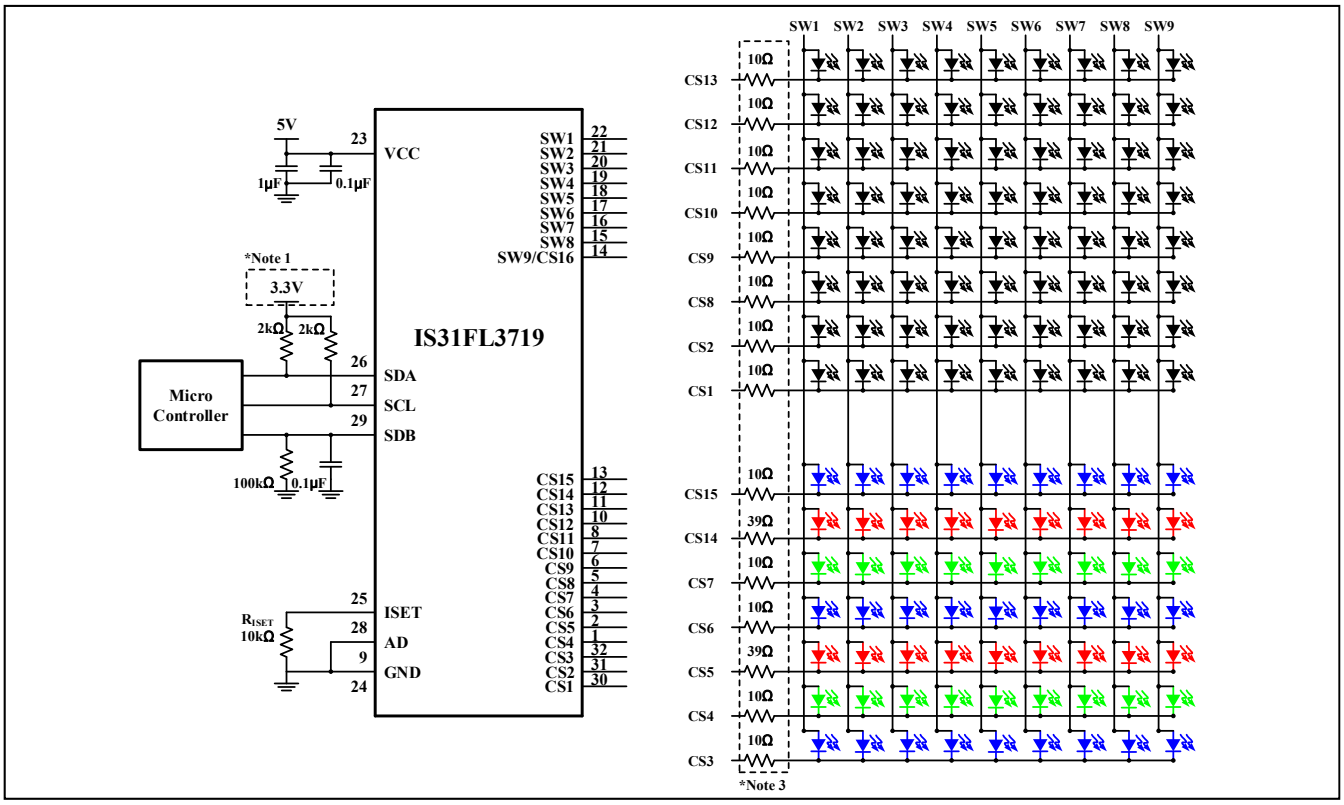



**Figure 2** Typical Application Circuit (15×9, RGB)

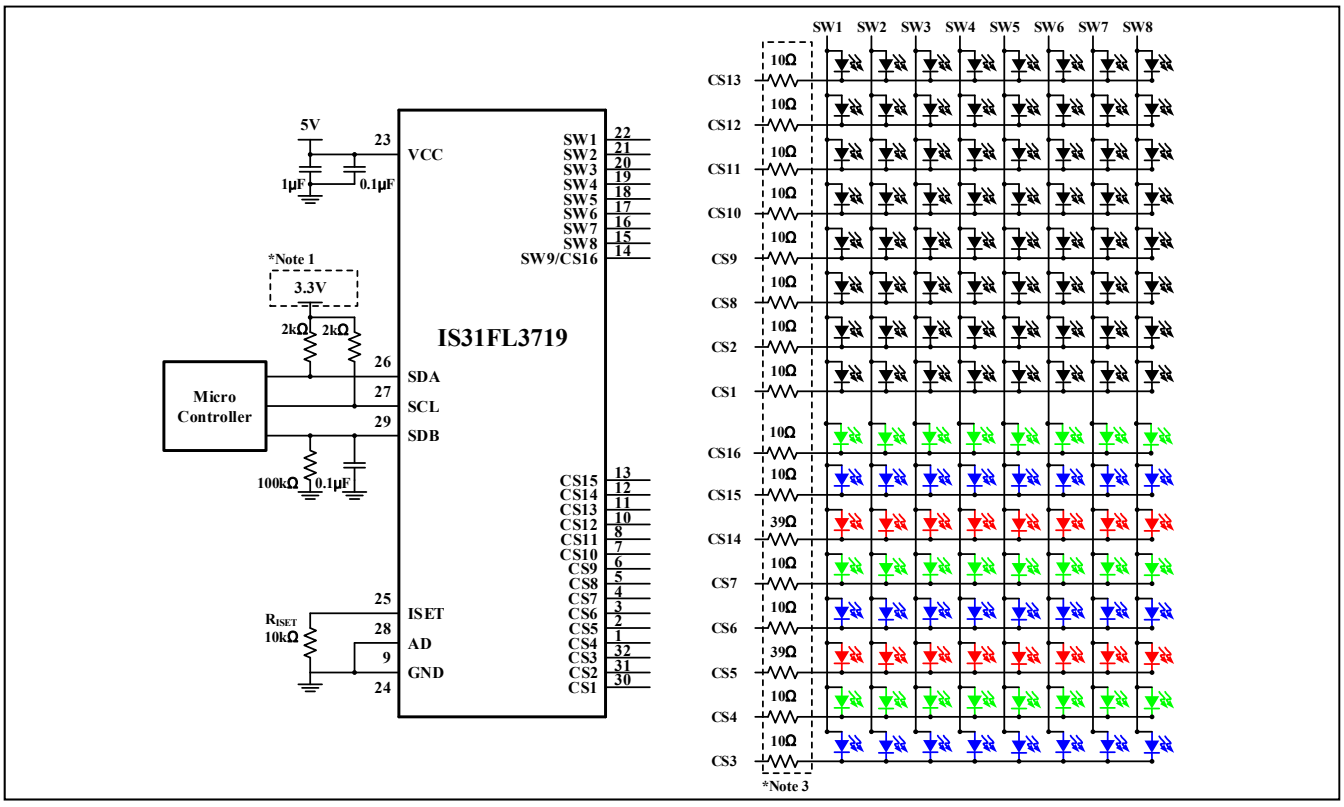
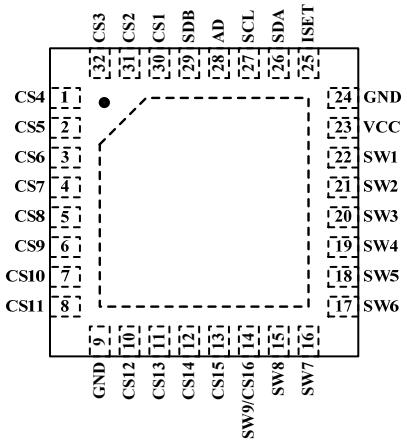
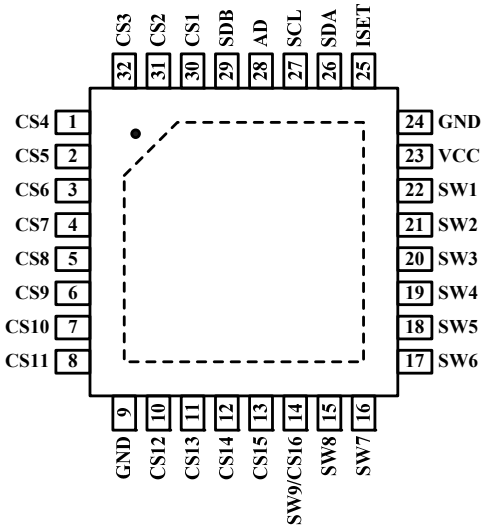



**Figure 3** Typical Application Circuit (16×8, RGB)

**Note 3:** These optional resistors are for offloading the thermal dissipation ($P=I^2R$) away from the IS31FL3719, for red LED, it is recommended to use about 30Ohm more than blue/green LED, to offload extra voltage due to lower forward voltage of red LED.

