IC Embedded Solutions of SMD LEDs

Application Note-

Hardware/Software Design Guidelines

AN1001
Ver.: 1.0

Abstract

With the world trend of LED matrix, strip and light string products becoming brighter, easier and simpler in design, LEDs with embedded IC chips have become a revolutionary practical concept that helps reduce costs and design complexity of the hardware and software, also can shorten the customer's product development timeline. LITEON provides a variety of IC solution packages to meet several different application requirements.
This application note clearly describes the practical circuit reference design and its required surrounding components, to help users reduce the design difficulty and shorten project development period. And provides the reference control code template. The purpose of this application note is to help users reduce unnecessary failures in the project development stages.

Scope

All LITEON SMD LEDs with IC Embedded P/Ns.

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A. Introduction of IC Embedded LEDs

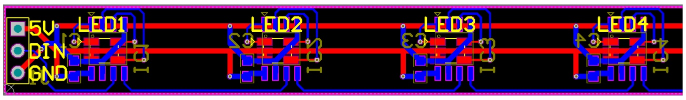
i. Why LEDs Need IC Embedded

The general full-color LED is controlled by the driver IC to perform various effect changes, such as breathing, flame, gradient, streamer, colorful, marquee and so on. In this traditional way of use, module manufacturers need to have a deeper understanding of both LED components and driver ICs to choose the most suitable combination. In case of an abnormality in the module, they have to determine the problem by themselves. Is it from the LED component or the driver IC.

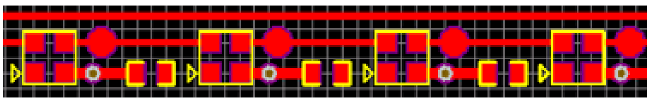
With the gradual prevalence of system integration and comprehensive solutions, products that combine LEDs and their driver ICs have also emerged. There are two main advantages of embedding IC into SMD LEDs:

1. Simplify the circuit design
   (a) Increase SMT yield due to simplified circuit
   (b) Same LED component price but lower overall cost
   (c) Reduce material costs for fewer electronic components required
   (d) Less space requirements
2. Make it easier to use
   (a) PWM full color mixing, all colors are controlled by code, not resisters
   (b) Commonality between projects, one LED meet all colors requirement
   (c) Uniform color from more concentrated CIE distribution
   (d) No need Vf binning, so no need groups of resistors to make many BOMs

For circuit design, the complexity of circuit can be dramatically dropped, and the PCB can be decreased from double later to single layer. But the function will maintain unchanged.



Double layer PCB - LEDs and driver ICs are used separately


Single layer PCB - When IC embedded into LEDs

For cost design, the components used are also deduced a lot. Here are back side of PCBs with/without IC embedded LEDs respectively.

B. LITEON IC Embedded Product Details – Product Line-up and Comparison

LITEON IC embedded series uses driver chips that come from high-end Taiwan-based IC-design houses. It contains 3 channels, PWM-embedded, and constant current output.

Product Type	Photo	Part No.	Package Size L x W x H (mm)	Embedded IC Control Signal (/each color)	IC Driving Current (/each channel)	Mix White Brightness Typical (mcd)	Current Adjustable (Yes/No)	Bypass Function (Yes/No)	Cascade Capability (max.)
PLCC		LTST-E563CEGBW	5.0 x 5.0 x 1.6	8-bit	5mA	900	No	No	120
		LTST-E563CEGB1W	5.0 x 5.0 x 1.6	8-bit	12mA	2000	No	No	Unlimited
		LTST-E563CEGB2W	5.0 x 5.0 x 1.6	8-bit	20mA	3000	No	No	Unlimited
		LTST-E563CHEGBW	5.0 x 5.0 x 1.6	8-bit	18mA	3200	No	No	1024
		LTST-E683CEGBW	3.5 x 2.8 x 1.9	8-bit	5mA	600	No	No	Unlimited
		LTST-E683CEGB1W	3.5 x 2.8 x 1.9	8-bit	12mA	1300	No	No	Unlimited
		LTST-E683CEGB2W	3.5 x 2.8 x 1.9	8-bit	20mA	1900	No	No	Unlimited
		LTST-E183CEGBW	1.8 x 1.8 x 0.6	8-bit	5mA	500	No	No	Unlimited
		LTST-E183CEGB1W	1.8 x 1.8 x 0.6	8-bit	12mA	880	No	No	Unlimited
		LTST-E183CEGB2W	1.8 x 1.8 x 0.6	8-bit	20mA	1250	No	No	Unlimited
		LTST-G353CEGB3W	3.5 x 3.5 x 0.95	8-bit	5mA	600	No	Yes	Unlimited
		LTST-G353CEGB4W	3.5 x 3.5 x 0.95	8-bit	12mA	1300	No	Yes	Unlimited
		LTST-G353CEGB5W	3.5 x 3.5 x 0.95	8-bit	20mA	1900	No	Yes	Unlimited
		LTST-G353CEGB7W	3.5 x 3.5 x 0.95	(10+4)-bit	5mA	1000	Yes	Yes	1024
		LTST-416CEGBW	4.5 x 1.7 x 1.6	8-bit	5mA	900	No	No	120
		LTST-416CEGBW-P	4.5 x 1.7 x 1.6	8-bit	5mA	600	No	No	Unlimited
		LTST-416CEGB1W-P	4.5 x 1.7 x 1.6	8-bit	12mA	1300	No	No	Unlimited
		LTST-416CEGB2W-P	4.5 x 1.7 x 1.6	8-bit	20mA	1900	No	No	Unlimited
ChipLED		LTST-E263CEGBK	1.8 x 1.8 x 0.65	8-bit	5mA	400	No	No	120
		LTST-E133CEGBK	1.3 x 1.3 x 0.4	8-bit	5mA	400	No	No	Unlimited
		LTST-E133HEGBK	1.3 x 1.3 x 0.4	8-bit	12mA	1200	No	No	Unlimited

