

# IS31FL3216A

## 16 CHANNELS LED DRIVER

July 2017

### GENERAL DESCRIPTION

The IS31FL3216A is a fun light LED controller with an audio modulation mode. It can store data of 8 frames with internal RAM to play small animations automatically.

IS31FL3216A can sample the input signal to modulate the intensity of LEDs, or control 8 frames playing by internal ADC block.

The LED current of each channel can be set in 256 steps by adjusting the PWM duty cycle through an I2C interface. 8 channels can be used as GPIO ports.

IS31FL3216A is available in QFN-28 (4mm × 4mm). It operates from 2.7V to 5.5V over the temperature range of -40°C to +105°C.

### APPLICATIONS

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

### FEATURES

- 2.7V to 5.5V supply
- I2C interface, automatic address increment function
- Internal RAM
- Modulate LED brightness with 256 steps PWM
- PWM frequency up to 26kHz
- Each channel can be controlled independently
- Auto Frame Play Mode with 8 frames
- 8 frames memory for animations
- Audio Frame Mode with 8 frames
- 8 of 16 outputs not used as LED drivers can be used as GPIO ports
- 8 levels of maximum intensity control
- 8kV HBM ESD
- Over-temperature protection
- -40°C to +105°C temperature range
- QFN-28 (4mm × 4mm) package