## PIN CONFIGURATION

| Package | Pin Configuration (Top View) |
|---|---|
| QFN-32 |  |
| eTQFP-32 |  |



## PIN DESCRIPTION

| No. | Pin | Description |
|---|---|---|
| 1~8, 10~13 | CS4~CS15 | Current sinks output. |
| 9,24 | GND | Ground. |
| 14 | SW9/CS16 | Switch power source / current sinks output. |
| 15~22 | SW8~SW1 | Switch power source. |
| 23 | VCC | Power supply. |
| 25 | ISET | Current setting pin. |
| 26 | SDA | Serial data. |
| 27 | SCL | Serial clock. |
| 28 | AD | I2C Address setting. |
| 29 | SDB | Shutdown the chip when pull to low. |
| 30~32 | CS1~CS3 | Current sinks output. |
| Thermal Pad | Thermal Pad | Need to connect to GND pins. |

## ORDERING INFORMATION

**Industrial Range: -40°C to +125°C**

| Order Part No. | Package | QTY/Reel |
|---|---|---|
| IS31FL3719-QFLS4-TR | QFN-32, Lead-free | 2500 |
| IS31FL3719-TQLS4-TR | eTQFP-32, Lead-free | |

## 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), $\theta_{JA}$ | 50.4°C/W (QFN)<br>35.5°C/W (eTQFP) |
| ESD (HBM)<br>ESD (CDM) | ±8kV<br>±750V |

**Note 4:** 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°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 | $V_{SDB}$=$V_{CC}$=5V, 8-bit mode, All LEDs PWM=0x00, OSC=8MHz | | 1.29 | 1.9 | mA |
| | | $V_{SDB}$=$V_{CC}$=3.6V, 8-bit mode, All LEDs PWM=0x00, OSC=8MHz | | 0.82 | 1.3 | |
| $I_{SD}$ | Shutdown current | $V_{SDB}$= 0V | | 0.6 | 2 | μA |
| | | $V_{SDB}$= $V_{CC}$= 5V, software shutdown mode | | 0.7 | 2 | |
| | | $V_{SDB}$= 0V | | 0.43 | 2 | |
| | | $V_{SDB}$= $V_{CC}$= 3.6V, software shutdown mode | | 0.43 | 2 | |
| $I_{OUT}$ | Peak current of CSy | $R_{ISET}$= 10kΩ, $I_{OUT}$= 34.6mA | 31.8 | 34.6 | 37.4 | mA |
| $\Delta I_{MAT}$ | Sink current between channels | $I_{OUT}$= 34.6mA (Note 5) | -6 | | 6 | % |
| $\Delta I_{ACC}$ | Sink current Between device to device | $I_{OUT}$= 34.6mA (Note 6) | -6 | | 6 | % |
| $I_{LED}$ | Average current on each LED<br>$I_{LED}$ = $I_{OUT(PEAK)}$/Duty | $R_{ISET}$= 10kΩ, n= 8, Duty=1/8.205 | | 4.21 | | mA |
| $V_{HR}$ | Current switch headroom voltage SWx | $I_{SW}$= 600mA | | 500 | 780 | mV |
| | Current sink headroom voltage CSy | $I_{OUT}$= 34.6mA | | 450 | 600 | |
| $t_{SCAN}$ | Period of scanning of single SWx | 8-bit PWM mode | | 32 | 40 | μs |
| | | 6+2-bit PWM mode | | 4 | 5 | |
| $t_{NOL1}$ | Non-overlap blanking time during scan, the SWx and CSy are all off during this time | 8-bit PWM mode | | 0.55 | 0.7 | μs |
| | | 6+2-bit PWM mode | | 0.25 | 0.35 | |
| $t_{NOL2}$ | Delay total time for CS1 to CS16, during this time, the SWx is on but CSy is not all turned on | 8-bit PWM mode, 32kHz (Note 7) | | 0.27 | | μs |
| | | 16MHz OSC, 6+2-bit PWM mode (Note 7) | | 0.1 | | |
| $V_{OD}$ | CSy pin open detect threshold | $V_{CC}$= 5V, $R_{ISET}$= 10kΩ, $I_{OUT}$≥0.1mA, measured at CSy | 0.12 | 0.24 | | V |
| $V_{SD}$ | LED short detect threshold | $V_{CC}$= 5V, $R_{ISET}$= 10kΩ, $I_{OUT}$≥ 0.1mA, measured at ($V_{CC}$-$V_{CSy}$) | 0.6 | 1.0 | 1.4 | V |

## ELECTRICAL CHARACTERISTICS

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

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Logic Electrical Characteristics (SDA, SCL, AD, SDB)** | | | | | | |
| $V_{IL}$ | Logic “0” input voltage | $V_{CC}$= 2.7V~5.5V | GND | | 0.3$V_{CC}$ | V |
| $V_{IH}$ | Logic “1” input voltage | $V_{CC}$= 2.7V~5.5V | 0.7$V_{CC}$ | | $V_{CC}$ | V |
| $V_{IL}$ | Logic “0” input voltage | $V_{CC}$= 4.5V~5.5V | GND | | 0.3$V_{CC}$ | V |
| $V_{IH}$ | Logic “1” input voltage | $V_{CC}$= 4.5V~5.5V | 0.5$V_{CC}$ | | $V_{CC}$ | V |
| $V_{HYS}$ | Input schmitt trigger hysteresis | $V_{CC}$= 5V (Note 7) | | 0.35 | | V |
| $I_{IL}$ | Logic “0” input current | SDB= L, $V_{INPUT}$= L (Note 7) | | 5 | | nA |
| $I_{IH}$ | Logic “1” input current | SDB= L, $V_{INPUT}$= H (Note 7) | | 5 | | nA |

## DIGITAL INPUT I2C SWITCHING CHARACTERISTICS (NOTE 7)

| 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 5:** $I_{OUT}$ mismatch (bit to bit) $\triangle I_{MAT}$ is calculated:

$$\Delta I_{MAT} = \pm \left( \frac{I_{OUT(MAX)} - I_{OUT(MIN)}}{\left( \frac{I_{OUT0} + I_{OUT1} + ... + I_{OUT23}}{24} \times 2 \right)} \right) \times 100\%$$

**Note 6:** $I_{OUT}$ accuracy (device to device) $\triangle I_{ACC}$ is calculated:

$$\Delta I_{ACC} = \pm MAX \left( \frac{I_{OUT(MIN)} - I_{OUT(IDEAL)}}{I_{OUT(IDEAL)}} \right) \times 100\%$$

Where $I_{OUT(IDEAL)}$= 34.6mA when $R_{ISET}$= 10kΩ.

**Note 7:** Guaranteed by design.

## DETAILED DESCRIPTION

### I2C INTERFACE

IS31FL3719 uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31FL3719 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 | 01101 | 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 400kHz I2C with 4.7kΩ, 1MHz I2C with 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 IS31FL3719.

The timing diagram for the I2C is shown in Figure 4. 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 IS31FL3719's acknowledge. The master releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the IS31FL3719 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 IS31FL3719, the register address byte is sent, most significant bit first. IS31FL3719 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 IS31FL3719 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 IS31FL3719, load the address of the data register that the first data byte is intended for. During the IS31FL3719 acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to IS31FL3719 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 IS31FL3719 (Figure 7).

### READING OPERATION

Most of the registers can be read.

To read the register, after I2C start condition, the bus master must send the IS31FL3719 device address with the R/$\overline{W}$ bit set to "0", followed by the register address which determines which register is accessed. Then restart I2C, the bus master should send the IS31FL3719 device address with the R/$\overline{W}$ bit set to "1". Data from the register defined by the command byte is then sent from the IS31FL3719 to the master (Figure 8).

