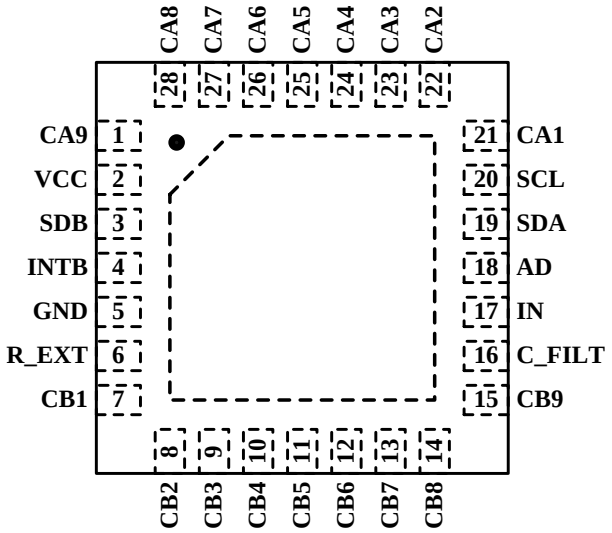
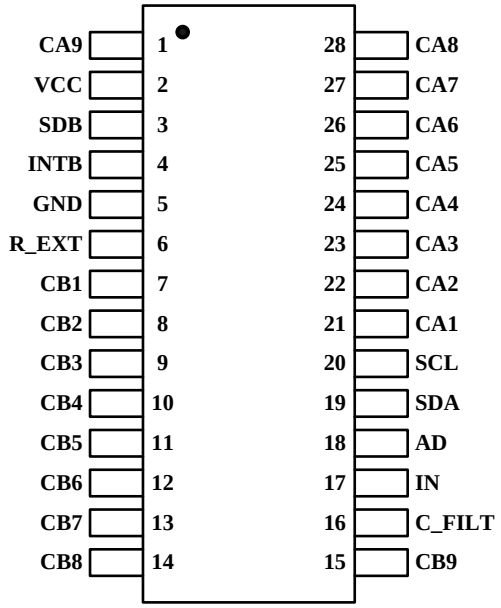
**APPLICATION NOTE**

## GENERAL DESCRIPTION

The IS31FL3731 is a compact LED driver for 144 single LEDs. The device can be programmed via an I2C compatible interface. The IS31FL3731 offers two blocks each driving 72 LEDs with 1/9 cycle rate. The required lines to drive all 144 LEDs are reduced to 18 by using the cross-plexing feature optimizing space on the PCB. Additionally each of the 144 LEDs can be dimmed individually with 8-bit allowing 256 steps of linear dimming.

To reduce CPU usage up to 8 frames can be stored with individual time delays between frames to play small animations automatically. LED frames can be modulated with audio signal.

## PIN CONFIGURATION

| Package | Pin Configuration (Top View) |
|---|---|
| QFN-28 |  |
| SSOP-28 |  |

## TYPICAL APPLICATION CIRCUIT

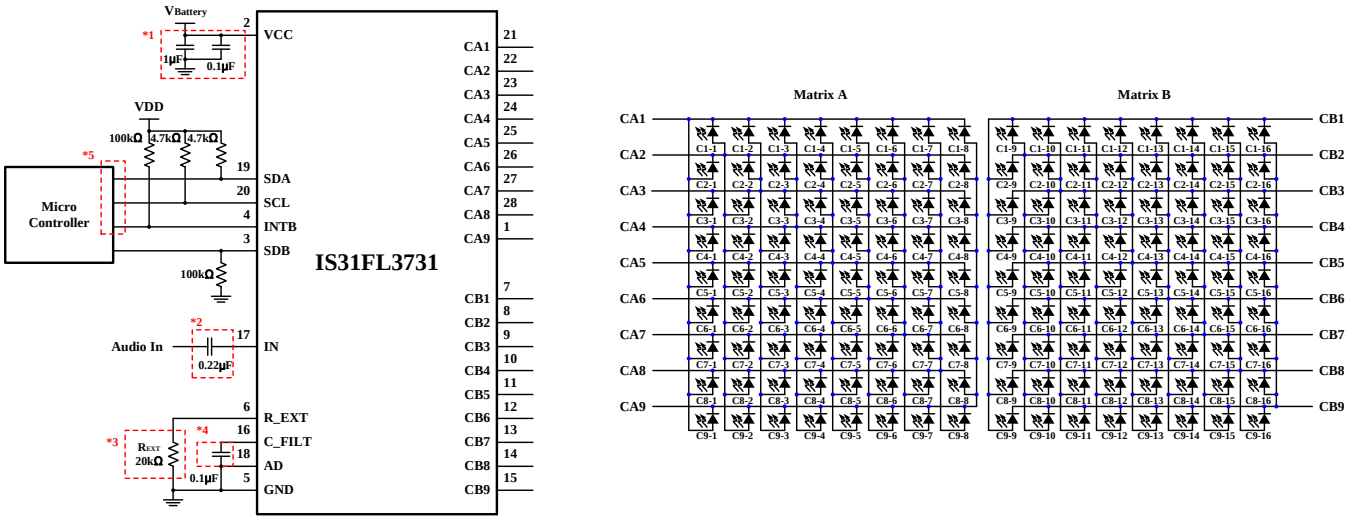



**Fig 1** Typical Application Circuit

*1: The bypass capacitor which connects to VCC pin should be placed close to the IC as possible to decrease the ripple from supply voltage, some cases the >=2.2uF MLCC bypass cap will have acoustic noise, and from the PCB line of power supply to VCC pin, >=2.2uF MLCC is not recommended because it may have acoustic noise, try to use noise suppression cap or tantalum cap

The VCC capacitor's ground side should connect to the GND well especially for SSOP-28 package

*2: The audio input capacitor (0.22μF) should be placed as close as possible to the IC.

*3: The recommended minimum value of $R_{EXT}$ is 18kΩ, or it may cause a large current. $R_{EXT}$ should be placed as close as possible to the IC.

*4: The audio filter capacitor (0.1μF) should be placed as close as possible to the IC.

*5: The voltage which pulling I2C and INTB pins up should be above 1.4V. 1.8V and 2.8V are allowed.

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

*7: The traces connect from the IC to LED should be short and thick.

**Q1：IS31FL3731 can support 8×9×2 LEDs. How should the circuit be if not all of the LEDs are used?**

A：Each LED can be disconnected as what customers want (Figure 2). But the corresponding LED Control Register (8 Pages) should be shut down if the LED is disconnected. As below, the LED Control Register for the Matrix A should be:

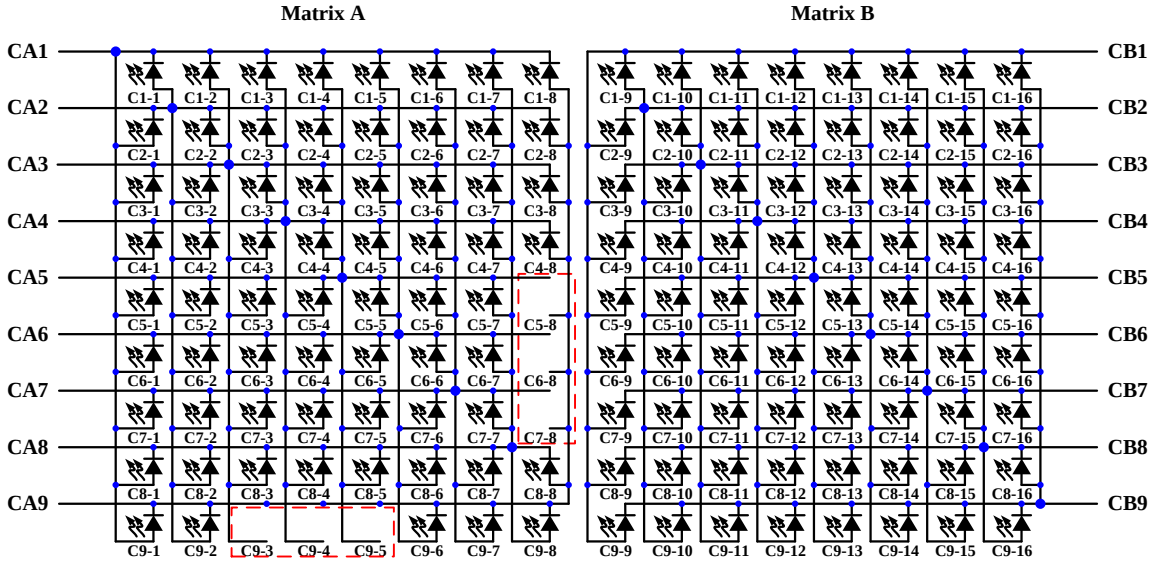



**Fig 2** C9-1 to C9-8 and C1-8 to C9-8 are disconnected

/*register 0x00,0x01*/0xff, 0xff,

/*register 0x02,0x03*/0xff, 0xff,

/*register 0x04,0x05*/0xff, 0xff,

/*register 0x06,0x07*/0x7f, 0xff, //C5-8 is NC

/*register 0x08,0x09*/0x7f, 0xff,//C6-8 is NC

/*register 0x0a,0x0b*/0x7f, 0xff, //C7-8 is NC

/*register 0x0c,0x0d*/0xff, 0xff,

/*register 0x0e,0x0f*/0xff, 0xff,

/*register 0x10,0x11*/0xE3,0xff, //C9-3~C9-5 are NC

**Q2：What's the function of internal SRAM for IS31FL3731?**

A：IS31FL3731 drive 144 LEDs and each LED can be dimmed in 256 steps which requiring great data to write into microcontroller. It will consume lots of system resource if there is no SRAM. SRAM can store pre-programmed animation and color-effect lighting and free-up the microcontroller to do other system functions resulting in increased performance and battery life.

**Q3：The IC can store 8 frames data at best. How does it achieve if more frames animation display?**

A：Each 4 frames writing in Frame Registers is recommended if there are more frames to play (Figure 3). First, store 8 frames data and play 4 frames in front. Then play last 4 frames and writing new data in the Frame Registers (1~4) at the same time. Play the new 4 frames (1~4) and write new data in the Frame Registers (5~8).

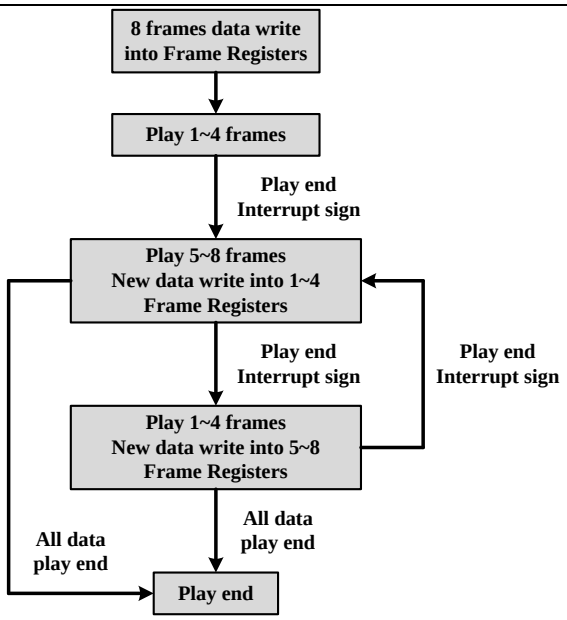



**Fig 3** More frame data writing in

**Q4：What's the definition of Page and how to use it?**

A：There are nine Pages in IS31FL3731 and corresponding registers in each Page (Figure 4). The Frame Registers are stored in Page One to Page Eight and Function Register is stored in Page Nine. Register address in each Page is from 00h. Page One to Page Eight have the same register format.

The Command Register should be configured first after writing in the slave address to choose the available register (Frame Registers and Function Registers). Then write data in the choosing register. The Command Register should be configured again if registers in other Page requiring setting.

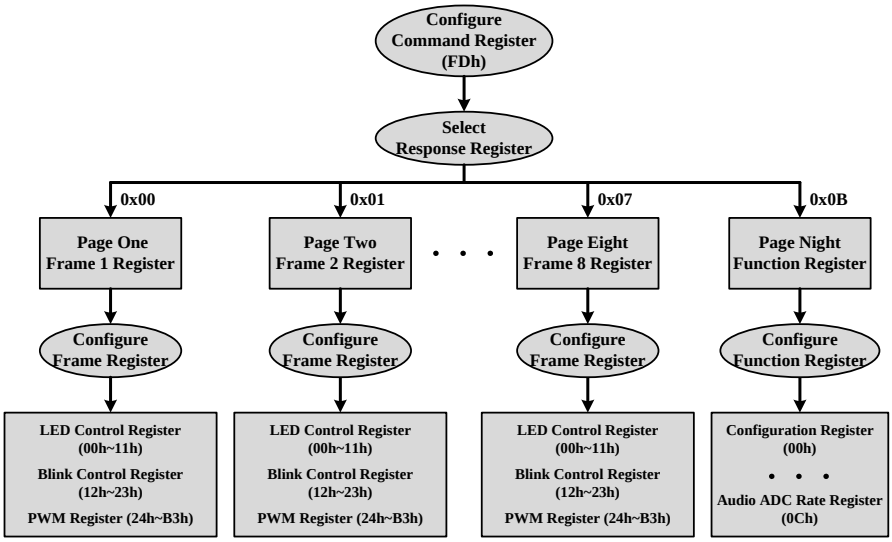



**Fig 4** Register Control

**Q5：How the I2C goes on for IS31FL3731? Is the I2C interface standard?**

A：The I2C goes on below:

Start—Slave Address—Page Address—Page Data—Stop; Start—Slave Address —Register Address—Register Data—Stop

The I2C interface is standard.

**Q6：Can the registers be read and how to read data from registers?**

A：All of registers in IS31FL3731 can be read. But Frame Registers can only be read in software shutdown mode as SDB pin is high. The Function Register can be read in software shutdown mode or operating mode.

To read the device data, the bus master must first send the IS31FL3731 address with the R/$\overline{W}$ bit set to "0", followed by the Command Register address, FDh, then send command data which determines which response register is accessed.

After a restart, the bus master must send the IS31FL3731 address with the R/$\overline{W}$ bit set to "0" again, followed by the register address which determines which register is accessed. Then restart I2C, the bus master should send the

IS31FL3731 address with the R/$\overline{W}$ bit set to "1". Data from the register defined by the command byte is then sent from the IS31FL3731 to the master (Figure 6). The IC supports address auto increment.

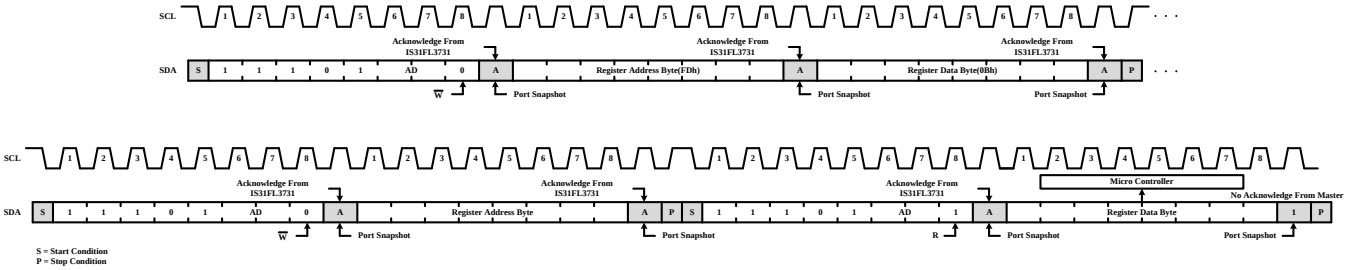



**Fig 6** Reading from IS31FL3731

**Q7：What's the "Reserve" meaning for 04h Register?**

A：04h Register is reserve without function. Writing any date into it will be ok by address auto increment. 04h register also can be read. But the data which read from 04h will be random and not the same as what write in.