### TYPICAL APPLICATION CIRCUIT

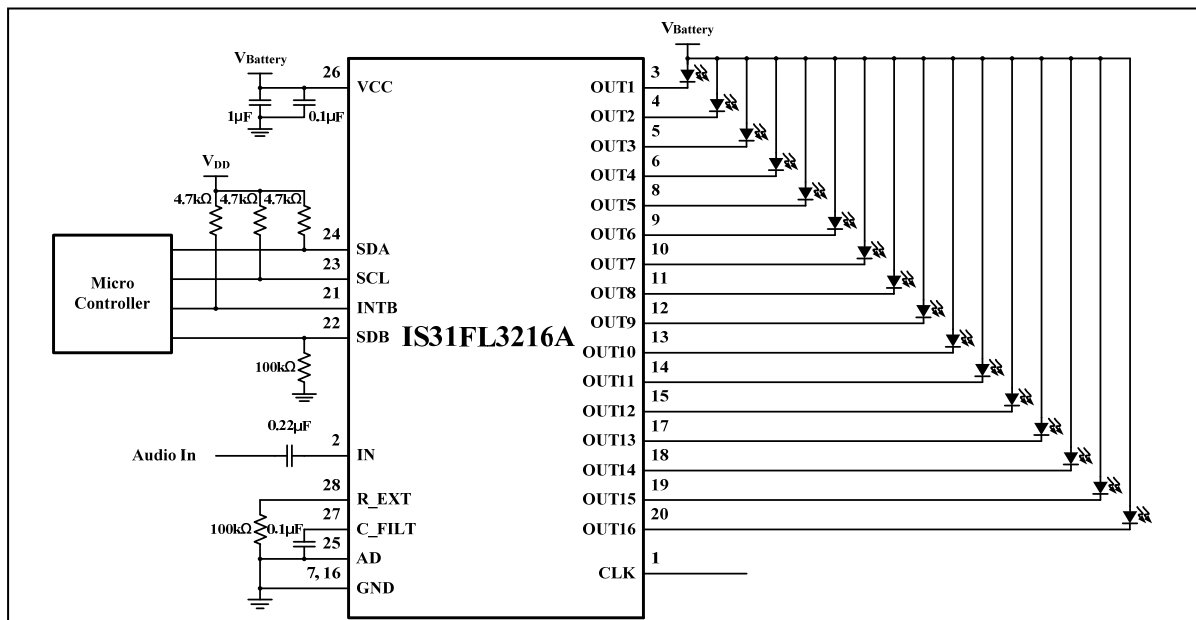


Figure 1 Typical Application Circuit

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

# IS31FL3216A

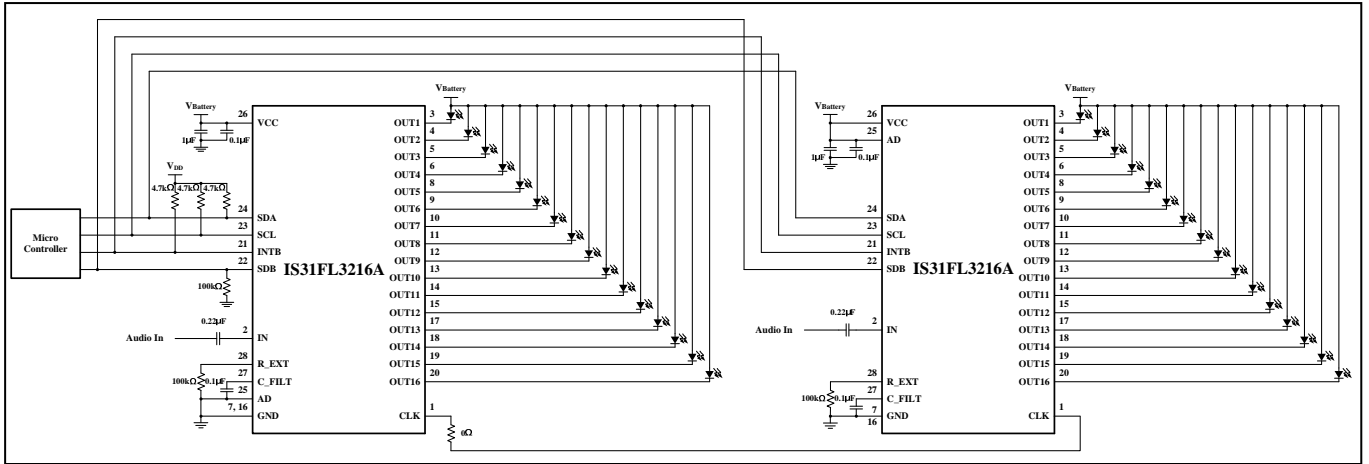
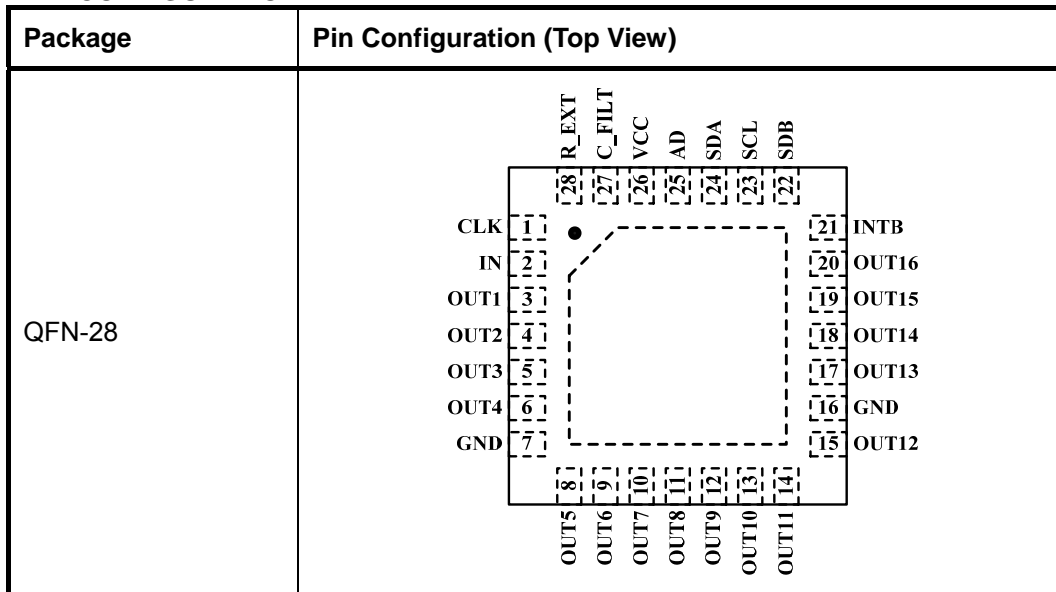


Figure 2 Typical Application Circuit (Cascade Mode)

# IS31FL3216A

## PIN CONFIGURATION



## PIN DESCRIPTION

| No.     | Pin           | Description  |
|---------|---------------|--|
| 1       | CLK           | Clock for chip cascade.                              |
| 2       | IN            | Audio signal input.                                  |
| 3 ~ 6   | OUT1 ~ OUT4   | Output channel.                                      |
| 7,16    | GND           | Ground.  |
| 8 ~ 11  | OUT5 ~ OUT8   | Output channel.                                      |
| 12 ~ 15 | OUT9 ~ OUT12  | Output channel. Also can be configured as GPIO port. |
| 17 ~ 20 | OUT13 ~ OUT16 | Output channel. Also can be configured as GPIO port. |
| 21      | INTB          | Interrupt output, active low.                        |
| 22      | SDB           | Shutdown, pull to GND in the shutdown mode.          |
| 23      | SCL           | Serial clock input.                                  |
| 24      | SDA           | Serial data input.                                   |
| 25      | AD            | I2C address pin.                                     |
| 26      | VCC           | Power supply.  |
| 27      | C_FILT        | Filter capacitor for audio control.                  |
| 28      | R_EXT         | External resistor to regulate the output current.    |
|         | Thermal Pad   | Connect to GND.                                      |

# IS31FL3216A

## ORDERING INFORMATION

Industrial Range: -40°C to +105°C

| Order Part No.       | Package           | QTY/Reel |
|----------------------|-------------------|----------|
| IS31FL3216A-QFLS3-TR | QFN-28, Lead-free | 2500     |

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# IS31FL3216A

## ABSOLUTE MAXIMUM RATINGS

|  |                       |
|--|-----------------------|
| Supply voltage, $V_{CC}$                 | -0.3V ~ +6.0V         |
| Voltage at any input pin                 | -0.3V ~ $V_{CC}+0.3V$ |
| Current in GND terminal                  | 1A                    |
| 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 ~ +105°C        |
| Thermal resistance, $\theta_{JA}$        | 51.4°C /W             |
| ESD (HBM)                                | ±8kV                  |
| 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

$T_A = 25^\circ\text{C}$ ,  $V_{CC} = 2.7V \sim 5.5V$ , unless otherwise noted. Typical values are  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 3.6V$ .

| Symbol    | Parameter  | Condition   | Min. | Typ.           | Max. | Unit |
|-----------|--|---|------|----------------|------|------|
| $V_{CC}$  | Supply voltage   |   | 2.7  |                | 5.5  | V    |
| $I_{CC}$  | Quiescent power supply current                                   | $V_{SDB} = V_{CC}$  |      | 5.2            |      | mA   |
| $I_{SD}$  | Shutdown current   | $V_{SDB} = 0V$ or software shutdown   |      | 1              |      | μA   |
| $I_{OUT}$ | Average output current   | PWM Control Mode, $V_{DS}=0.6V$<br>PWM duty cycle=0xFF, 03h=0x70                            |      | 21<br>(Note 1) |      | mA   |
|           |  | Audio Frame Mode, $V_{DS}=0.6V$<br>$V_{IN} = 3V_{p-p}$ , 1kHz square wave<br>Audio gain=0dB |      | 18<br>(Note 1) |      |      |
| $V_{HR}$  | Current sink headroom voltage<br>(when use as GPIO output ports) | $I_{OUT} = 20mA$  |      | 400            |      | mV   |
| $f_{PWM}$ | PWM frequency of output  |   |      | 26             |      | kHz  |

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

|          |                         |                              |     |   |     |    |
|----------|-------------------------|------------------------------|-----|---|-----|----|
| $V_{IL}$ | 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 | $V_{IN} = 0V$ (Note 2,3)     |     | 5 |     | nA |
| $I_{IH}$ | Logic “1” input current | $V_{IN} = V_{CC}$ (Note 2,3) |     | 5 |     | nA |

# IS31FL3216A

## 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:** The average output current of each channel is  $I_{OUT}$ .

**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  $0.7 \times V_{CC}$ .

# IS31FL3216A

## DETAILED DESCRIPTION

### I2C INTERFACE

The IS31FL3216A uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31FL3216A 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.