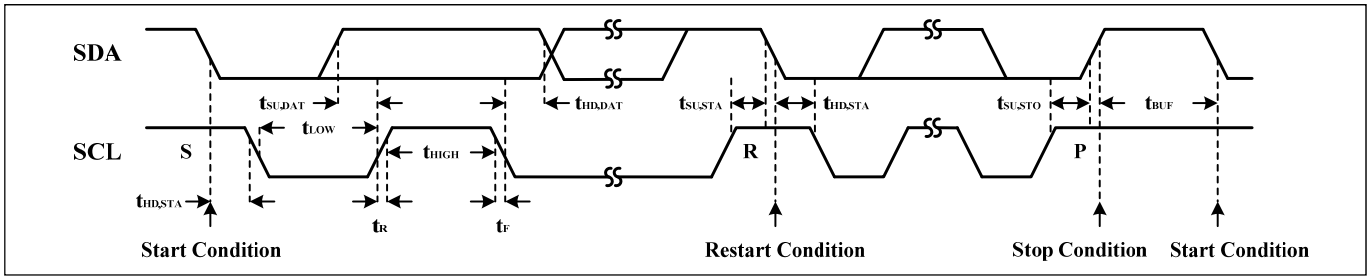



**Figure 4** I2C Interface Timing

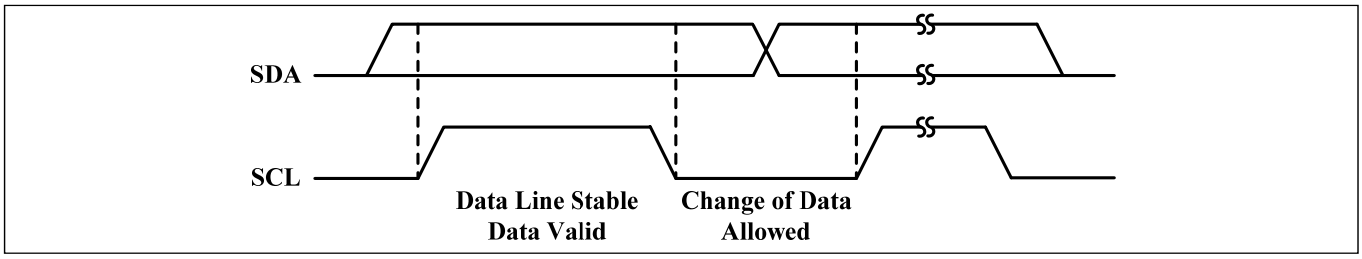



**Figure 5** I2C Bit Transfer

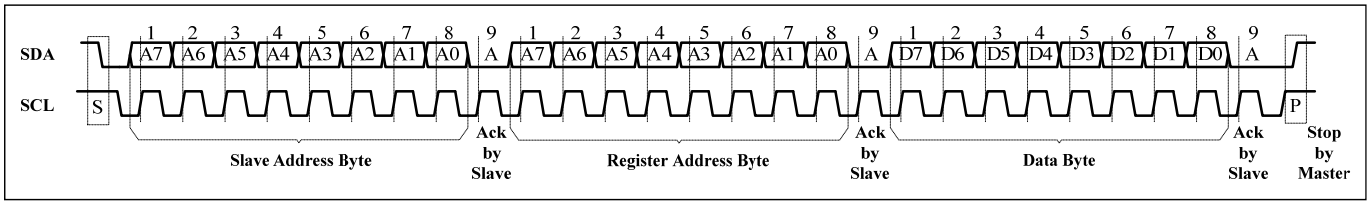



**Figure 6** I2C Writing to IS31FL3719 (Typical)

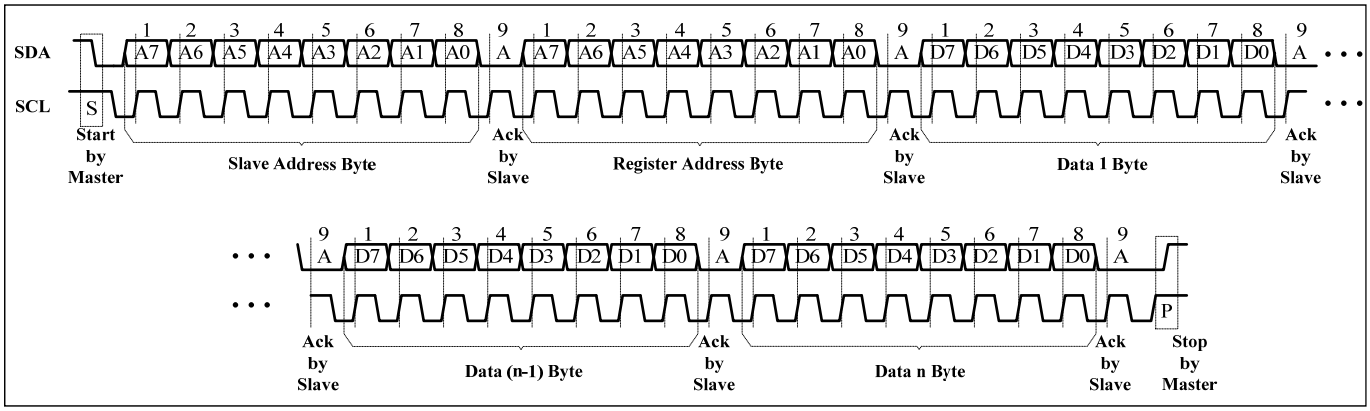



**Figure 7** I2C Writing to IS31FL3719 (Automatic Address Increment)

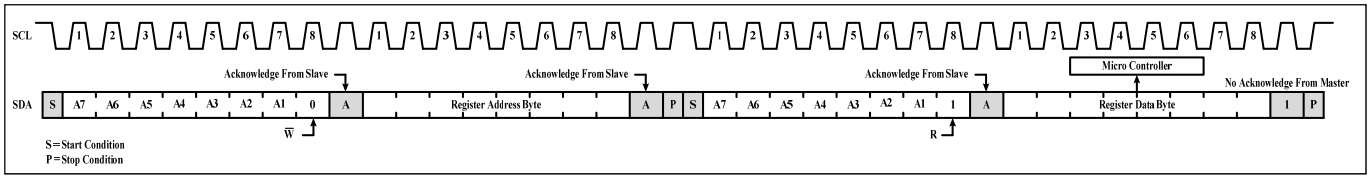



**Figure 8** I2C Reading from IS31FL3719

**Table 2 Register Definition**

| Address | Name | Function | Table | R/W | Default |
|---|---|---|---|---|---|
| 10h~56h | PWM Register | Set PWM value for LED | 3 | R/W | 0000 0000 |
| 61h~69h | On off control registers | For those no PWM LED on off control | 4 | R/W | 0000 0000 |
| A0h | Configuration Register | Configure the operation mode | 5 | R/W | 0001 0000 |
| A1h | Global Current Control Register | Set the global current | 6 | R/W | 0000 0000 |
| A2h | PWM Frequency Register | Set PWM frequency | 7 | R/W | 0000 0001 |
| A4h | Pull Down/Up Level Selection Register | Set the pull down for SWx and pull up for CSy | 8 | R/W | 1010 0010 |
| B0h | Open/short enable register | Enable open/short function with position | 9 | W | 0000 0000 |
| B1h | Open/short register | Store the open/short information | 10 | R | 0000 0000 |
| EFh | Reset Register | Reset the registers value to default | - | W | 0000 0000 |

### PWM Register

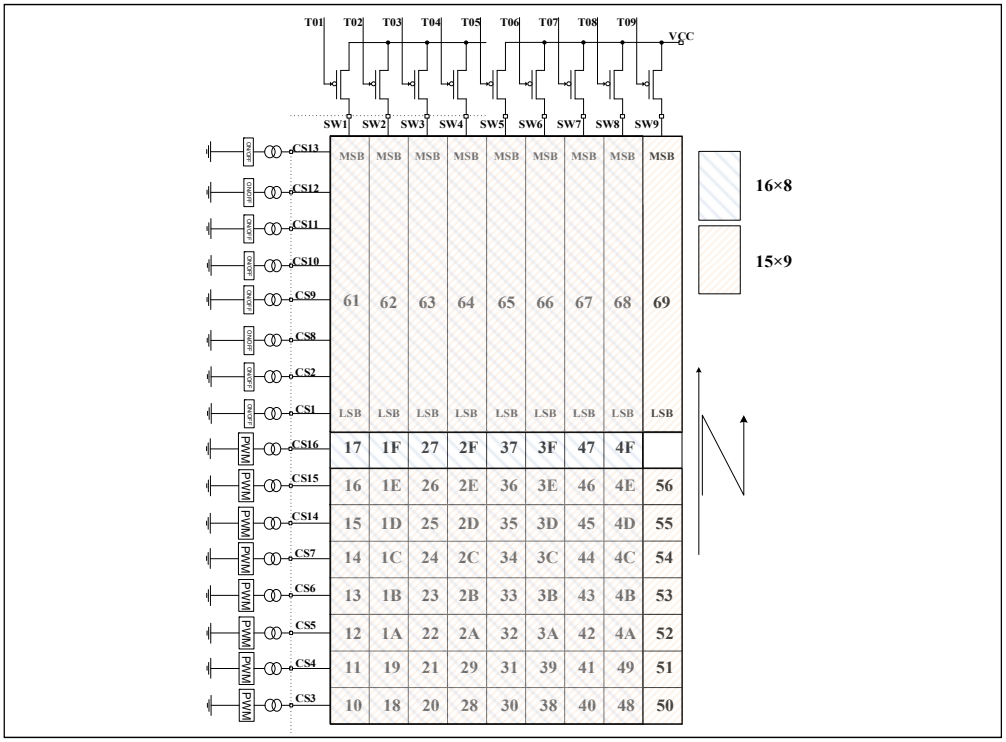



**Figure 9** PWM and ON/OFF Register

**Table 3 10h ~ 56h PWM Register**

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

Each LED dot has a byte to modulate the PWM duty in 256 steps. The PWM clock frequency is set by the PWM Frequency Register (A2h). The following calculations assume A2h is configured for 32kHz PWM, A2h= "0x01" for $t_{SCAN}$=32μs, the period of scanning and 0.55μs is $t_{NOL1}$, the non-overlap time and 0.27μs is the CSy delay time.