**Q8：Could SDB pin be used in1.8V by GPIO port?**

A：1.8V voltage could be used to control SDB pin. Any voltage above 1.4V will be recognized high level. Low level from GPIO port is recommended to control SDB pin when power on.

**Q9：Could IS31FL3731 drive RGB?**

A：Yes, the IS31FL3731 can drive 32 common cathode / common anode RGBs at best (Figure 7 and 8). The location of red LED must follow the below circuit and the black location could connect single LED except red one, or the IC can't work normally.

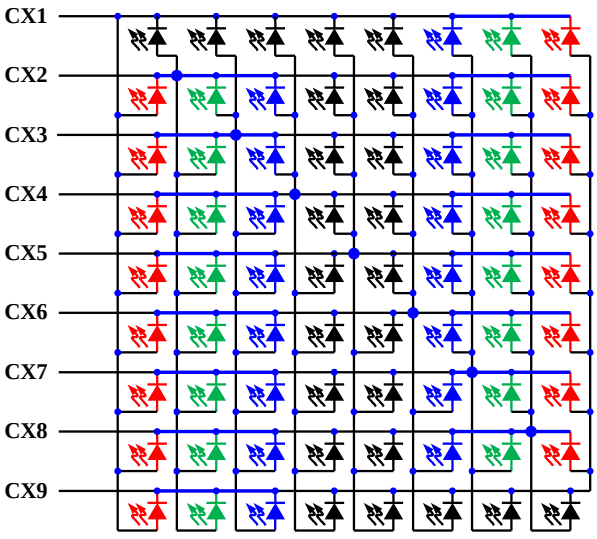



**Fig 7** Common Cathode RGB Connection (X=A/B)

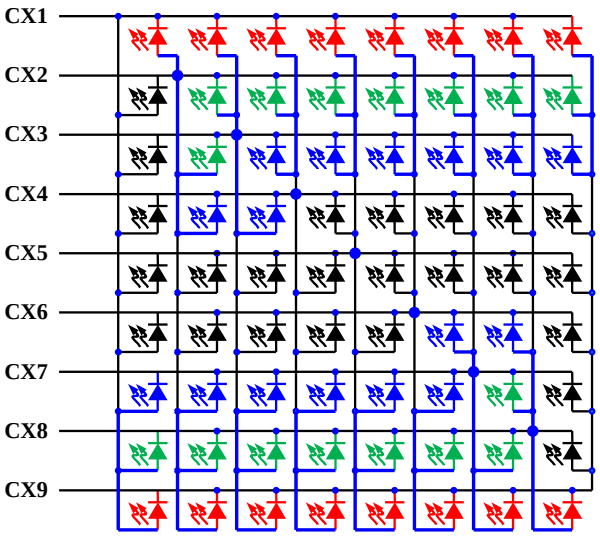



**Fig 8** Common Anode RGB Connection (X=A/B)

**Q10：Could IS31FL3731 display follow audio signal? What's the different between Audio Modulate and Audio Frame Play?**

A：IS31FL3731 has two audio play modes. Audio Modulate Mode and Audio Frame Play Mode. The intensity of LEDs is adjusted by the input signal in Audio Modulate Mode. The input signal is higher the intensity of display is stronger. There

will be no display when no audio signal. In Audio Frame Play Mode it stores data of 8 frames and the 8 frames playing follow the input signal. It plays the first frame when the value is the smallest and plays the eighth frame when the value is the biggest.

1) Audio Modulate Mode (Intensity)

By setting the AE bit of the Audio Synchronization Register (06h) to "1" (need to turn off MODE bit of the Configuration Register (00h) to "00"), IS31FL3732 operates with audio synchronization. The intensity of LEDs is adjusted by the input signal. The audio input gain can be set by the AGC Control Register (0Bh).

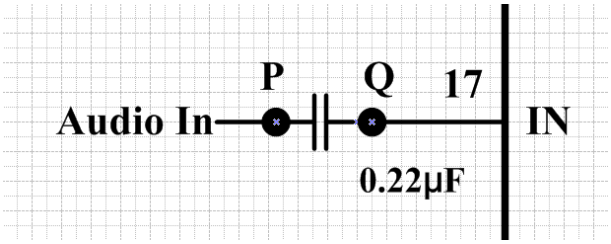



**Fig 9** Typical Application Circuit

Normally, the point Q will have a DC voltage about 1.6V(Bias Voltage), if the input signal (AC) is lower than it, the internal ADC will sample the voltage and determine the output. Below shows the DV value vs. the output frame position.

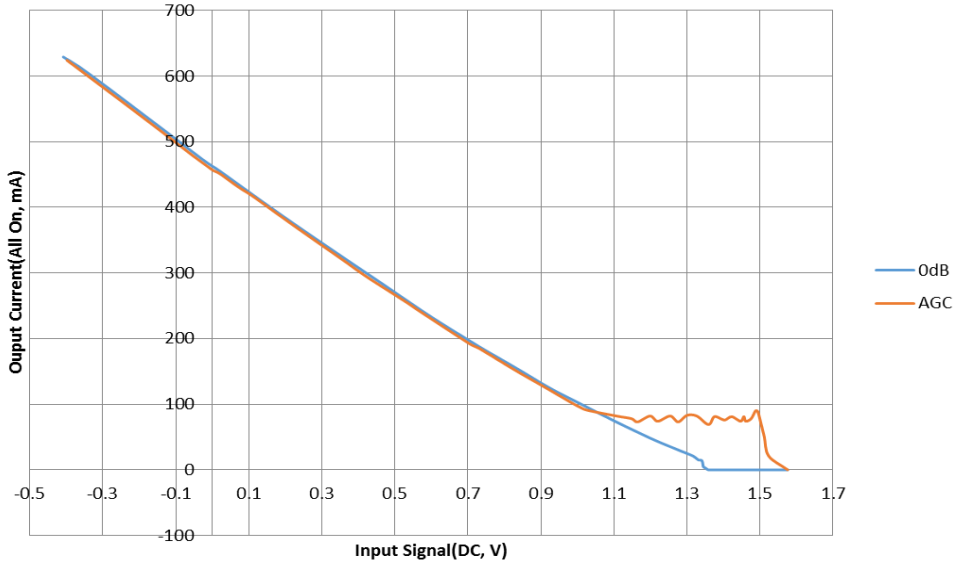



**Fig 10** DV input value vs. the output current

The test condition is: VCC=5V, RSET=20k, GCC=0xff, V(IN pin)=1.576V(for this part, tpy. Value is 1.6V)

Set the MODE bit of the Configuration Register (00h) to "00"

Set the AE bit of the Audio Synchronization Register (06h) to "1"

When the audio signal is varying from 0V to –Vsignal at point P, the point Q's voltage will go to V(IN pin)- Vsignal, and the LED will ouput the corresponding current and get the audio synchronize effect.

The PWM data need to program before start enable this mode.

2) AUDIO FRAME PLAY MODE

By setting the MODE bit of the Configuration Register (00h) to "1x", the IS31FL3732 operates in Audio Frame Play Mode. It stores data of 8 frames and the 8 frames playing follow the input signal. 0Ch 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.