The complete slave address is:

**Table 1 Slave Address**

| Bit   | A7:A3 | A2:A1 | A0  |
|-------|-------|-------|-----|
| Value | 11101 | AD    | 1/0 |

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 IS31FL3216A.

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 IS31FL3216A's acknowledge. The master releases the SDA line high (through a pull-up

resistor). Then the master sends an SCL pulse. If the IS31FL3216A 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 IS31FL3216A, the register address byte is sent, most significant bit first. IS31FL3216A 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 IS31FL3216A must generate another acknowledge to indicate that the data was received.

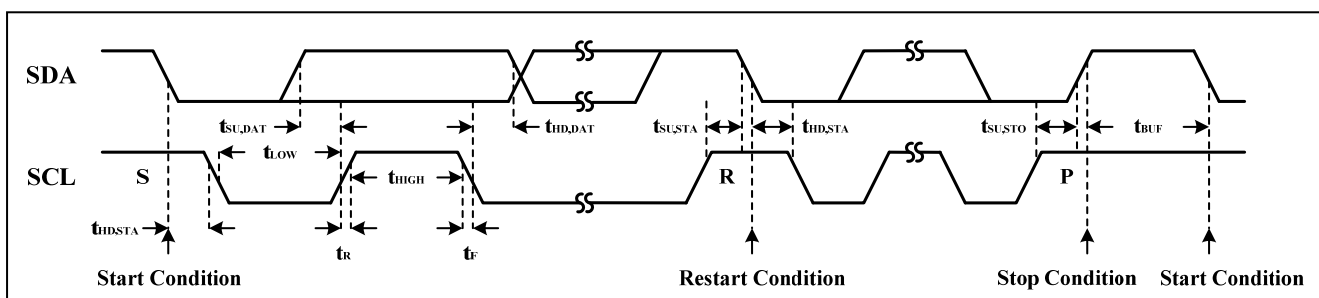
The "STOP" signal ends the transfer. To signal "STOP", the SDA signal goes high while the SCL signal is high.

### ADDRESS AUTO INCREMENT

To write multiple bytes of data into IS31FL3216A, load the address of the data register that the first data byte is intended for. During the IS31FL3216A acknowledge of receiving the data byte, the internal address pointer will increment by one. The next data byte sent to IS31FL3216A 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 IS31FL3216A (Figure 6).

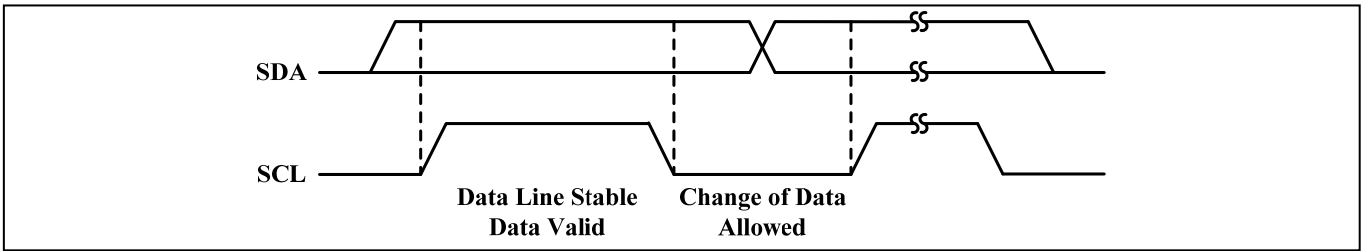
### READING PORT REGISTERS

To read the device data, the bus master must first send the IS31FL3216A address with the R/W bit set to "0", followed by the command byte, which determines which register is accessed. After a restart, the bus master must then send the IS31FL3216A address with the R/W bit set to "1". Data from the register defined by the command byte is then sent from the IS31FL3216A to the master (Figure 7).