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

$I_{LED}$ computed by Formula (1):

$$I_{LED} = \frac{PWM}{256} \times I_{OUT\,(PEAK)} \times Duty \qquad (1)$$

$$PWM = \sum_{n=0}^{7} D[n] \cdot 2^n$$

Where Duty is the duty cycle of SWx, when n=9,

8-bit PWM mode:

$$Duty = \frac{32\mu s}{(32\mu s + 0.55\mu s + 0.27\mu s)} \times \frac{1}{9} = \frac{1}{9.23} \qquad (2)$$

6+2-bit PWM mode:

$$Duty = \frac{4\mu s}{(4\mu s + 0.25\mu s + 0.1\mu s)} \times \frac{1}{9} = \frac{1}{9.7875} \qquad (2)$$

When n=8,

8-bit PWM mode:

$$Duty = \frac{32\mu s}{(32\mu s + 0.55\mu s + 0.27\mu s)} \times \frac{1}{8} = \frac{1}{8.205} \qquad (2)$$

6+2-bit PWM mode:

$$Duty = \frac{4\mu s}{(4\mu s + 0.25\mu s + 0.1\mu s)} \times \frac{1}{8} = \frac{1}{8.7} \qquad (2)$$

$I_{OUT}$ is the output current of CSy (y=1~16),

$$I_{OUT(PEAK)} = \frac{350}{R_{ISET}} \times \frac{GCC}{128} \qquad (3)$$

GCC is the Global Current Control Register (A1h) value, $R_{ISET}$ is the external resistor of ISET pin. D[n] stands for the individual bit value, 1 or 0, in location n.

For example: if D7:D0=1011 0101 (0xB5, 181), GCC= 111 1111, 8-bit PWM mode, n=9, $R_{ISET}$=10kΩ:

$$I_{LED} = \frac{181}{256} \times \frac{350}{10\,k\Omega} \times \frac{127}{128} \times \frac{1}{9.23}$$

if D7:D0=1001 0100 (0x94, 148), GCC= 111 1111, 6+2bit PWM mode, n=8, $R_{ISET}$=10kΩ:

$$I_{LED} = \frac{148}{256} \times \frac{350}{10\,k\Omega} \times \frac{127}{128} \times \frac{1}{8.7}$$

**Table 4 61h ~ 69h ON OFF Control Register**

| Bit | D7:D0 |
|---|---|
| Name | OOF (CS13~CS8, CS2, CS1) |
| Default | 0000 0000 |

Each LED of CS1, CS2, CS8~CS13 have an ON OFF control register (OOF), the OOF bit control the on and off of the LED. When the OOF bit is "1", the LED will turn on, the average current of each LED is equal to ILED when PWM value is 0xFF. When the OOF bit is "0", the LED will turn off.

**Table 5 A0h Configuration Register**

| Bit | D7:D4 | D3 | D2:D1 | D0 |
|---|---|---|---|---|
| Name | SWS | PMS | - | SSD |
| Default | 0001 | 0 | 00 | 0 |

The Configuration Register sets operating mode of IS31FL3719.

When SSD is "0", IS31FL3719 works in software shutdown mode and for normal operation the SSD bit should set to "1".

PMS select the PWM mode.

SWS control the duty cycle of the SWx, default mode is 1/8.

When PWM Mode is 6+2 mode, the PWMF bits should be set to "1001" (256kHz, 16MHz OCS).

| **SSD** | Software Shutdown Control |
|---|---|
| 0 | Software shutdown |
| 1 | Normal operation |

| **PMS** | PWM Mode Select |
|---|---|
| 0 | 8-bit mode |
| 1 | 6+2-bit mode |

| **SWS** | SWx Setting |
|---|---|
| 0000 | n=9, SW1~SW9, 9SW×15CS matrix |
| 0001 | n=8, SW1~SW8, 8SW×16CS matrix |
| 0010 | n=7, SW1~SW7, 7SW×16CS matrix, SW8 no-active |
| 0011 | n=6, SW1~SW6, 6SW×16CS matrix, SW7~SW8 no-active |
| 0100 | n=5, SW1~SW5, 5SW×16CS matrix, SW6~SW8 no-active |
| 0101 | n=4, SW1~SW4, 4SW×16CS matrix, SW5~SW8 no-active |
| 0110 | n=3, SW1~SW3, 3SW×16CS matrix, SW4~SW8 no-active |
| 0111 | n=2, SW1~SW2, 2SW×16CS matrix, SW3~SW8 no-active |
| 1000 | SW1~SW9 with same phase, all on. |
| Others | SW1~SW9, SW1~SW9, 9SW×15CS matrix |

**Table 6 A1h Global Current Control Register**

| Bit | D7 | D6:D0 |
|---|---|---|
| Name | - | GCC |
| Default | 0 | 000 0000 |

The Global Current Control Register modulates all CSy (y=1~16) DC current which is noted as $I_{OUT}$ in 128 steps, maximum GCC is "111 1111".

$I_{OUT}$ is computed by the Formula (3):

$$I_{OUT(PEAK)} = \frac{350}{R_{ISET}} \times \frac{GCC}{128}$$

$$GCC = \sum_{n=0}^{6} D[n] \times 2^n$$

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

**Table 7 A2h PWM Frequency**

| Bit | D7:D4 | D3:D0 |
|---|---|---|
| Name | - | PWMF |
| Default | 0000 | 0001 |

Set the PWM frequency, default setting is 32kHz, 8MHz OSC. When PWM Mode is 6+2 mode, the PWMF bits should be set to "1001" (256kHz, 16MHz OCS).

| **PWMF** | PWM frequency setting |
|---|---|
| 0001 | 32kHz<br>(when n=9, scanning rate is 32/9=3.5kHz) |
| 0010 | 8kHz (8MHz OCS) |
| 0011 | 2kHz (8MHz OCS) |
| 0100 | 1kHz (8MHz OCS) |
| 0101 | 500Hz (8MHz OCS) |
| 0110 | 250Hz (8MHz OCS) |
| 0111 | 125Hz (8MHz OCS) |
| 1001 | 256kHz (16MHz OCS)<br>(when n=9, scanning rate is 256/9=28.4kHz) |

**Table 8 A4h Pull Down/Up Voltage Selection Register**

| Bit | D7 | D6:D4 | D3 | D2:D0 |
|---|---|---|---|---|
| Name | PHC | CSPUL | DGEN | SWPDL |
| Default | 1 | 010 | 0 | 010 |

The Pull Down/Up Voltage Selection Register sets phase choice and deghost options of IS31FL3719.

When PHC is "1", IS31FL3719 enables 180-degree phase delay function.

When DGEN is "1", IS31FL3719 enables deghost function. The CSPUL sets the CSy pull up voltage level and SWPDL sets the SWx pull down voltage level.

| PHC | Phase choice |
|---|---|
| 0 | 0 degree phase delay |
| 1 | 180 degree phase delay |

| DGEN | De-ghost Enable Control |
|---|---|
| 0 | Disable |
| 1 | Enable |

| SWPDL | SWx Pull Down Level Section Bit |
|---|---|
| 000 | No pull |
| 001 | 2.8V |
| 010 | 2.4V |
| 011 | 2.0V |
| 100 | 1.6V |
| 101 | 1.2V |
| 110 | 0.8V |
| 111 | GND |

| CSPUL | CSy Pull up Level Selection Bit |
|---|---|
| 000 | No pull |
| 001 | $V_{CC}$-2.8V |
| 010 | $V_{CC}$-2.4V |
| 011 | $V_{CC}$-2.0V |
| 100 | $V_{CC}$-1.6V |
| 101 | $V_{CC}$-1.2V |
| 110 | $V_{CC}$-0.8V |
| 111 | $V_{CC}$ |

If CSPUL sets to “111” (pull to VCC) and SWPDL sets to “111” (pull to GND), there will be large reverse voltage like -5V on LED and may break down the LED.

**Table 9 B0h Open Short Enable Register**

| Bit | D7 | D6:D5 | D4 | D3:D0 |
|---|---|---|---|---|
| Name | - | OSDE | CSC | SWC |
| Default | 0 | 00 | 0 | 0000 |

When OSDE set to “01”, open detection will be trigger once, the user could trigger open detection again by set OSDE from “00” to “01”.

When OSDE set “10”, short detection will be trigger once, the user could trigger short detection again by set OSDE from “00” to “10”.