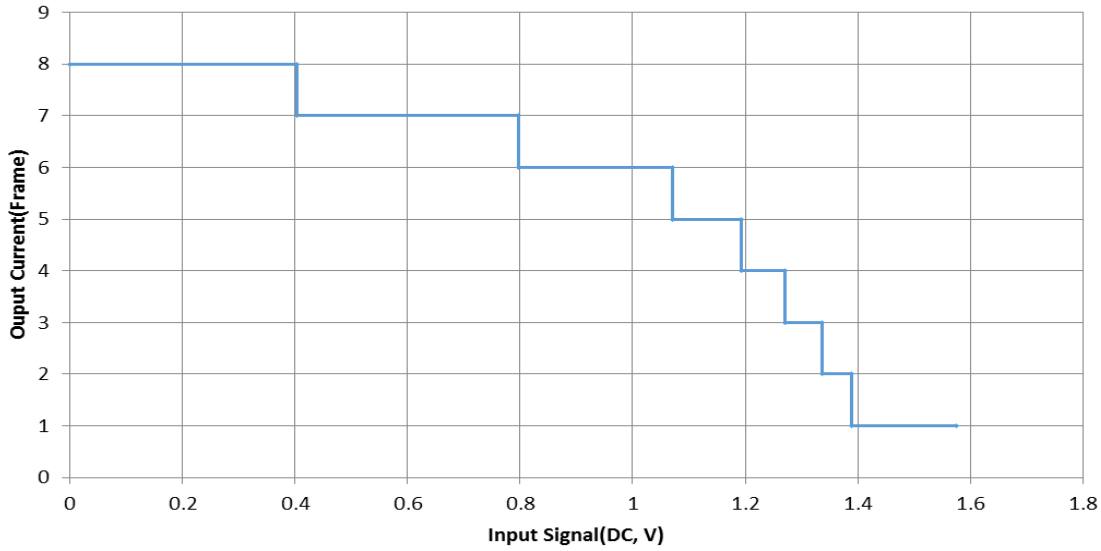



**Fig 11** DV input value vs. the output frame position

The test condition is: VCC=5, VRSET=20k, GCC=0xff, V(IN pin)=1.576V(for this part, tpy. Value is 1.6V)

Set the MODE bit of the Configuration Register (00h) to "1x"

Clear the AE bit of the Audio Synchronization Register (06h)

When the audio signal is varying from 0V to –Vsignal at point P, the point Q's voltage will go to V(IN pin)- Vsignal, and the frame will switch to the corresponding frame and get the audio frame synchronize effect.

The 8 frame data need to program before start enable this mode.

**Q11：What's the blink function and how to achieve?**

A：The blink function can make each LED on and off switching by configured time. By setting the BE bit of the Display Option Register (05h) to "1", blink function enable. If the BE bit is set to "1", each LED can be controlled by the Blink Control Registers (12h~23h in Page One to Page Eight). The Display Option Register (05h) is used to set the blink period time, BPT, and the duty cycle is 50%.

**Q12：When the breath function will be available? Does it affect the breath function when switch pictures quickly in Picture Mode?**

A：The breath function will be available in Picture Mode and Auto Frame Play Mode. And it should be shut down in Audio Modulate Mode.

When writing into switching command during FOT and ET in Picture Mode, it will display the last picture while fade in. When writing during FIT, the command is inefficacy (Figure 9).

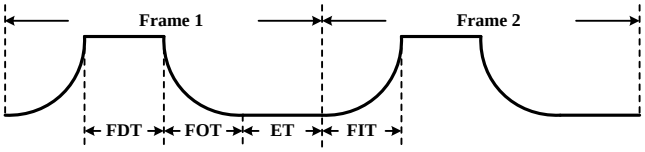



**Fig 12** Breathing function

**Q13：How does the IS31FL3731 scan and how long the whole scan cycle?**

A：The required signals to drive all 144 LEDs have been reduced to 18 by using a multiplexing feature. The scan time for each channel is 115μs (Typ.) and interval time is 20μs (Typ.) (Figure 10). Matrix A and B can scan together and the whole scan cycle is (115+20)×9 = 1215μs.

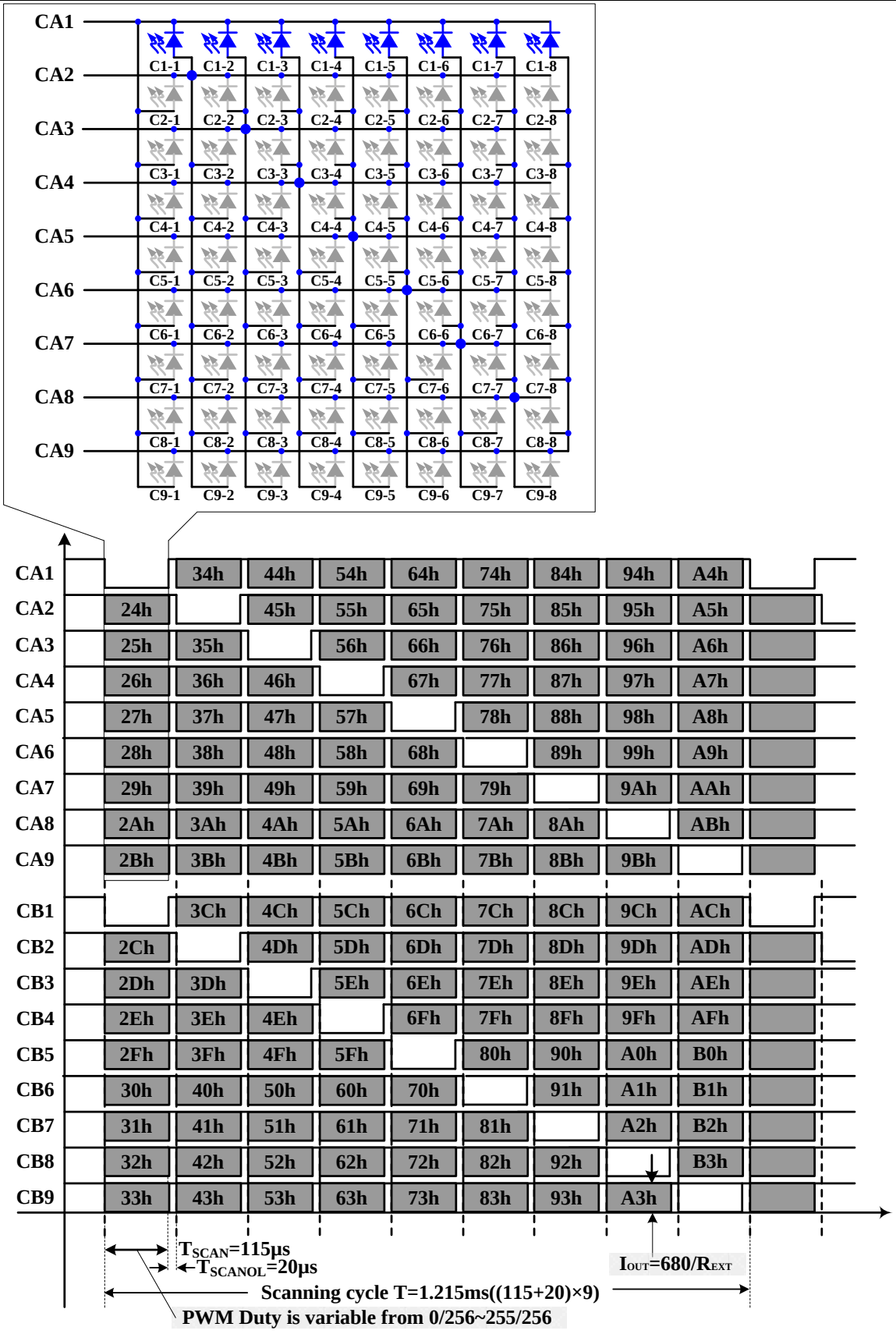



**Fig 13** Scanning timing

Note: 1) CXx low means the CXx work as sink and others work as source

2) In $T_{SCANOL}$ al the CXx pins are float

**Q14：The brightness of the LED is not enough ($R_{EXT}$ =20k), can I get more current for each LED?**

A：As stated in page item 3, the minimum $R_{EXT}$ is 18k and as mentioned in item 13, the Iout(each pin's output current is 680/RWXT, when REXT=20k, Iout=34mA, when REXT=18k, Iout=37.8mA.