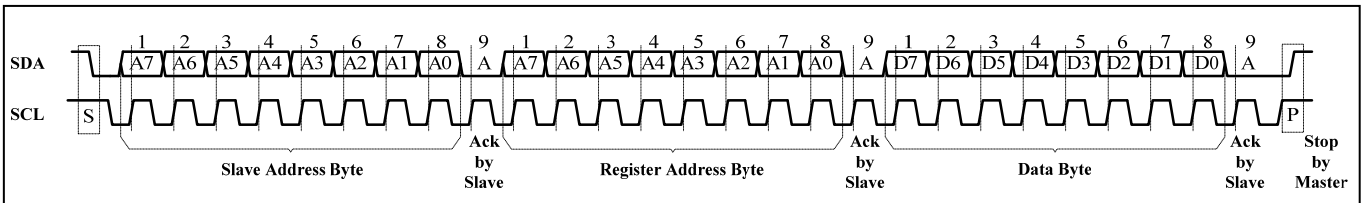


**Figure 3** Interface timing

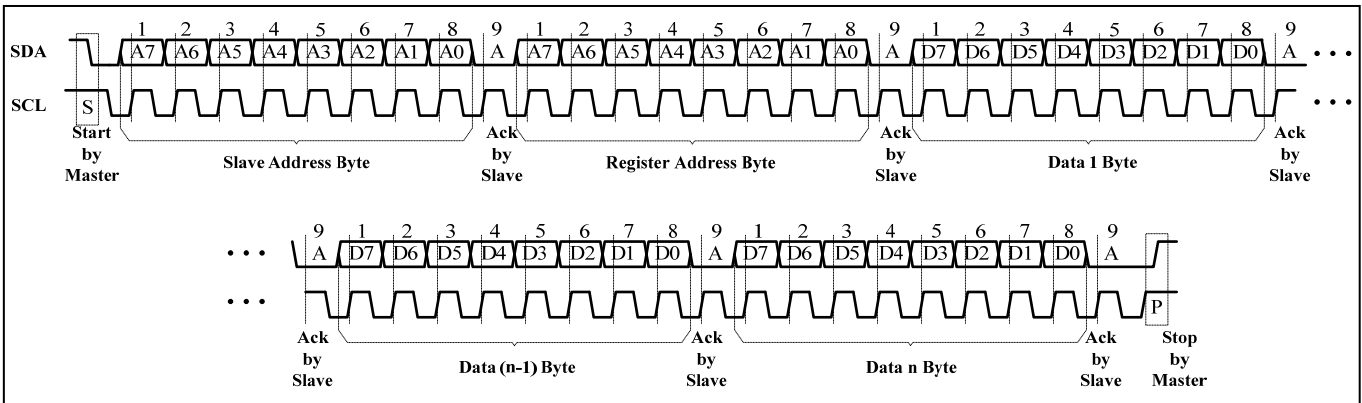
# IS31FL3216A



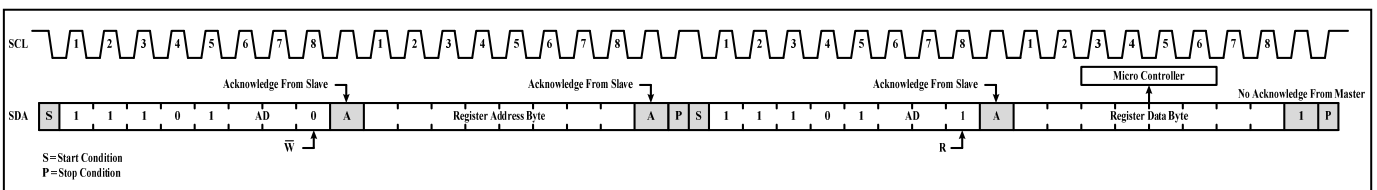
**Figure 4** Bit transfer



**Figure 5** Writing to IS31FL3216A (Typical)



**Figure 6** Writing to IS31FL3216A (Automatic Address Increment)



**Figure 7** Reading from IS31FL3216A



# IS31FL3216A

## REGISTER DEFINITION

**Table 2 Register Function**

| Address | Name                           | Function  | Table | R/W | Default   |
|---------|--------------------------------|---|-------|-----|-----------|
| 00h     | Configuration Register         | Set the operating mode of IS31FL3216A                 | 3     | W   | 1000 0000 |
| 01h     | LED Control Register           | OUT9~OUT16 enable bit                                 | 4     | W   | 1111 1111 |
| 02h     |                                | OUT1~OUT8 enable bit                                  | 5     | W   |           |
| 03h     | Lighting Effect Register       | Set the output current and the audio gain             | 6     | W   | 0000 0000 |
| 04h     | Channel Configuration Register | Set the operating mode of OUT9~OUT16                  | 7     | W   |           |
| 05h     | GPIO Configuration Register    | Set the operating mode of OUT9~OUT16 as the GPIO port | 8     | W   |           |
| 06h     | Output Port Register           | Set the logic level of OUT9~OUT16 as the output port  | 9     | W   |           |
| 07h     | Interrupt Control Register     | Set the interrupt function of OUT9~OUT16              | 10    | W   |           |
| 08h     | State Register                 | Store the state of OUT9~OUT16 as the input port       | 11    | R   |           |
| 09h     | ADC Sample Rate Register       | Set the ADC sample rate of the input signal           | 12    | W   | 0000 0000 |
| 10h~1Fh | PWM Register                   | Set the PWM duty cycle data                           | 13    | W   | -         |
| 20h~AFh | Frame Register                 | Store the data of 8 frames                            | 14    | W   |           |
| B0h     | Update Register                | Load PWM Register data                                | -     | W   | xxxx xxxx |
| B6h     | Frame Delay Register           | Set the delay time between each frame                 | 15    | W   | 0000 0000 |
| B7h     | Frame Start Register           | Set the start frame in Auto Frame Play Mode           | 16    | W   |           |

**Table 3 00h Configuration Register**

| Bit     | D7  | D6:D5 | D4 | D3:D0 |
|---------|-----|-------|----|-------|
| Name    | SSD | MODE  | AE | -     |
| Default | 1   | 00    | 0  | 0000  |

The Configuration Register sets the operating mode of IS31FL3216A.

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

**MODE** Operation Mode Selection  
 00 PWM Control Mode  
 01 Auto Frame Play Mode  
 10 Audio Frame Mode  
 11 Not available

**AE** Audio Modulated Enable  
 0 Output current is set by register  
 1 Output current is modulated by audio signal

**Table 4 01h LED Control Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | 1111 1111  |

**Table 5 02h LED Control Register (OUT1~OUT8)**

| Bit     | D7:D0     |
|---------|-----------|
| Name    | OUT8:OUT1 |
| Default | 1111 1111 |

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

**OUTx** LED State  
 0 LED off  
 1 LED on

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**Table 6 03h Lighting Effect Register**

| Bit     | D7 | D6:D4 | D3   | D2:D0 |
|---------|----|-------|------|-------|
| Name    | CM | CS    | AGCE | AGS   |
| Default | 0  | 000   | 0    | 000   |

The Lighting Effect Register sets the output current and the audio gain.