Notes:

【E563C】: 5050 PLCC, 4-pins with 8-bit color grayscale.

【E683C】: 3528 PLCC, 4-pins with 8-bit color grayscale.

【E183C】: 1818 PLCC, 4-pins with 8-bit color grayscale.

【G353C-3/4/5W】: 3535 PLCC, 6-pins with 8-bit color grayscale. Bypass function.

【G353C-7W】: 3535 PLCC, 6-pins with 10-bit color grayscale, 4-bit current tunable. Bypass function.

【416C】: 4517 top/side view PLCC, 1.6t 6-pins with 8-bit color grayscale.

【416C-P】: 4517 top/side view PLCC, 1.6t 6-pins with 8-bit color grayscale. Cost design.

【E263C】: 1818 ChipLED, 4-pins with 8-bit color grayscale.

【E133C】: 1313 ChipLED, 4-pins with 8-bit color grayscale.

i. LED Chip Applied in the Packages

LITEON's IC embedded series products are using EPISTAR dice which provides mid-high intensity output to meet video/decorative/full color effects.

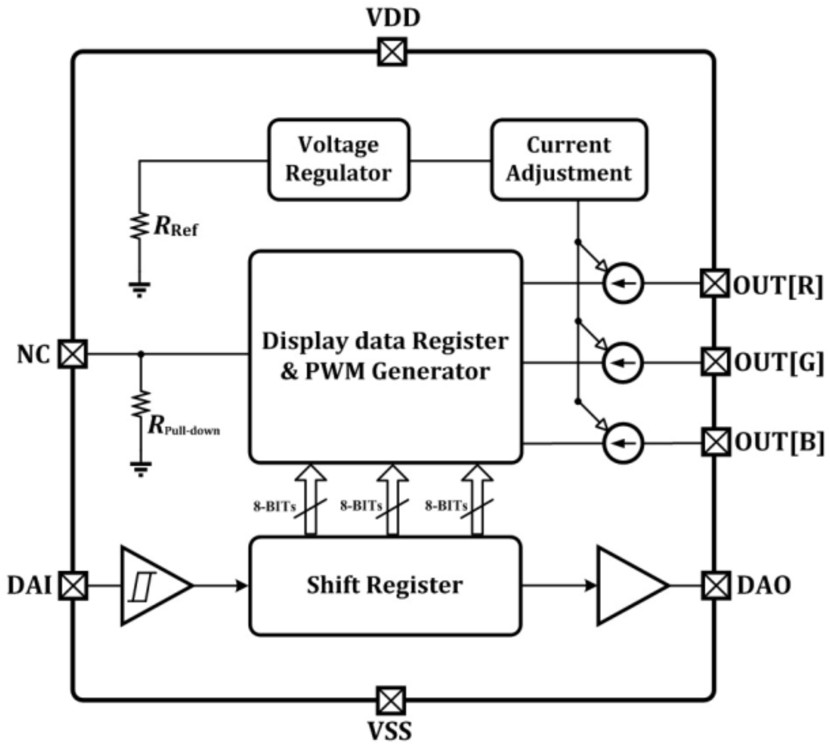
ii. Differences in Driver Chip Performances

LITEON provides two grades IC to meet normal and high-resolution applications.