Set the SWC bits to choose one SWx in the LED matrix, and set the CSC bit to choose “CS16: CS14, CS7:CS3” or “CS13: CS8, CS2:CS1” on this SWx, the 8 LEDs open/short detect result will be stored in the Open/Short Register (B1h).

| OSDE | Open or Short Detect Enable |
|---|---|
| 00 | Disable |
| 01/11 | Enable open detect |
| 10 | Enable short detect |

| CSC | CSy Choose |
|---|---|
| 0 | CS16: CS14, CS7:CS3 |
| 1 | CS13: CS8, CS2:CS1 |

| SWC | Choose the SWx |
|---|---|
| 0001 | SW1 line |
| 0010 | SW2 line |
| 0011 | SW3 line |
| 0100 | SW4 line |
| 0101 | SW5 line |
| 0110 | SW6 line |
| 0111 | SW7 line |
| 1000 | SW8 line |
| 1001 | SW9 line |

**Table 10 B1h Open/Short Register (Read Only)**

| Bit | D7:D0 |
|---|---|
| Name | CS16: CS14, CS7:CS3<br>CS13: CS8, CS2:CS1 |
| Default | 0000 0000 |

When OSDE (B0) is set to “01”, open detection will be trigger once, and the open information will be stored at B1h.

When OSDE (B0) is set to “10”, short detection will be trigger once, and the open information will be stored at B1h.

Before set OSDE, the GCC recommend to set to 0x0F

### EFh Reset Register

Once the Reset Register is updated with 0xAE, all the IS31FL3719 registers will be reset to their default values. Upon initial power-up, the IS31FL3719 registers will also reset to their default values for a blank display.

## APPLICATION INFORMATION

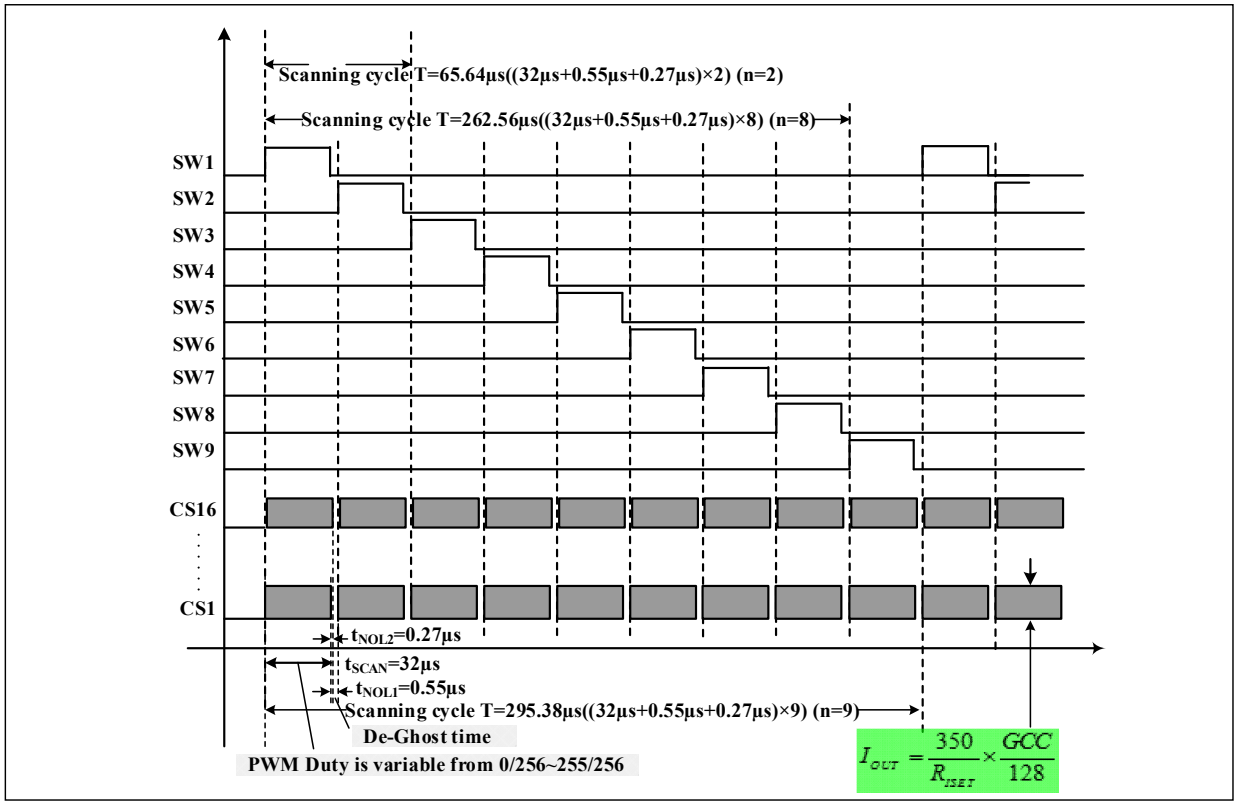



**Figure 10** Scanning Timing (8-bit Mode, 32kHz)

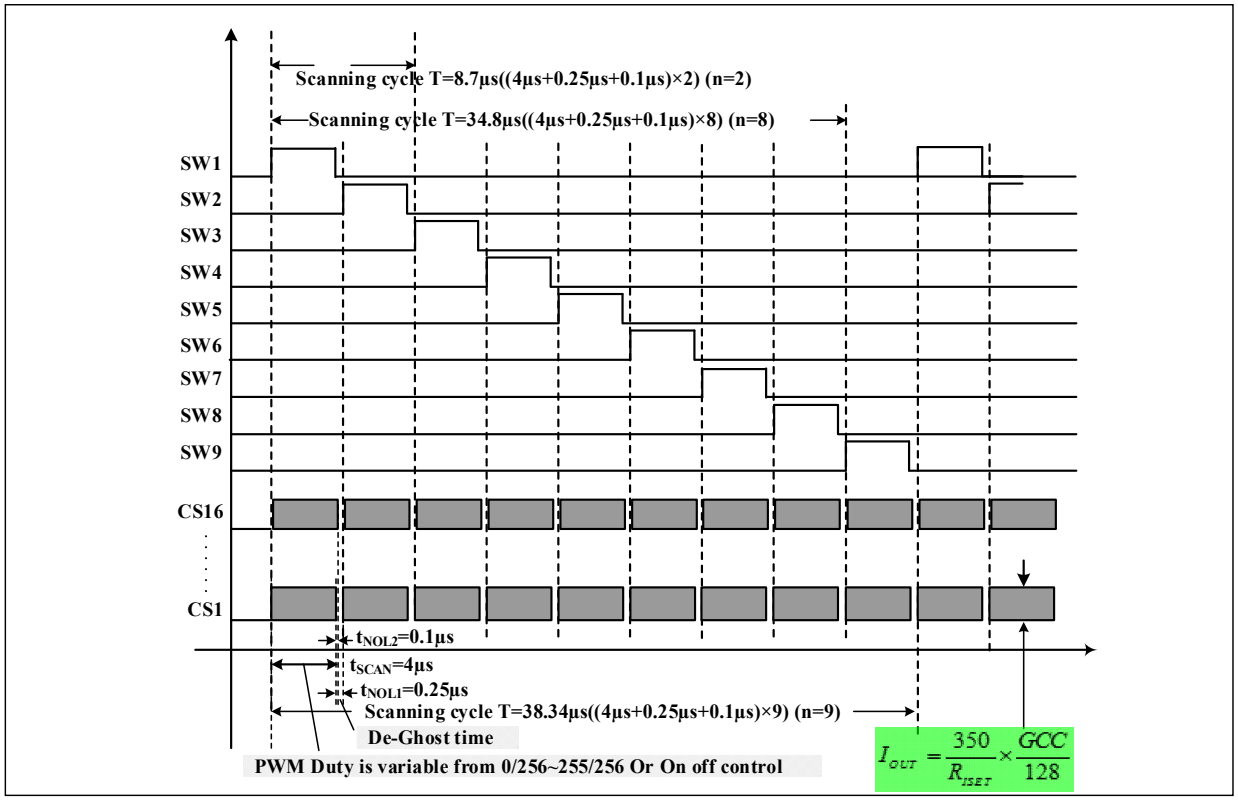



**Figure 11** Scanning Timing (6+2-bit Mode, 256kHz)

## SCANNING TIMING

As shown in Figure above, the SW1~SW9 is turned on by serial, LED is driven 15 by 9 within the SWx (x=1~9) on time (SWx, x=1~9 is source and it is high when LED on), including the non-overlap blanking time during scan, the duty cycle of SWx (active high, x=1~9) is (n=9):

8bit PWM mode:

$$Duty = \frac{32\mu s}{(32\mu s + 0.55\mu s + 0.27\mu s)} \times \frac{1}{9} = \frac{1}{9.23} \quad (2)$$

6+2bit PWM mode:

$$Duty = \frac{4\mu s}{(4\mu s + 0.25\mu s + 0.1\mu s)} \times \frac{1}{9} = \frac{1}{9.7875} \quad (2)$$

Or (n=8):

8bit PWM mode:

$$Duty = \frac{32\mu s}{(32\mu s + 0.55s + 0.27\mu s)} \times \frac{1}{8} = \frac{1}{8.205} \quad (2)$$

6+2bit PWM mode:

$$Duty = \frac{4\mu s}{(4\mu s + 0.25\mu s + 0.1\mu s)} \times \frac{1}{8} = \frac{1}{8.7} \quad (2)$$

Where PMS bit in A0h is "0" (8-bit mode) and PWM Frequency Register A2h= "0x01" (PWM frequency= 32kHz) for $t_{SCAN}$= 32μs, the period of scanning and 0.55μs is $t_{NOL1}$, the non-overlap time and 0.27μs is the CSy delay time. Where PMS bit in A0h is "1" (6+2-bit mode) and PWM Frequency Register A2h= "0x05" (PWM frequency= 256kHz) for $t_{SCAN}$= 4μs, the period of scanning and 0.25μs is $t_{NOL1}$, the non-overlap time and 0.1μs is the CSy delay time.