**CM** Chip Cascade Mode  
 0 Master Mode  
 1 Slave Mode

**CS** Output Current Selection  
 000  $I_{LED} \times 1.0$   
 001  $I_{LED} \times 0.75$   
 010  $I_{LED} \times 0.5$   
 011  $I_{LED} \times 0.25$   
 100  $I_{LED} \times 2.0$   
 101  $I_{LED} \times 1.75$   
 110  $I_{LED} \times 1.5$   
 111  $I_{LED} \times 1.25$

The  $I_{LED}$  is set by the resistor  $R_{EXT}$ . Please refer to Page 14 for detail information.

**AGCE** AGC Enable  
 0 Enable  
 1 Disable

**AGS** Audio Gain Selection  
 000 0dB  
 001 3dB  
 010 6dB  
 011 9dB  
 100 12dB  
 101 15dB  
 110 18dB  
 111 21dB

**Table 7 04h Channel Configuration Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | 0000 0000  |

Configure the operating mode of OUT9~OUT16. If any port is set as GPIO, the Lighting Effect Register will be unavailable for the port.

**OUTx** Channel Configuration  
 0 LED output  
 1 GPIO port

**Table 8 05h GPIO Configuration Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | 0000 0000  |

Set the state of OUT9~OUT16 as the GPIO port.

**OUTx** GPIO Configuration  
 0 Output port  
 1 Input port

**Table 9 06h Output Configuration Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | 0000 0000  |

Set the logic level of OUT9~OUT16 as the output port.

**OUTx** Output State  
 0 Output low  
 1 Output high

**Table 10 07h Interrupt Control Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | 0000 0000  |

Set the interrupt function of OUT9~OUT16 as the input port.

**OUTx** Interrupt Function Enable  
 0 Enable  
 1 Disable

**Table 11 08h State Register (OUT9~OUT16)**

| Bit     | D7:D0      |
|---------|------------|
| Name    | OUT16:OUT9 |
| Default | xxxx xxxx  |

Store the input state of OUT9~OUT16 as the input port (Write only). The INTB pin will be pulled high until the MCU reads the data of State Register.

# IS31FL3216A

**Table 12 09h ADC Sample Rate Register**

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

The value of ADC Sample Rate Register decides the sample rate of ADC for Audio Frame Mode. The sample rate could be computed using the Formula (1):

$$SR = 100kHz / \sum_{n=0}^7 D[n] \cdot 2^n \quad (1)$$

Where “n” indicates the bit location in the respective ADC Sample Rate Register.

For example: D7:D0 = 10110100

$$SR = 100kHz / (2^2 + 2^4 + 2^5 + 2^7) = 556Hz$$

**Table 13 10h~1Fh PWM Register (OUT16~OUT1)**

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

The PWM Registers adjusts LED luminous intensity in 256 steps.

The value of a channel’s PWM Register decides the average output current for each output, OUT1~OUT16. The average output current may be computed using the Formula (2):

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

Where “n” indicates the bit location in the respective PWM Registers.

For example: D7:D0 = 10110101

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

$I_{MAX}$  is set by the CS bit of Lighting Effect Register (03h).

**Table 14 20h~AFh Frame Register Address List**

| Frame   | LED Control Register | PWM Register |
|---------|----------------------|--------------|
| Frame 1 | 20h ~ 21h            | 22h ~ 31h    |
| Frame 2 | 32h ~ 33h            | 34h ~ 43h    |
| Frame 3 | 44h ~ 45h            | 46h ~ 55h    |
| Frame 4 | 56h ~ 57h            | 58h ~ 67h    |
| Frame 5 | 68h ~ 69h            | 6Ah ~ 79h    |
| Frame 6 | 7Ah ~ 7Bh            | 7Ch ~ 8Bh    |
| Frame 7 | 8Ch ~ 8Dh            | 8Eh ~ 9Dh    |
| Frame 8 | 9Eh ~ 9Fh            | A0h ~ AFh    |

Frame Registers store the data of 8 frames. Each frame is controlled by two LED Control Registers and sixteen PWM Registers.

The detail about the LED Control Register is shown in Table 4, 5 and the PWM Register is shown in Table 13.

## B0h Update Register

The data sent to the PWM Register will be stored in temporary registers. A write operation of “0000 0000” to the Update Register is required to update the registers.

**Table 15 B6h Frame Delay Register**

| Bit     | D7:D5 | D4:D0 |
|---------|-------|-------|
| Name    | FDT   | -     |
| Default | 000   | 00000 |

Set the delay time between each frame in Auto Frame Play Mode.

| FDT | Frame Delay Time |
|-----|------------------|
| 000 | 4.87ms           |
| 001 | 9.5ms            |
| 010 | 19ms             |
| 011 | 38ms             |
| 100 | 76ms             |
| 101 | 152ms            |
| 110 | 304ms            |
| 111 | 608ms            |

**Table 16 B7h Frame Start Register**

| Bit     | D7:D5 | D4:D0 |
|---------|-------|-------|
| Name    | FS    | -     |
| Default | 000   | 00000 |