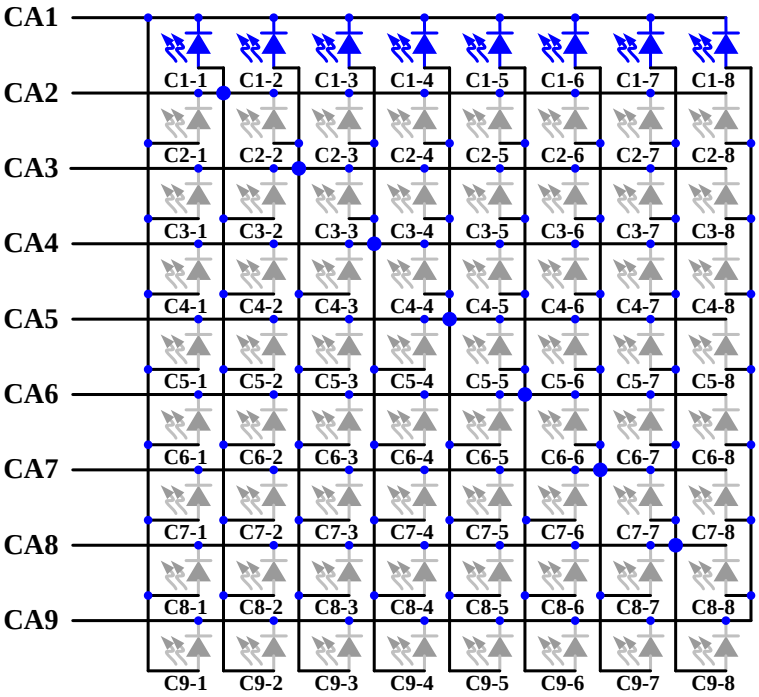



**Fig 14** Scanning timing 2

Since IS31FL3731 is not a boost or buck, so as shown in about figure, at this time, the CA1 work as sink and CA2-9 work as source, VCC =（VCC – VCAx(2-9)）+ Vf + VCA1

VCA1 is the headroom voltage of CA1, VCAx(2-9) is one the CA2-9 pin voltage, VCC – VCAx(2-9) is the headroom voltage of these pins, Vf is the forward voltage of LED,

When REXT=20k, Iout=34mA, means the current from CA2~CA9 to CA1 is 34mA each, and total current thru CA1 is 34mAx8=272mA, the spec in EC is as below:

| | | | | | | |
|---|---|---|---|---|---|---|
| $V_{HR}$ | Current sink headroom voltage C1~C9 | $I_{sink}$ = 270mA *(注释 2)* | | 400 | | mV |
| | Current source headroom voltage C1~C9 | $I_{source}$ = 34mA | | 400 | | |

**Fig 15** Headroom voltage (EC of datasheet)

If VCC=5V, VCA1=0.4V, Vf=3.7V@34mA（Blue LED）, (VCC – VCAx)=VCC-Vf-VCA1=0.9V

If VCC=5V, VCA1=0.4V, Vf=2.1V@34mA（Red LED）, (VCC – VCAx)=VCC-Vf-VCA1=2.4V

If VCC=3.6V, VCA1=0.4V, Vf=3.7V@34mA（Blue LED）, (VCC – VCAx)=VCC-Vf-VCA1=-0.5V

So when VCC is not enough, the output will decrease, they Vf will decrease, the two headroom will decrease, and they will get a new balance

Below is some calculation show relationship of REXT and VCC:

Table 1 REXT vs. VCC

| VCC | $R_{EXT}$ | Iout [1] | Vf [2] (If=Set Value) | $V_{Sink}$ | $V_{Source}$ | Result [3] | IC Power [4] |
|---|---|---|---|---|---|---|---|
| 3.3V | 20k | 34mA | 2.1V | 0.4V | 0.8V | Can get the Iout | 599mW |
| 3.3V | 20k | 34mA | 3.7V | 0.4V | <0V | $V_{Source}$ is not enough, can't get the setting current | |
| 3.6V | 20k | 34mA | 2.1V | 0.4V | 1.1V | Can get the Iout | 699mW |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3.6V | 20k | 34mA | 3.7V | 0.4V | <0V | $V_{Source}$ is not enough, can't get the setting current | |
| 5.0V | 20k | 34mA | 2.1V | 0.4V | 2.5V | Can get the Iout but the total power is too much | 1.35W |
| 5.0V | 20k | 34mA | 3.7V | 0.4V | 0.9V | Can get the Iout | 606mW |
| 5.0V | 18k | 37.8mA | 2.2V | 0.42V | 2.38V | Can get the Iout but the total power is too much, easy over temperature protect | 1.45W |
| 5.0V | 18k | 37.8mA | 3.8V | 0.42V | 0.78V | Can get the Iout | 622mW |
| 5.0V | 15k | 45.3mA | 2.25V | 0.5V | 2.25V | Can get the Iout but the total power is too much, easy over temperature protect | 1.45W |
| 5.0V | 15k | 45.3mA | 4.0V | 0.5V | 0.5V | Can get the Iout | 652mW |
| 5.0V | 14k | 48.6mA | 4.05V | 0.5V | 0.45V | $V_{Source}$ is not enough, can't get the setting current | |
| 5.0V | 13k | 52.3mA | 4.1V | 0.55V | 0.35V | $V_{Source}$ is not enough, can't get the setting current | |
| 5.0V | 12k | 56.7mA | 4.15V | 0.6V | 0.25V | $V_{Source}$ is not enough, can't get the setting current | |

Note:

[1] Iout=680/$R_{EXT}$

[2]Vf refer to Everlight 19-337/R6GHBHC-A01/2T high Vf refer to Blue/White/Green LED, low Vf refer to Red/Yellow LED

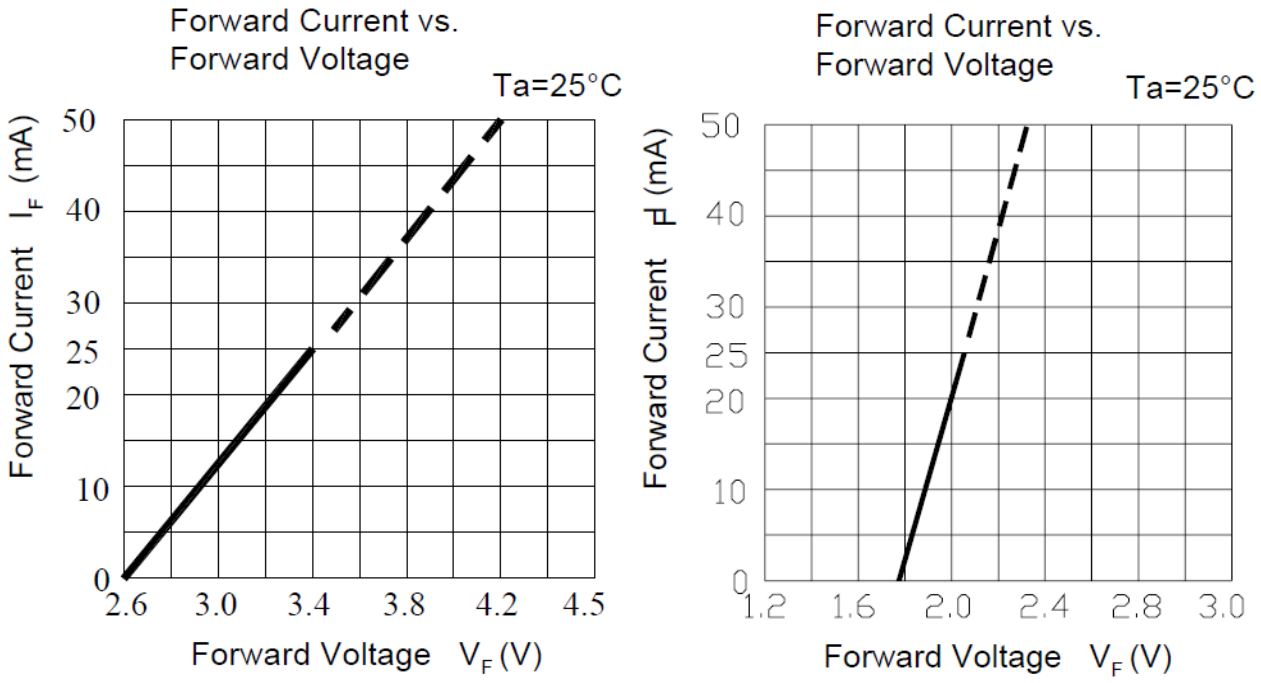



**Fig 16** Vf vs. If of Blue(Left) and Red(right) LED（19-337/R6GHBHC-A01/2T）

[3]Power=Iout*16*(9/10.5) * (VCC-Vf), 16 is amount of outputs，(9/10.5) is the duty cycle