	8-bit Driver IC	14-bit Driver IC
Grayscale	2^8 x 2^8 x 2^8=2^{24} colors	2^{10} x 2^{10} x 2^{10}=2^{30} colors
Current Tunable	NA	2^4 x 2^4 x 2^4=2^{12} steps
Serial Data Pin	Data_in, Data_out	Data_in, Data_out, Auxiliary Data_in
Clock Pin	No clock pin required	No clock pin required
VDD	4.2~5.5V	4.2~5.5V
Signal High Level	2.7/3.3V~VDD	3.3V~VDD
Signal Low Level	0~0.3VDD	0~0.3VDD
Current Setting (Fixed current)	5/12/18/20mA to LED dice	5mA to LED dice
ESD (IC)	8kV	8kV
Resume Data Transmission	Yes/No	Yes

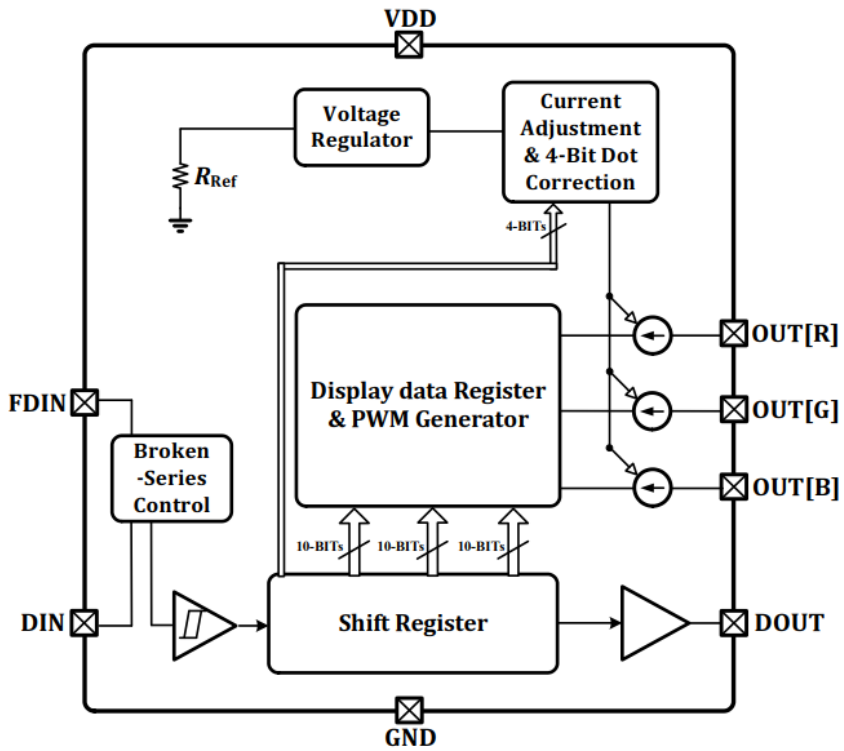
iii. Driver Operation Block Diagram

1. 8-bit Driver IC (8-bit PWM color grayscale)



Pad Names	Function Descriptions
NC	NC in the package
DAI	Serial DATA_IN
DAO	Serial DATA_OUT
VDD	Input DC voltage
VSS	Ground
OUT[R]	Connection to red LED dice
OUT[G]	Connection to green LED dice
OUT[B]	Connection to blue LED dice

2. 14-bit Driver IC (10-bit PWM color grayscale and 4-bit current tunable)



Pad Names	Function Descriptions
FDIN	Auxiliary Serial DATA_IN
DIN	Serial DATA_IN
DOUT	Serial DATA_OUT
VDD	Input DC voltage
GND	Ground
OUT[R]	Connection to red LED dice
OUT[G]	Connection to green LED dice
OUT[B]	Connection to blue LED dice