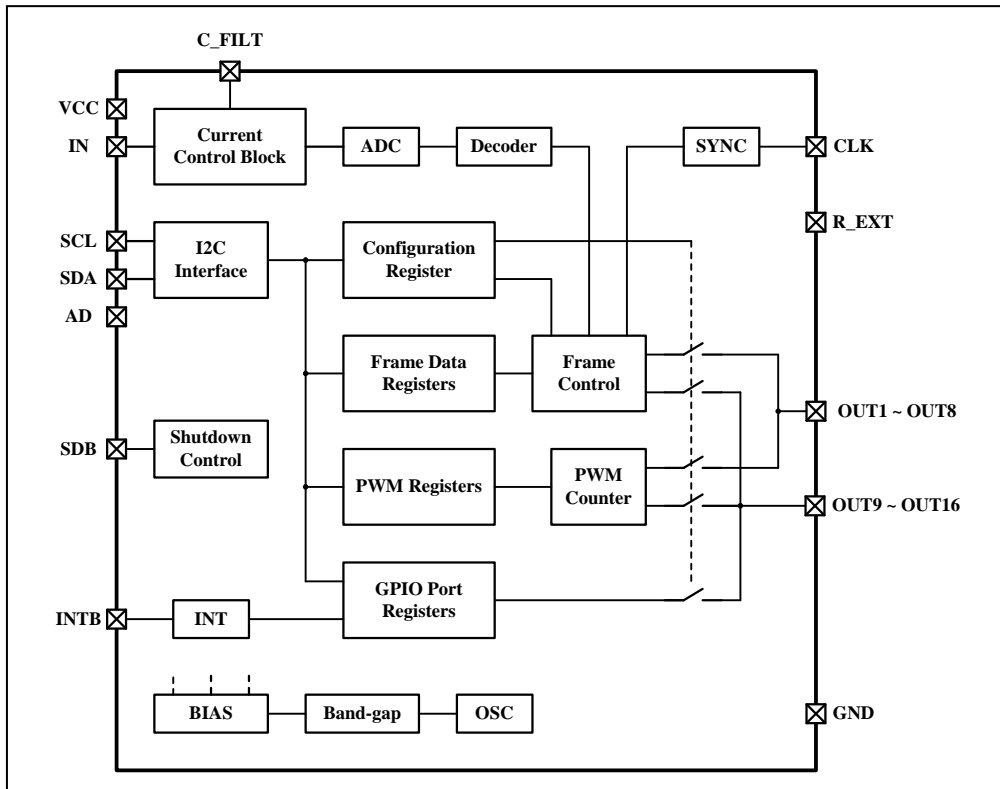
Set the start frame in Auto Frame Play Mode.

| FS  | Frame Start |
|-----|-------------|
| 000 | Frame 1     |
| 001 | Frame 2     |
| 010 | Frame 3     |
| 011 | Frame 4     |
| 100 | Frame 5     |
| 101 | Frame 6     |
| 110 | Frame 7     |
| 111 | Frame 8     |

For example, if FS bit sets to “011”, it plays from the fourth frame to the eighth frame then cycled back to the first frame.

# IS31FL3216A

## FUNCTIONAL BLOCK DIAGRAM



# IS31FL3216A

## APPLICATION INFORMATION

### PWM CONTROL

By setting the MODE bit of the Configuration Register (00h) to "00", IS31FL3216A operates in PWM Control Mode. The LED brightness of 16 channels 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.

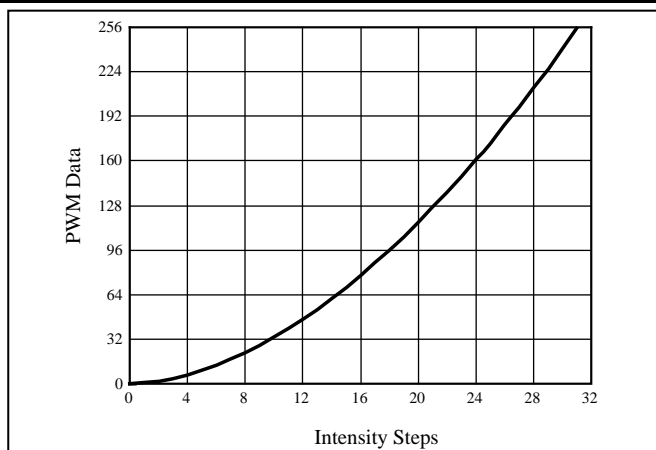
### GAMMA CORRECTION

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 IS31FL3216A 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 17 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   |

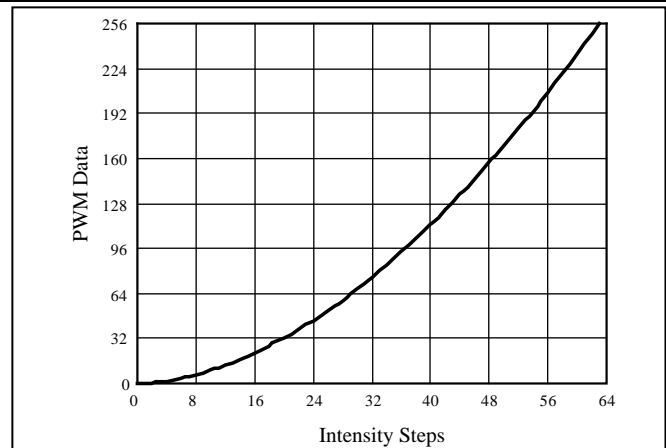


**Figure 8** Gamma Correction (32 Steps)

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 18 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 9** 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.

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## AUTO FRAME PLAY MODE

By setting the MODE bit of the Configuration Register (00h) to “01”, the IS31FL3216A operates in Auto Frame Play Mode. It stores data of 8 frames and automatically plays in order. Customers can configure the delay time between each two frames and the first playing frame by setting the Frame Delay Register (B6h) and the Frame Start Register (B7h).

## AUDIO FRAME MODE

By setting the MODE bit of the Configuration Register (00h) to “10”, the IS31FL3216A operates in Audio Frame Mode. It stores data of 8 frames and the 8 frames playing follow the input signal. 09h register is used to set the ADC sample rate for the input signal to control frames playing. It plays the first frame when the value is the smallest and plays the eighth frame when the value is the biggest (See Table 14).

## AUDIO MODULATED MODE AND GAIN SETTING

By setting the AE bit of the Configuration Register (00h) to “1”, IS31FL3216A operates in Audio Modulated Mode. The intensity of LEDs is adjusted by the input signal. The audio input gain can be set by the Lighting Effect Register (03h).

## CHANNEL MODE SETTING

IS31FL3216A has 16 channels for LEDs output. OUT9~OUT16 also can be set as GPIO ports. By setting the OUTx bit of the Channel Configuration Register (04h) to “1”, the corresponding channel will be used as GPIO port. When the OUTx is set to “0”, the corresponding channel will be used as LED output.