In summary, if VCC is far more than Vf, the part will go to thermal shutdown protection easily, and if VCC is close to the Vf, the current may can't get the setting current(will less than it), so when choosing the REXT, need to consider about the VCC

**Q15：Except reduce $R_{EXT}$, can I get more current for each dot?**

A：Since matrix A and B are synchronical, so they can connect in parallel, each dot will get twice current but the LED quantity the driver can drive will be half(72 LED), in firmware, the matrix B's registers will control another half of the LED, for example, for C1-1, 0x24 controls half of the output current and 0x2C controls another half

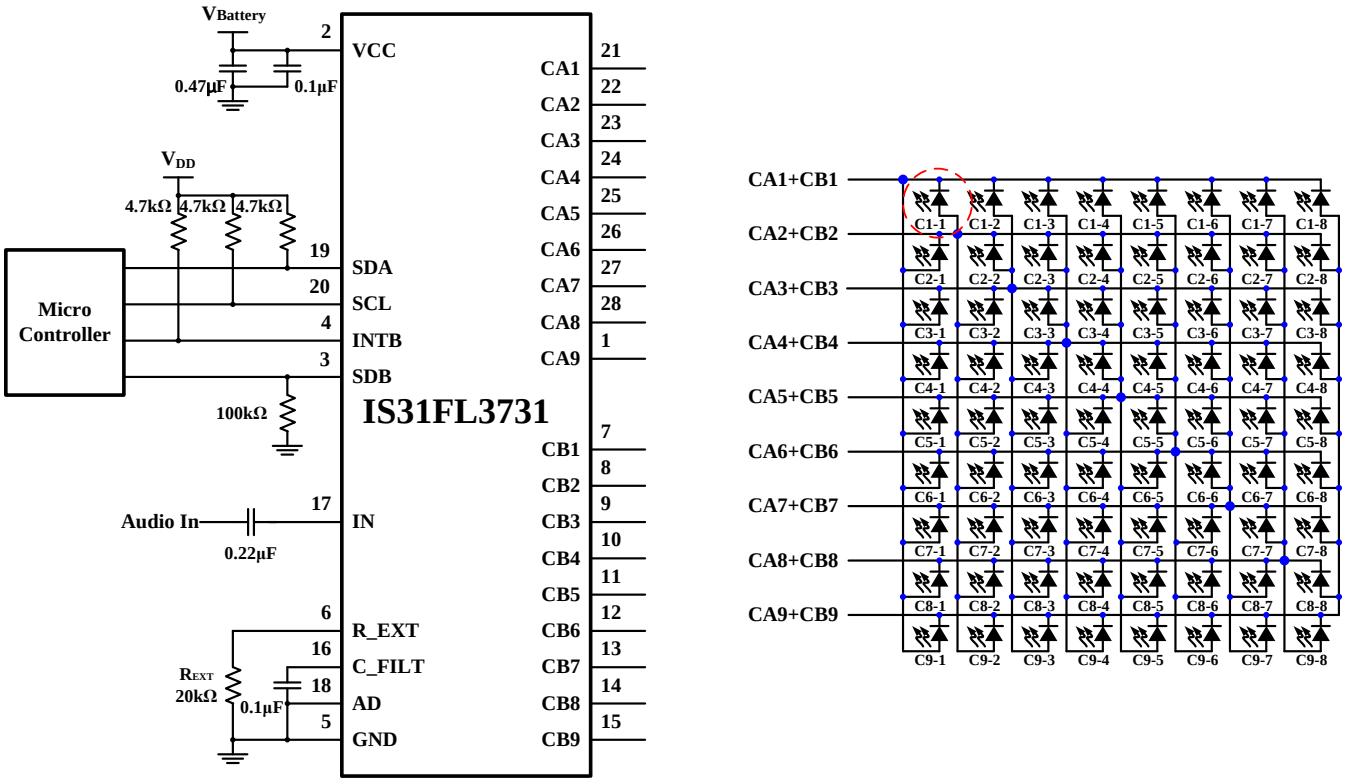



**Fig 17** Typical application-AB matrix connected in parallel

**Q16：Is there anyway to adjust the global current**

A：The internal block doesn't have the register to adjust the global current, practically we can use an external circuit as below to use a PWM signal to adjust the global current.

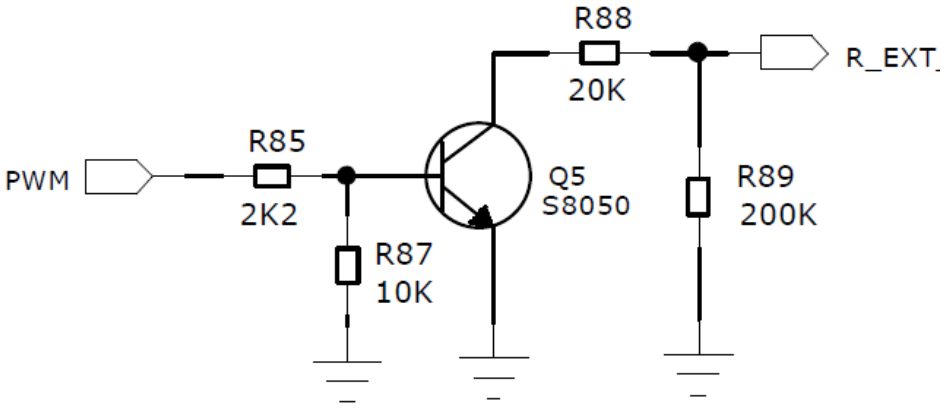



**Fig 18** PWM adjust global current

REXT pin is a reference voltage for all the output, about 1.2V, adjust the voltage can adjust all the output's current glabally, use the transistor (NPN), when it is open, the REXT pin will be pull to some level and averagely it will adjust the global current.

**Q17：SDB PIN or Software Shutdown operate process**

A：when initial and shutdown the IS31FL3731, please follow the sequence as Fig 19

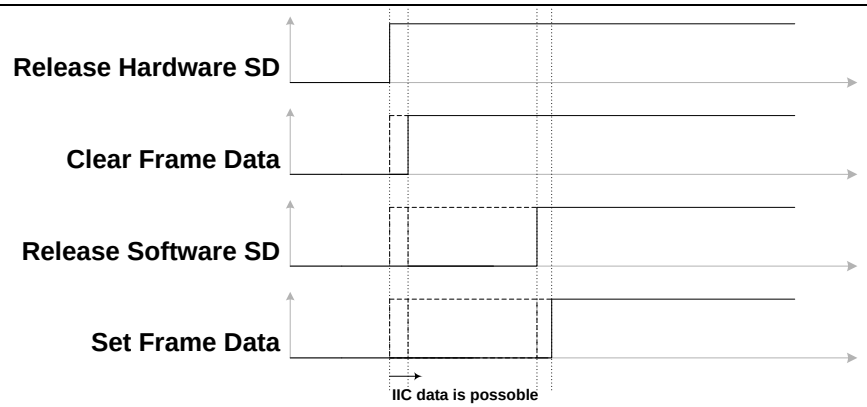



**Fig 19** Initialization Sequence


**Fig 20** Shutdown Sequence

Key points:

1 when initial power up, the data of Frame 1 ~ frame 8 is random, before release the shutdown, make sure they are cleared, or you may see the matrix flicker once between you release shutdown and you update the onoff and PWM data.