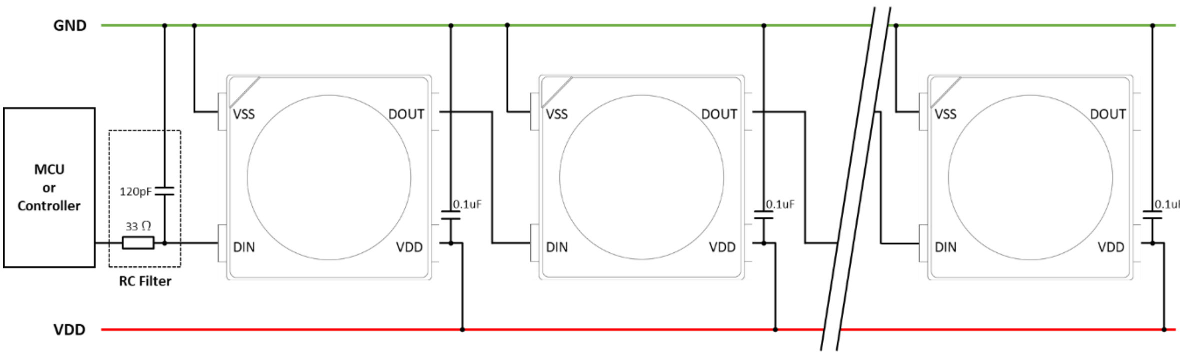
C. Circuit Design Guidelines and Precautions

i. For Normal Driver IC Embedded LEDs

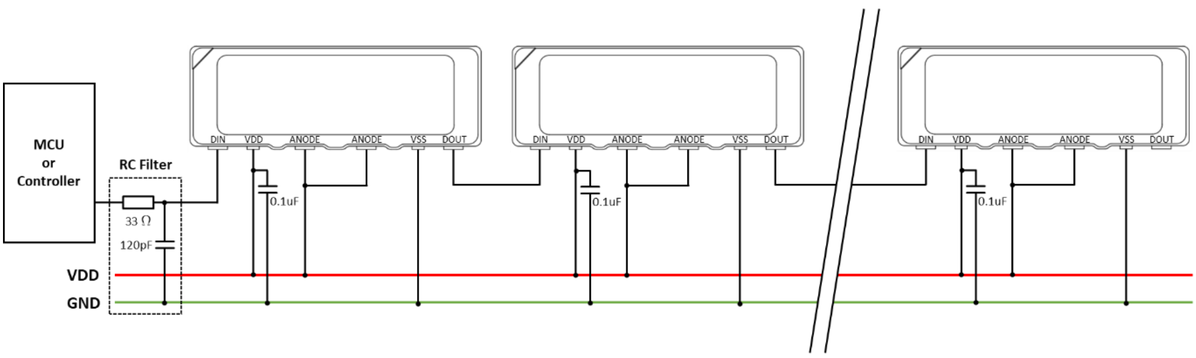
Cascading connection for normal driver IC embedded LEDs is shown as below. The data signal is transmitted one-by-one. The output of the previous one is connected to the input of the next one. As for the power positive and negative, all LED positives should be connected to VDD and all LED negatives should be connected to ground.

To ensure the function of LED driver IC work normally, every LED positive pin (should be IC Vcc and LED anode individually or commonly) need connect one capacitor. It can guarantee good power feed quality and cascade stability. The recommended capacitance value is 0.1uF. The capacitors should be placed as close to the LED pin as possible to maximize the effect. Besides, the quality of capacitors will affect the effect, too.

The RC filter is necessary to avoid the surge or noise to affect product work normally. The capacitance value 120pF and the resistance value 33ohm is just for reference. The most suitable value is calculated from $f_c = \frac{1}{2\pi RC}$. The f_c is different by cases and needs to be actually measured.



- An example for top view SMD LEDs cascading connection



- An example for top view SMD LEDs cascading connection

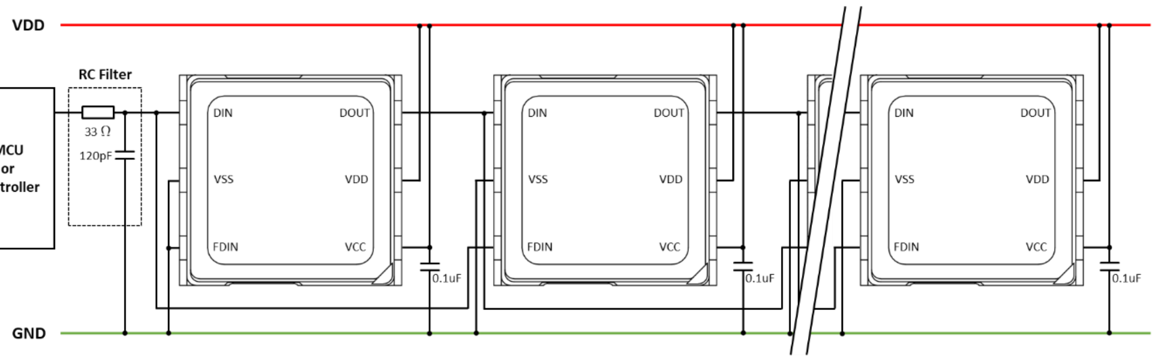
ii. For IC Embedded LEDs with Bypass Function

Cascading connection for IC embedded LEDs with bypass function is shown as below. The data signal is transmitted one-by-one. The output of the previous one is connected to the input of the next one. As for the power positive and negative, all LED positives should be connected to VDD and all LED negatives should be connected to ground.