## CASCADE FOR SYNCHRONIZATION OF CHIPS

Operating in the cascade mode can make two chips synchronize. By setting the CM bit of the Lighting Effect Register (03h) to “0”, IS31FL3216A operates as a master. The CLK pin offers the output clock signal. When the CM bit sets to “1”, IS31FL3216A operates as a slave. The CLK pin as a clock input pin. If there is only one chip to use, setting CM bit to “0” and the CLK pin should be floating.

## INTERRUPT FUNCTION

When OUT9~OUT16 configure as input port and the interrupt function enabled, the INTB pin is available. If any input port of OUT9~OUT16 has state changing, the INTB pin will be pulled low. The MCU can get the information via reading the State Register (08h). The INTB will be back to high until the MCU reading the State Register (08h).

## R<sub>EXT</sub>

The output current of each LED channel can be adjusted by the external resistor on pin 28, R<sub>EXT</sub>, as described in Formula (3).

$$I_{LED} [mA] = \frac{1.2}{R_{EXT} [k\Omega]} \times 1400 \quad (3)$$

For example, in Figure 1, R<sub>EXT</sub> = 100kΩ,

$$\text{So } I_{LED} = \frac{1.2}{100} \times 1400 = 16.8mA$$

The recommended minimum value of R<sub>EXT</sub> is 100kΩ. Smaller R<sub>EXT</sub> values will result in a per channel current whose total will exceed the absolute maximum package current rating causing thermal damage to the device.

The I<sub>LED</sub> defines the I<sub>MAX</sub> value which is set by the CS bit of Lighting Effect Register (03h). And the average output current of each output, I<sub>OUT</sub>, is calculated by the I<sub>MAX</sub> and PWM Register as Formula (2) in Table 13.

## PWM FREQUENCY

The IS31FL3216A output channels operate with a default PWM frequency of 26kHz. Because all the OUTx channels are synchronized, the DC 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.

Figure 10 below shows the variation of output PWM frequency across supply voltage and temperature.

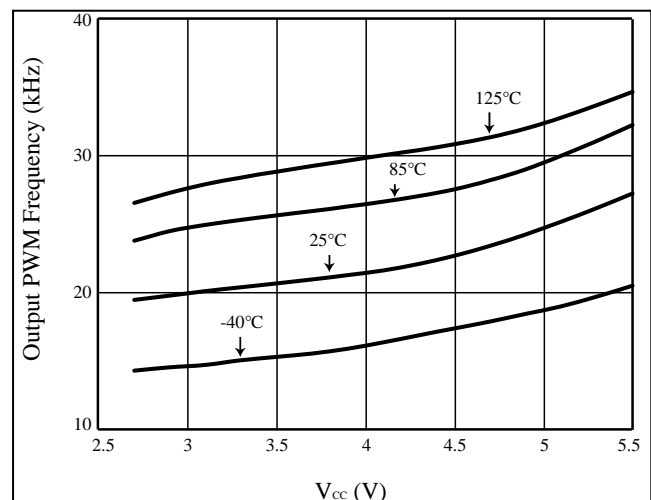


Figure 10 V<sub>CC</sub> vs. Output PWM Frequency

## SHUTDOWN MODE

Shutdown mode can either be used as a means of reducing power. During shutdown mode all registers

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retain their data and OUT9~OUT16 still can be available as GPIO port.

## **Software Shutdown**

By setting SSD bit of the Configuration Register (00h) to "1", the IS31FL3216A will operate in software shutdown mode, wherein they consume only 1 $\mu$ A (Typ.) current. When the IS31FL3216A 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.

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## CLASSIFICATION REFLOW PROFILES

| Profile Feature   | Pb-Free Assembly |
|---|------------------|
| <b>Preheat &amp; Soak</b>   |                  |
| Temperature min (T <sub>smin</sub> )  | 150°C            |
| Temperature max (T <sub>smax</sub> )  | 200°C            |
| Time (T <sub>smin</sub> to T <sub>smax</sub> ) (t <sub>s</sub> )                                  | 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> )   | 217°C            |
| Time at liquidous (t <sub>L</sub> )   | 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.   |