## POWER ON SEQUENCE

The IS31FL3719 integrates a power-on reset (POR) feature associated with the input supply voltage VCC. The IS31FL3719 will be initialized when VCC exceeds 2.4V (Typ., 2.7V max.) until then all the control circuits and configuration registers will be held in reset while the internal voltage stabilizes (≥2.4V).

The IS31FL3719 enters a hardware shutdown mode when the SDB pin is pulled low. During hardware shutdown the state Function Registers can be accessed but all analog circuits are disabled to conserve power. Once VCC stabilizes > 2.4V, a rising edge of the SDB signal will reset the I2C bus and cause the chip to exit hardware shutdown mode. Since there could be I2C bus transactions prior to the rising edge of the SDB pin, it is recommended to allow 10us prior to and after the rising edge before beginning any I2C bus transaction.

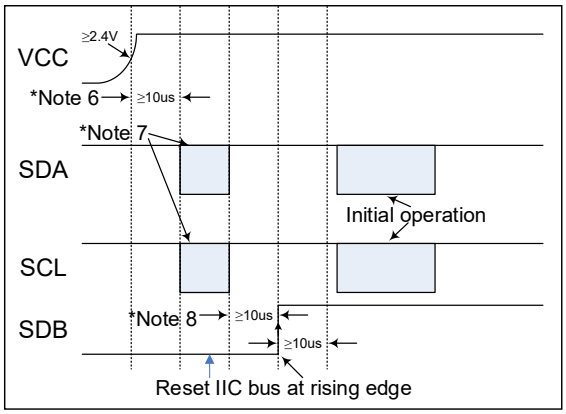



**Figure 12** SDB Pin Sequence

**Note 8:** There should be no I2C operation 10μs before VCC remain ≥2.4V.

**Note 9:** I2C operation is allowed while SDB is low and $V_{CC}$ ≥2.4V.

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

## PWM CONTROL

After setting the $I_{OUT}$ and GCC, the brightness of each LED (LED average current ($I_{LED}$)) can be modulated with 256 steps by PWM Register, as described in Formula (1).

$$I_{LED} = \frac{PWM}{256} \times I_{OUT\ (PEAK)} \times Duty \quad (1)$$

Where PWM is PWM Registers' (10h~56h) data showing in Table 3.

For example, in Figure 1, if $R_{ISET}$= 10kΩ, PWM= 1011 0101 (0xB5, 181), and GCC= 111 1111, 8bit PWM mode, then,

$$I_{OUT(PEAK)} = \frac{350}{R_{ISET}} \times \frac{GCC}{128}$$

$$I_{LED} = \frac{181}{256} \times \frac{350}{10\,k\Omega} \times \frac{127}{128} \times \frac{1}{9.23} \quad (n=9)$$

if D7:D0=1001 0100 (0x94, 148), GCC= 111 1111, 6+2bit PWM mode, $R_{ISET}$=10kΩ:

$$I_{LED} = \frac{148}{256} \times \frac{350}{10\,k\Omega} \times \frac{127}{128} \times \frac{1}{8.7} \quad (n=8)$$

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

## GAMMA CORRECTION

In order to perform a better visual LED breathing effect, we recommend using a gamma corrected PWM value to set the LED intensity. This results in a reduced number of steps for the LED intensity setting, but 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 IS31FL3719 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.

**Table 11 32 Gamma Steps with 256 PWM Steps**

| C(0) | C(1) | C(2) | C(3) | C(4) | C(5) | C(6) | C(7) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 4 | 6 | 10 | 13 | 18 |
| C(8) | C(9) | C(10) | C(11) | C(12) | C(13) | C(14) | C(15) |
| 22 | 28 | 33 | 39 | 46 | 53 | 61 | 69 |
| C(16) | C(17) | C(18) | C(19) | C(20) | C(21) | C(22) | C(23) |
| 78 | 86 | 96 | 106 | 116 | 126 | 138 | 149 |
| C(24) | C(25) | C(26) | C(27) | C(28) | C(29) | C(30) | C(31) |
| 161 | 173 | 186 | 199 | 212 | 226 | 240 | 255 |

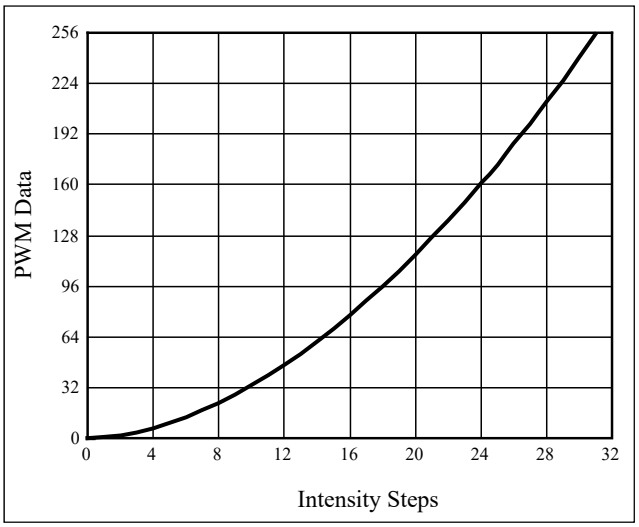



**Figure 13** Gamma Correction (32 Steps)

Choosing more gamma steps provides for a more continuous looking breathing effect. This is useful for very long breathing cycles. The recommended configuration is defined by the breath cycle T. When T=1s, choose 32 gamma steps, when T=2s, choose 64 gamma steps. The user must decide the final number of gamma steps not only by the LED itself, but also based on the visual performance of the finished product.

**Table 12 64 Gamma Steps with 256 PWM Steps**

| C(0) | C(1) | C(2) | C(3) | C(4) | C(5) | C(6) | C(7) |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| C(8) | C(9) | C(10) | C(11) | C(12) | C(13) | C(14) | C(15) |
| 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| C(16) | C(17) | C(18) | C(19) | C(20) | C(21) | C(22) | C(23) |
| 24 | 26 | 29 | 32 | 35 | 38 | 41 | 44 |
| C(24) | C(25) | C(26) | C(27) | C(28) | C(29) | C(30) | C(31) |
| 47 | 50 | 53 | 57 | 61 | 65 | 69 | 73 |
| C(32) | C(33) | C(34) | C(35) | C(36) | C(37) | C(38) | C(39) |
| 77 | 81 | 85 | 89 | 94 | 99 | 104 | 109 |
| C(40) | C(41) | C(42) | C(43) | C(44) | C(45) | C(46) | C(47) |
| 114 | 119 | 124 | 129 | 134 | 140 | 146 | 152 |
| C(48) | C(49) | C(50) | C(51) | C(52) | C(53) | C(54) | C(55) |
| 158 | 164 | 170 | 176 | 182 | 188 | 195 | 202 |
| C(56) | C(57) | C(58) | C(59) | C(60) | C(61) | C(62) | C(63) |
| 209 | 216 | 223 | 230 | 237 | 244 | 251 | 255 |

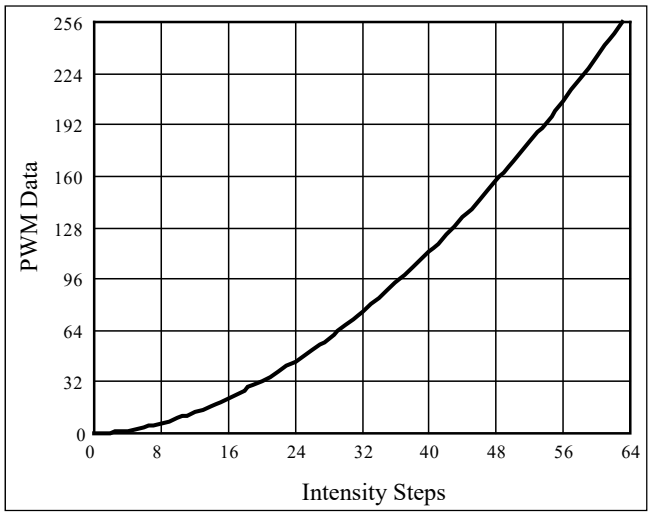



**Figure 14** Gamma Correction (64 Steps)

**Note:** The data of 32 gamma steps is the standard value and the data of 64 gamma steps is the recommended value.

## OPERATING MODE

IS31FL3719 can only operate in PWM Mode. The brightness of each LED can be modulated with 256 steps by PWM registers. For example, if the data in PWM Register is “0000 0100”, then the PWM is the fourth step.