2 every time release software or hardware shutdown, need to refresh the on off and PWM data once (in some case, some of the on off or PWM data make be cleared during this operation).

```
//Sample code for initial the IS31Fl3731
SDB=1;//Pull-High SDB pin, start to work

I2C_WriteByte(IS3731_GND,0xfd,0x00);//Point to DATA frame 0
for(i=0;i<=143;i++)I2C_WriteByte(IS3731_GND,(i+0x24),0x00);//Clear LED PWM Registers
//can also write with Automatic address increment, below is same
for(i=0;i<=17;i++)I2C_WriteByte(IS3731_GND,i,0x00);//Clear LED Control Registers

I2C_WriteByte(IS3731_GND,0xfd,0x0b);//frame 0b
I2C_WriteByte(IS3731_GND,0x0a,0x01);//Release SSD
//loop
{
I2C_WriteByte(IS3731_GND,0xfd,0x00);//DATA frame 0
for(i=0;i<=143;i++)I2C_WriteByte(IS3731_GND,(i+0x24),PWM);//Set LED PWM Registers
for(i=0;i<=17;i++)I2C_WriteByte(IS3731_GND,i,OnOff);//Set LED Control Registers
}
//Sample code for shutdown the IS31Fl3731
I2C_WriteByte(IS3731_GND,0xfd,0x0b);//frame 0b
I2C_WriteByte(IS3731_GND,0x0a,0x00);//Enable SSD
SDB=0;//Pull-Low SDB pin, shutdown the IS31Fl3731
```

**Q18：Can IS31FL3731 drive more than 32 RGB?**

A：In a 9*8 LED matrix, if the some LED's Vf(LED forward voltage) is much lower than the others, or as below, a red LED is connected into a blue matrix

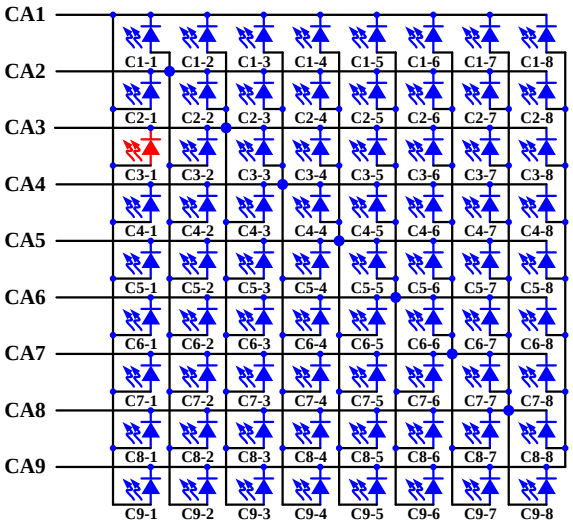



**Fig 21** A red LED is connected into a blue matrix

Due to:

1）parasitic capacitance of the PCB trace

2）parasitic capacitance of LED

3）parasitic capacitance of IS31FL3731 output

4）Some LED itself is sensitive to small current, or very small current will make its brightness visible

When the red LED is off and other especially the common anode ones are on, the red LED will be turn on slightly and we can observe it, or we call it ghost

In order to remove the ghost issue, we provide a connection as stated in Q9 or Fig 7 and Fig 8, but by that way IS31FL3731 can only drive 32 RGBs. For driving more than 32 RGBs, (24 RGBs in Matrix A, 48 for total)

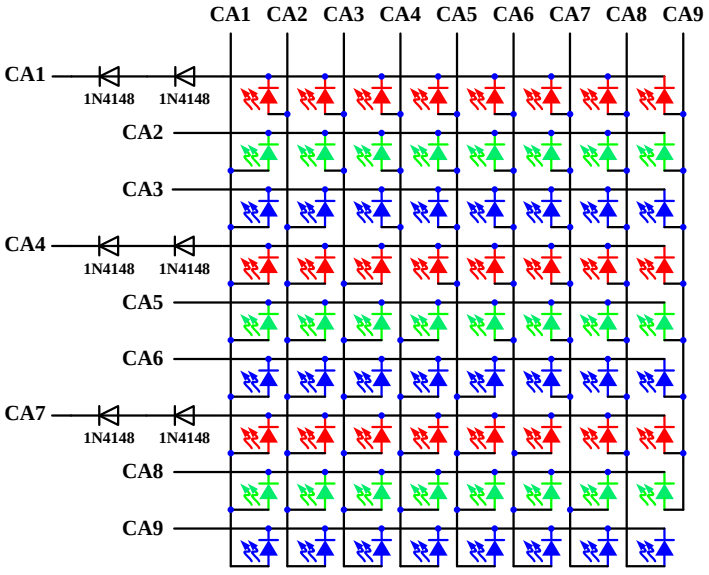



**Fig 22** Typical application-24 RGB application(Matrix A)

Key Points

1 red LED's Vf is about 2.1V only, connect 2 1N4148 in series to increase the Vf and make the difference smaller, can significantly eliminate the ghost issue

Note：in Q15, the matrix can connect as Fig 22 and drive 24 RGB with double LED current

**Q19：Can different color single color LED connect in one matrix?**

A： as describe in Q18, those lower Vf LED connect in higher Vf LED matrix will have ghost issue, but in some case you may only need to connect a few lower Vf LED like below:

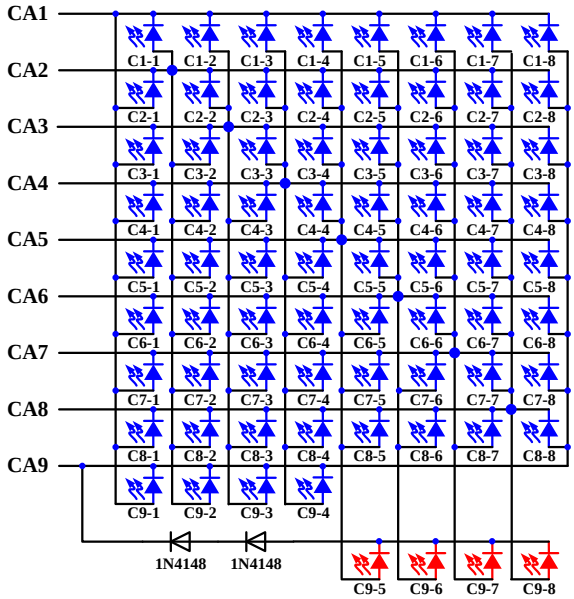



**Fig 23** Typical application-Single multi-color LED

Key points:

1 red LED's Vf is about 2.1V only, connect 2 1N4148 in series to increase the Vf and make the difference smaller, can significantly eliminate the ghost issue

2 IS31FL3731 has two matrix, try to arrange those Vf are almost same in same matrix

**Q20：How to prevent ghost image issue?**

A：When some LED is off, affected by the common anode or cathode LED's turning on, the off LED may be turned on slightly and our eyes can observe the low brightness, the reason for ghost are:

1）parasitic capacitance of the PCB trace

2）parasitic capacitance of LED

3）parasitic capacitance of IS31FL3731 output

4）Some LED itself is sensitive to small current, or very small current will make its brightness visible

According to the experience we have, for preventing the ghost:

1）connect as Q9, will have no ghost issue, shortcoming is one IS31FL3731 can only drive 32 RGBs

2）IS31FL3731 driving some all single color 0402/0201 SMD LED, or single color keyboard, due to long PCB trace or the LED is sensitive, some LED may have ghost

3）as mentioned in Q19, different color LED are connected in one matrix

For preventing the ghost:

A) Software(firmware)，IS31FL3731 has a option which can let all CXx（X=A/B, x=1~9）pull to 1/2 VCC when non-overlap blanking time. The definition is as below:

Table 2 0xC2 Ghost Image Prevention Register

| Bit | D7:D5 | D4 | D3:D0 |
|---|---|---|---|
| Name | - | **GEN** | - |
| Default | 000 | 0 | 0000 |

This register located in function register, can pull the scan non-overlap blanking time to VCC/2

Before write the GEN bit, need to write the 0xFD write 0x0B

| GEN | Ghost Image Prevention Bit |
|---|---|
| 1 | Enable ghost image prevention function, pull the scan non-overlap blanking time to VCC/2 |
| 0 | Disable ghost image prevention function, keep the scan interval hang |