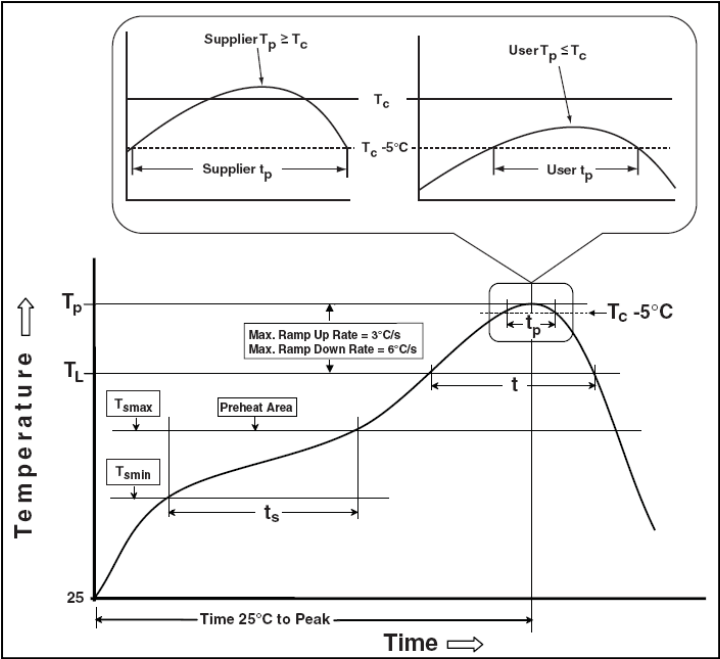


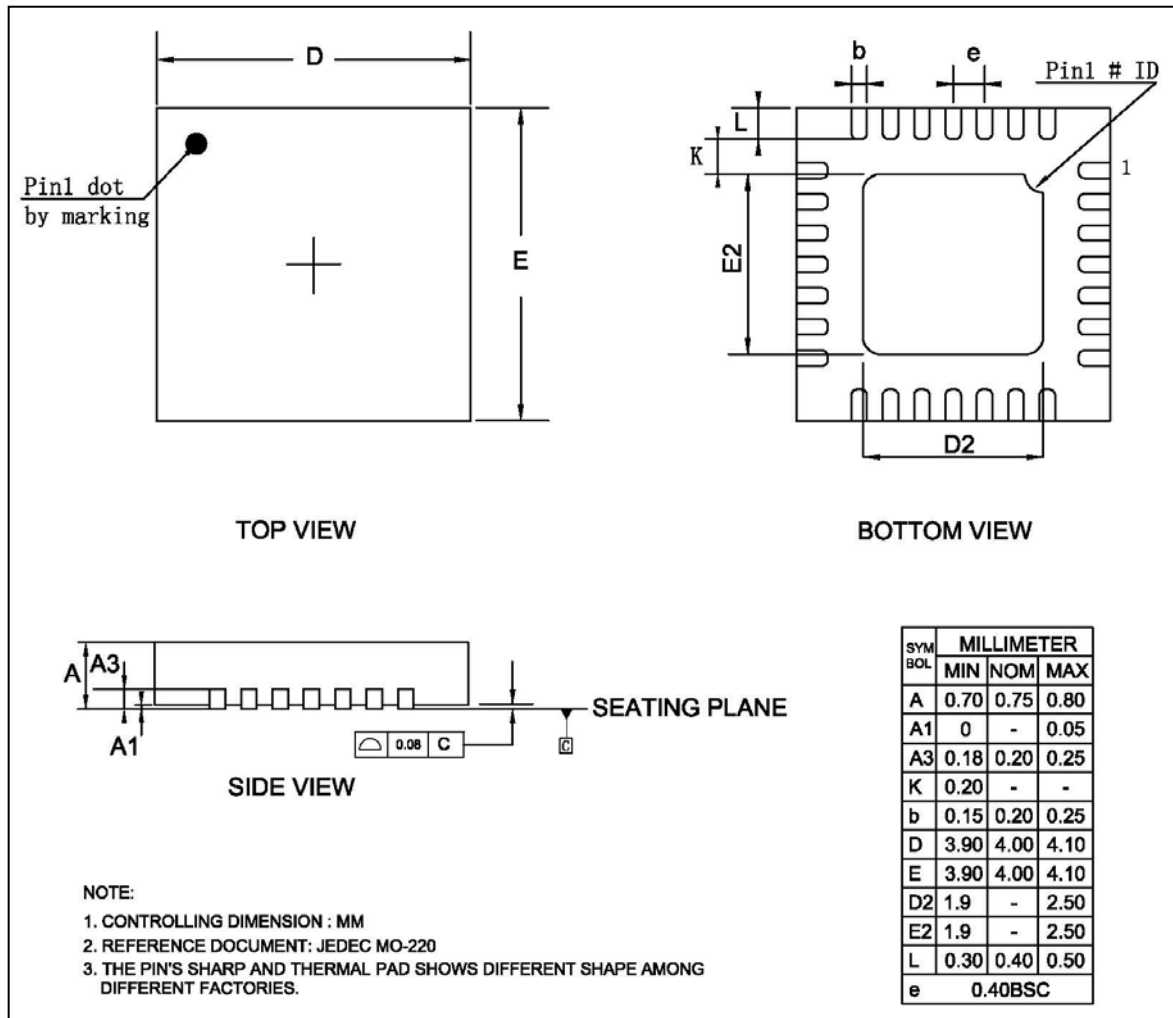
Figure 11 Classification profile



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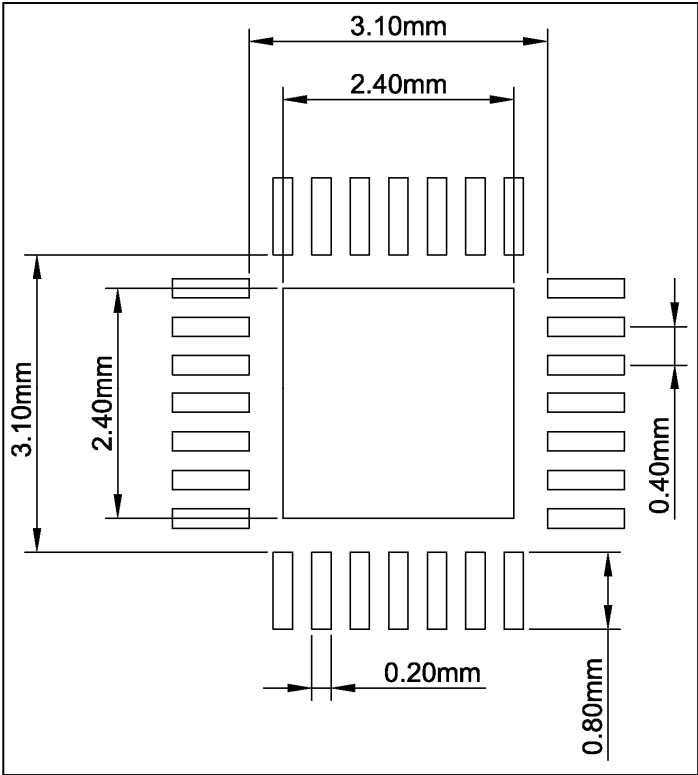
## PACKAGE INFORMATION

### QFN-28



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## RECOMMENDED LAND PATTERN



**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.

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## REVISION HISTORY

| Revision | Detail Information | Date       |
|----------|--------------------|------------|
| A        | Initial release    | 2017.07.03 |