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

## OPEN/SHORT DETECT FUNCTION

IS31FL3719 has individual LED open and short detection capability.

By setting the CSC bits and SWC bits of the Open Short Enable Register, 8 LEDs in the matrix can be selected for the open and short detection. By setting the OSDE bits of the Open Short Enable Register (B0h) from “00” to “01” or “10”, the LED Open/short Register will begin storing the open/short information. After 2 scan cycles, the MCU can read the open/short information stored in registers B1h. The open/short data will not get refreshed while setting the OSDE bit of the Open Short Enable Register.

There are two configurations which need to be set prior to configuring the OSDE bits:

1) 0x0F≤A1h≤0x7F adjust LED current
2) A4h=0x00, disable pullup/pulldown resistors

Where A1h is Global Current Control Register and A4h is the Pull Down/Up Resistor Selection Register.

The detect action is one-time event, so each time before reading out the open/short information, the OSDE bit of the Open Short Enable Register (B0h) needs to be set from “0” to “1” (clear before set operation).

## DE-GHOST FUNCTION

The “ghost” term is used to describe the behavior of an LED that should be OFF but instead glows dimly when another LED is turned ON. A ghosting effect typically can occur when multiplexing LEDs. In matrix architecture any parasitic capacitance found in the constant-current outputs or the PCB traces to the LEDs may provide sufficient current to dimly light an LED to create a ghosting effect.

To prevent this LED ghost effect, the IS31FL3719 has integrated Pull down resistors for each SWx (x=1~9) and Pull up resistors for each CSy (y=1~16). Select the Pull Down/Up Resistor Selection Register (A4h) which eliminates the ghost LED for a particular matrix layout configuration.

Typically, selecting the 2.4V will be sufficient to eliminate the LED ghost phenomenon.

The SWx Pull down resistors and CSy Pull up resistors are active only when the CSy/SWx output working the OFF state and therefore no power is lost through these resistors.

## SHUTDOWN MODE

Shutdown mode can be used as a means of reducing power consumption. During shutdown mode all registers retain their data.

### Software Shutdown

By setting SSD bit of the Configuration Register (A0h) to “0”, the IS31FL3719 will operate in software shutdown mode. When the IS31FL3719 is in software shutdown, all current sources are switched off, so that the matrix is blanked. All registers can be operated. Typical current consumption is 0.7μA.

### Hardware Shutdown

The chip enters hardware shutdown when the SDB pin is pulled low. When the IS31FL3719 is in hardware shutdown, all current sources are switched off, so that the matrix is blanked. All registers can be operated. Typical current consumption is 0.7μA.

The chip releases hardware shutdown when the SDB pin is pulled high.

If $V_{CC}$ has a risk of dropping below 1.75V but remain above 0.1V while the SDB pin is pulled low, please re-initialize all Function Registers before SDB is pulled high.

## LAYOUT

As described previously, depending on the current set resistor ($R_{ISET}$) value and current register settings, the chip can consume lots of power. Please consider the below factors during the PCB layout phase.

1. The $V_{CC}$ capacitors need to be close to the VCC pin 23 with their ground pins well connected to the GND of the chip.

2. $R_{ISET}$ should be close to the chip and the ground side should well connect to the GND of the chip.

3. The thermal pad should connect to ground pins and the PCB should have the thermal pad too, usually this pad should have 9 or 16 vias thru the PCB to the other side’s ground area to help radiate the heat. About the thermal pad size, please refer to the land pattern of each package.

4. The CSy pins will have a maximum current of 34.6mA ($R_{ISET}$=10kΩ). However, the SWx pins maximum current is larger since it is the combined current of the CSy pins. Therefore, the width of the SWx trace needs to be much wider than the CSy trace.

## CLASSIFICATION REFLOW PROFILES

| Profile Feature | Pb-Free Assembly |
|---|---|
| **Preheat & Soak**<br>Temperature min (Tsmin)<br>Temperature max (Tsmax)<br>Time (Tsmin to Tsmax) (ts) | 150°C<br>200°C<br>60-120 seconds |
| Average ramp-up rate (Tsmax to Tp) | 3°C/second max. |
| Liquidous temperature (TL)<br>Time at liquidous (tL) | 217°C<br>60-150 seconds |
| Peak package body temperature (Tp)* | Max 260°C |
| Time (tp)** within 5°C of the specified classification temperature (Tc) | Max 30 seconds |
| Average ramp-down rate (Tp to Tsmax) | 6°C/second max. |
| Time 25°C to peak temperature | 8 minutes max. |

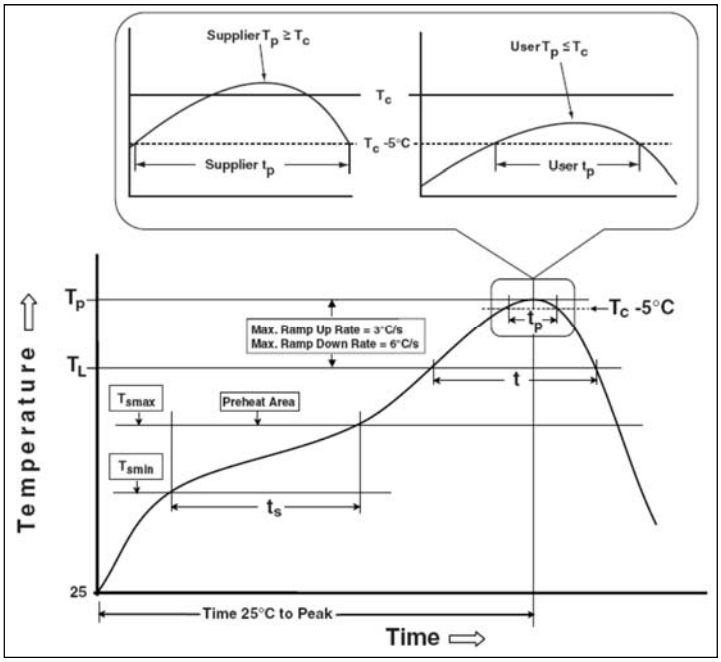
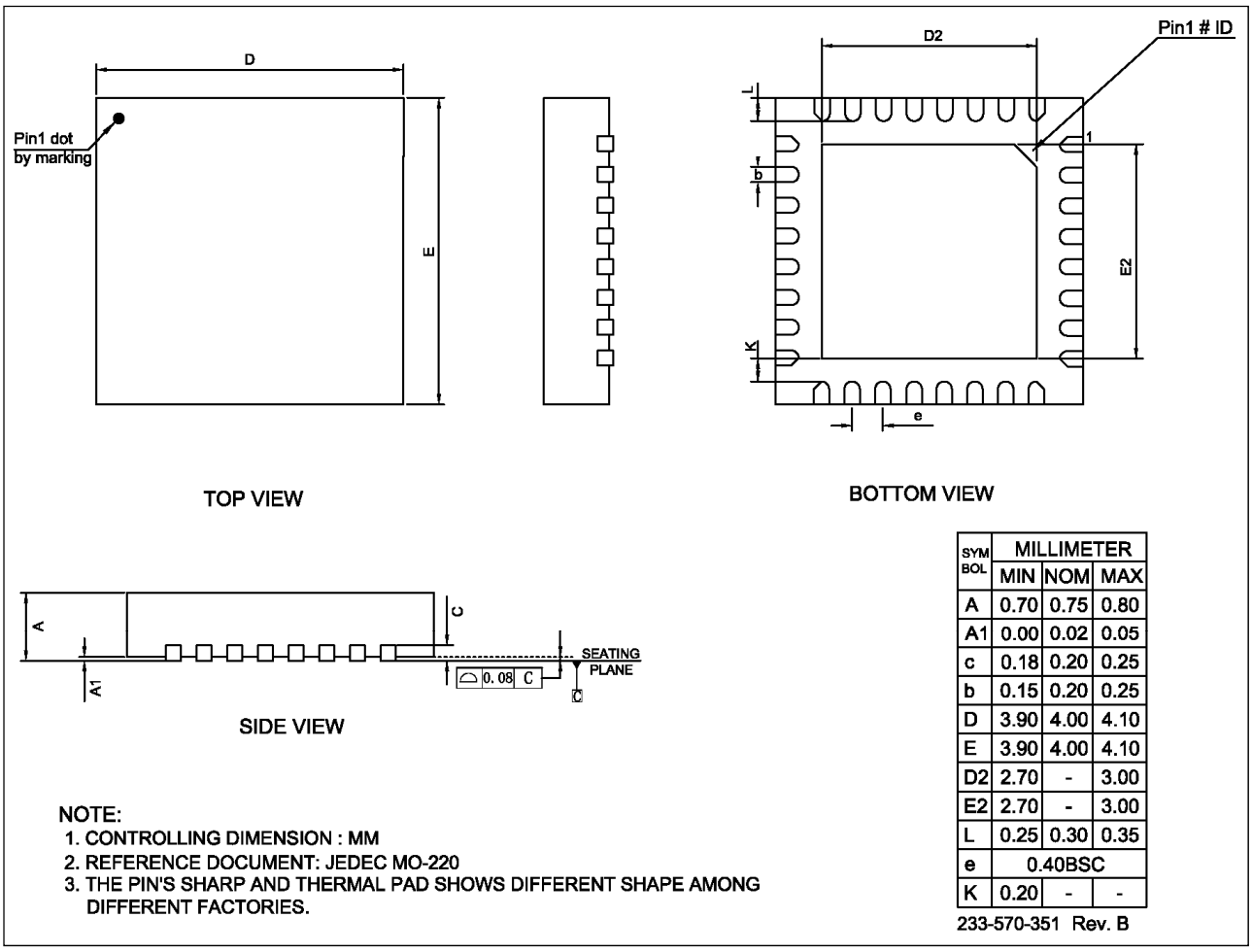