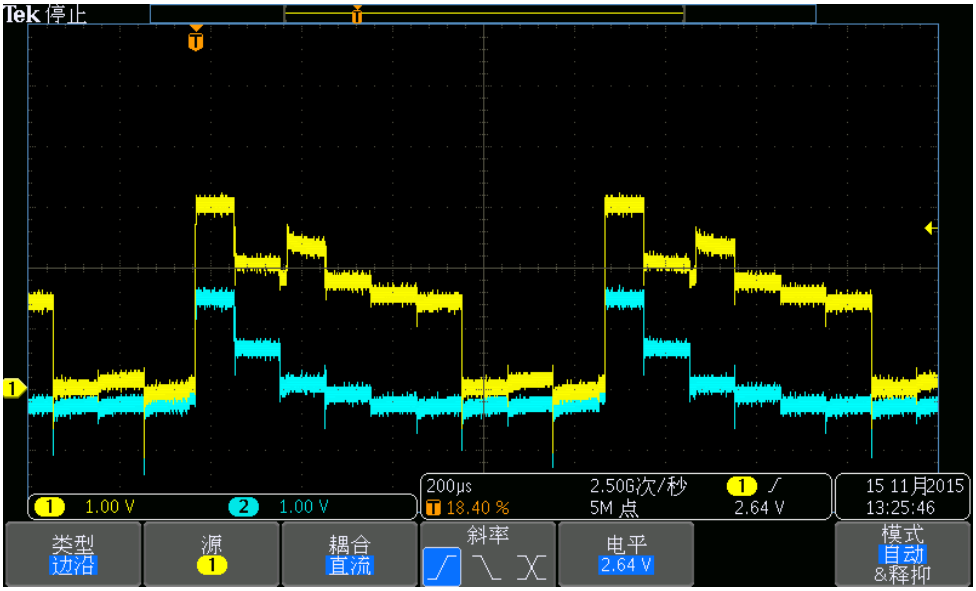



**Fig 24** 0xC2=0x00（Disable）(Yellow:CAx1, Cyan:CAx2)

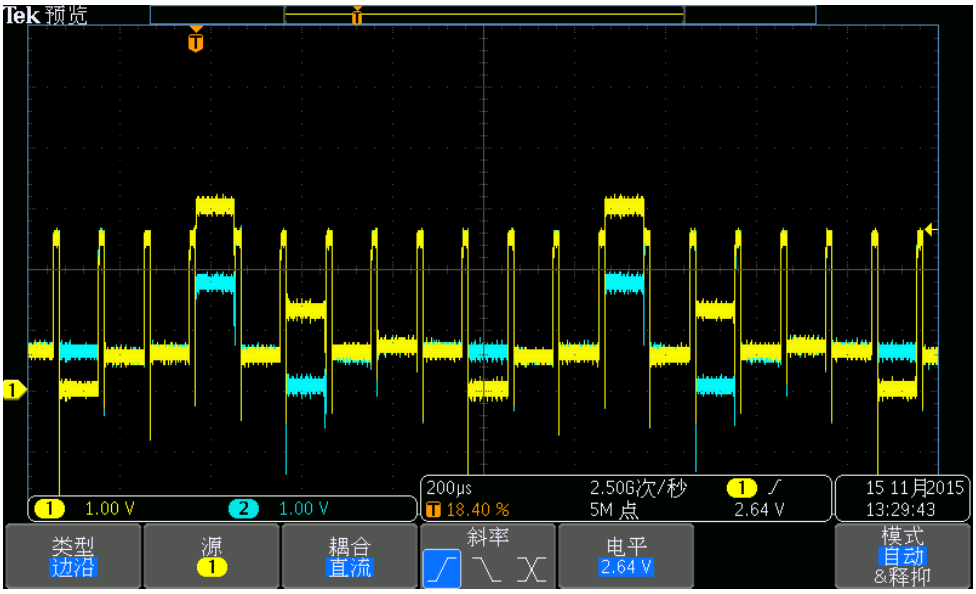



**Fig 25** 0xC2=0x10（Enable）(Yellow:CAx1, Cyan:CAx2)

Note:

1） this register only has this function, will not effect the other function of IS31FL3731,

2） will not add more power consumption.

This function only can pull to half VCC, and limited to the VCC, sometime it only can improve and can't completely eliminate the ghost issue, and need prevent by the hardware way

B) Hardware way

Software way can only pull to half VCC, below circuit can pull to about 1.2V for low Vf LED or 1.8V for high Vf LED, use the diodes (1N4148) clamping the non-overlap blanking time to certain voltage and eliminate the ghost issue.

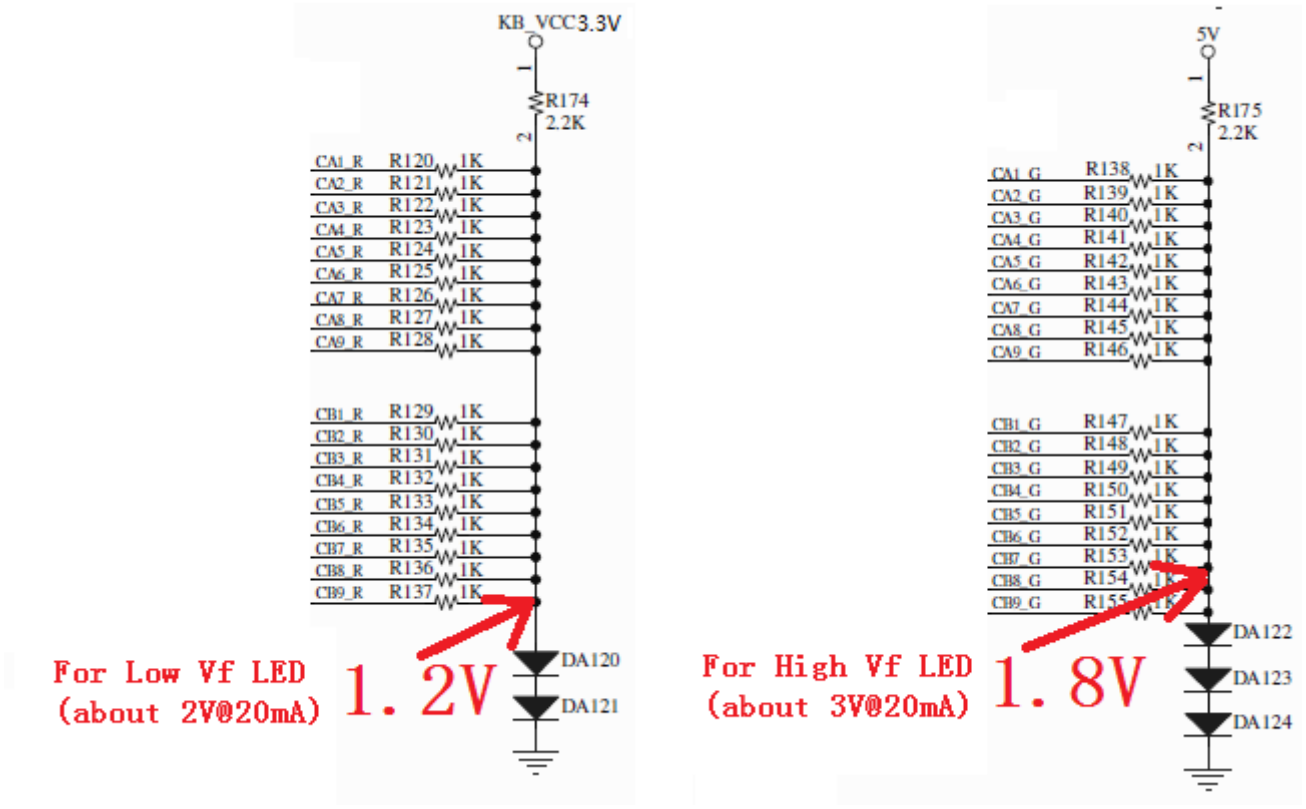



**Fig 26** Hardware ghost prevention reservation