**Figure 15** Classification Profile

## PACKAGE INFORMATION

### QFN-32

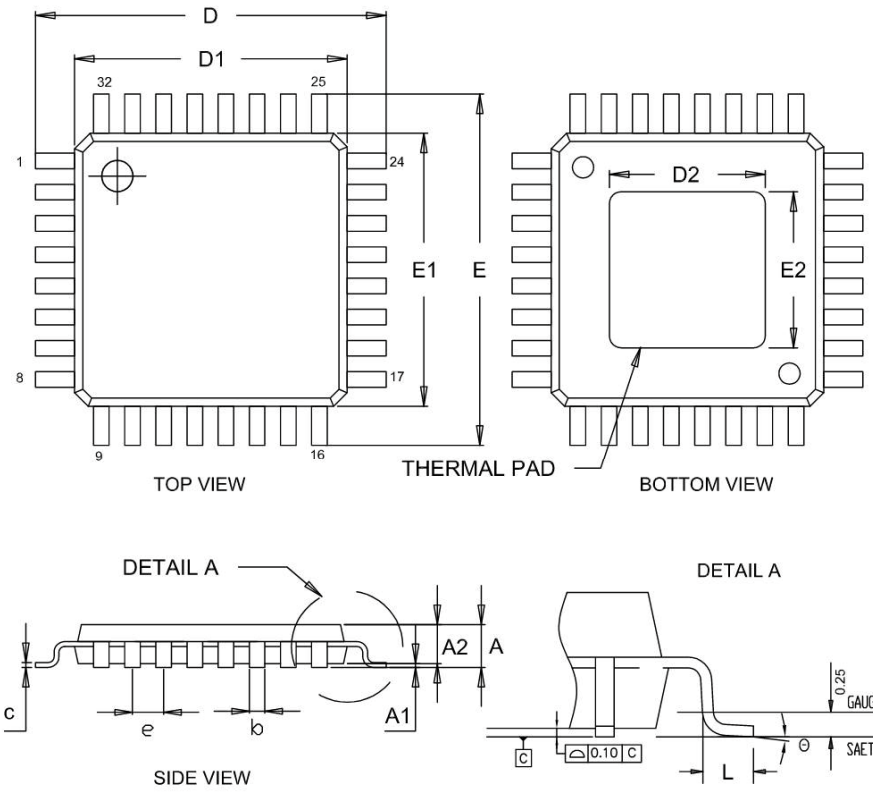



| SYMBOL | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | 0.70 | 0.75 | 0.80 |
| A1 | 0.00 | 0.02 | 0.05 |
| c | 0.18 | 0.20 | 0.25 |
| b | 0.15 | 0.20 | 0.25 |
| D | 3.90 | 4.00 | 4.10 |
| E | 3.90 | 4.00 | 4.10 |
| D2 | 2.70 | - | 3.00 |
| E2 | 2.70 | - | 3.00 |
| L | 0.25 | 0.30 | 0.35 |
| e | 0.40BSC | | |
| K | 0.20 | - | - |

NOTE:
1. CONTROLLING DIMENSION : MM
2. REFERENCE DOCUMENT: JEDEC MO-220
3. THE PIN'S SHARP AND THERMAL PAD SHOWS DIFFERENT SHAPE AMONG DIFFERENT FACTORIES.

233-570-351 Rev. B

**eTQFP-32**



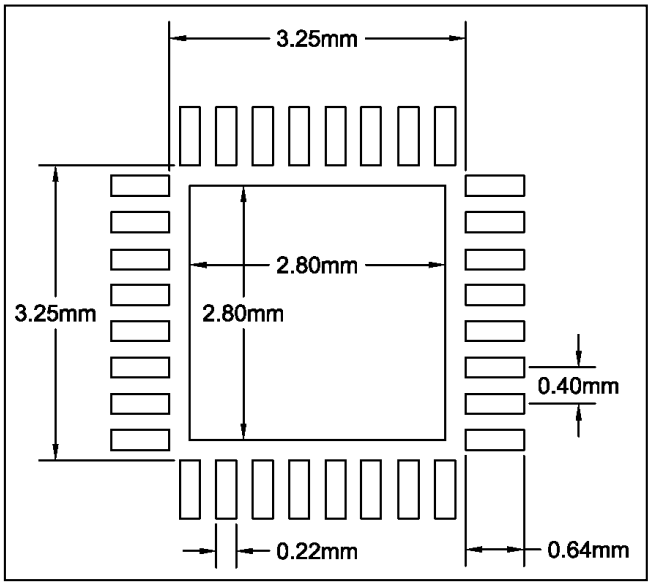

| SYMBOL | MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | — | — | 1.20 |
| A1 | 0.05 | — | 0.15 |
| A2 | 0.95 | 1.00 | 1.05 |
| D | | 9.00 BSC | |
| D1 | | 7.00 BSC | |
| D2 | 3.19 | — | 3.90 |
| E | | 9.00 BSC | |
| E1 | | 7.00 BSC | |
| E2 | 3.19 | — | 3.90 |
| L | 0.45 | — | 0.75 |
| b | 0.30 | — | 0.45 |
| e | | 0.80 BSC | |
| c | 0.09 | — | 0.20 |
| θ | 0° | 3.5° | 7° |

233-570-362 Rev. A

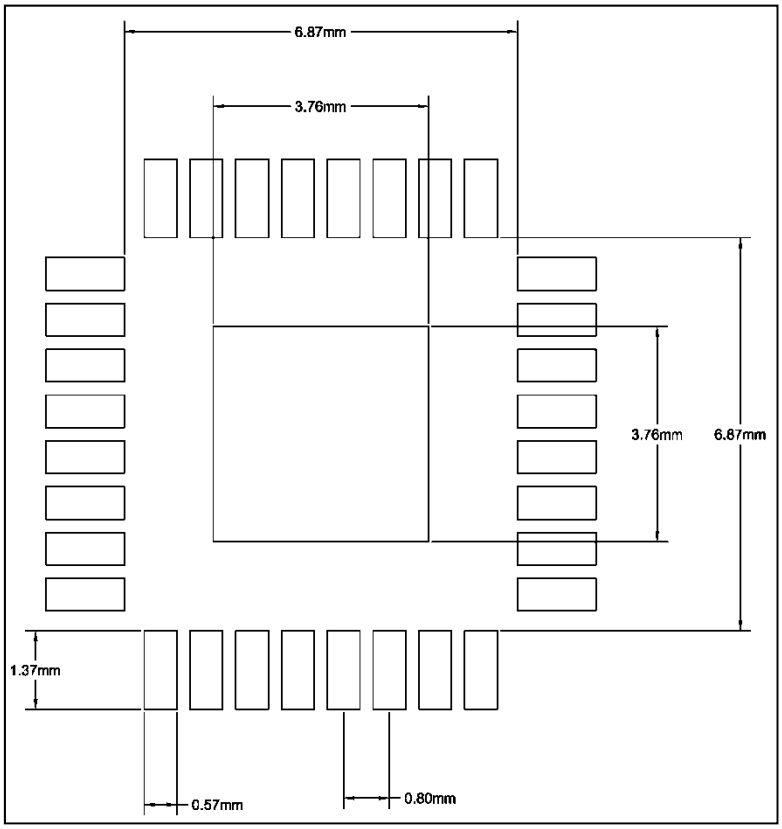
NOTE:
1. CONTROLLING DIMENSION : MM
2. REFERENCE DOCUMENT: JEDEC MS-026

## RECOMMENDED LAND PATTERN

### QFN-32




### eTQFP-32




**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 | 2022.02.22 |
| A | Release to mass product | 2022.03.18 |
| B | Update the EC table | 2022.05.09 |