To ensure the function of LED driver IC work normally, every LED positive pin (should be IC Vcc and LED anode individually or commonly) need connect one capacitor. It can guarantee good power feed quality and cascade stability. The recommended capacitance value is 0.1uF. The capacitors should be placed as close to the LED pin as possible to maximize the effect. Besides, the quality of capacitors will affect the effect, too.

The RC filter is necessary to avoid the surge or noise to affect product work normally. The capacitance value 120pF and the resistance value 33ohm is just for reference. The most suitable value is calculated from $f_c = \frac{1}{2\pi RC}$. The f_c is different by cases and needs to be actually measured.

The difference from normal driver IC embedded LEDs is the FDIN pin. It should be skipped the previous one and connected to the data output forward. In this way, if one LED fails, the other subsequent LEDs will not be affected and can work normally.



- An example for top view SMD LEDs with bypass function cascading

D. System Operation Timing Guidelines

i. For 8-bit Driver IC

E563C/E683C/E183C/G353C/416C/E263C/E133C product series use single communication wire for LED PWM control. After power on reset, the IC will fetch the first 24-bit data and latch to the shift-register itself. Then the second 24-bit data will be passed to next chip. The embedded IC has auto waveform reshaping amplification technology that makes it able to be used on long cascading applications. The LED PWM output controlled by duty ration which depends on the 24-bit data each for RGB outputs. All chips will latch new data when DIN port receives the reset signal (50us low-level signal).

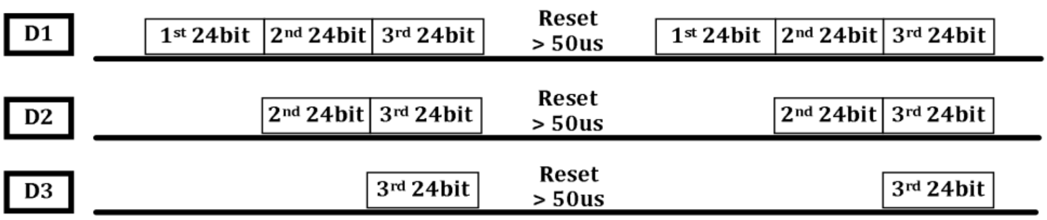


Fig. 1 Data Communication

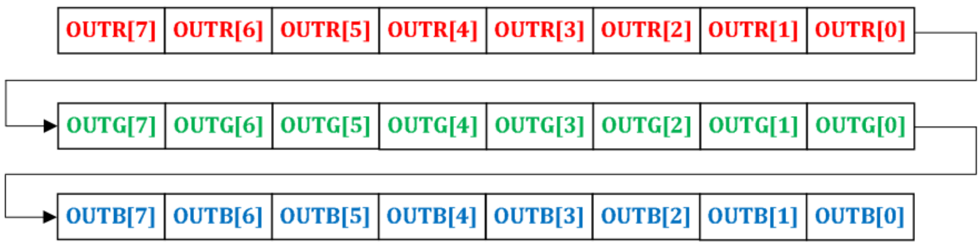


Fig. 2 Single Data in 24-bit for RGB

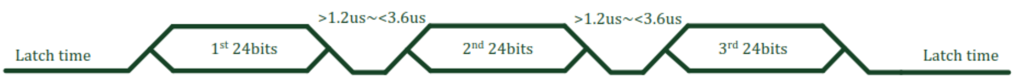


Fig. 3 Time Interval between 24bits signal

ii. For 14-bit Driver IC (4bits for current tunable; 10bits for color grayscale)

G353C product series uses single communication wire for LED PWM control. After power on reset, the IC will fetch the first 42-bit data and latch to the shift-register itself. Then the second 42-bit data will be passed to next chip. The Embedded IC has auto waveform reshaping amplification technology that makes it able to be used on long cascading applications. The LED PWM output controlled by duty ration which depends on the 42-bit data each for RGB outputs. All chips will latch new data when DIN port receives the reset signal (50us low-level signal).

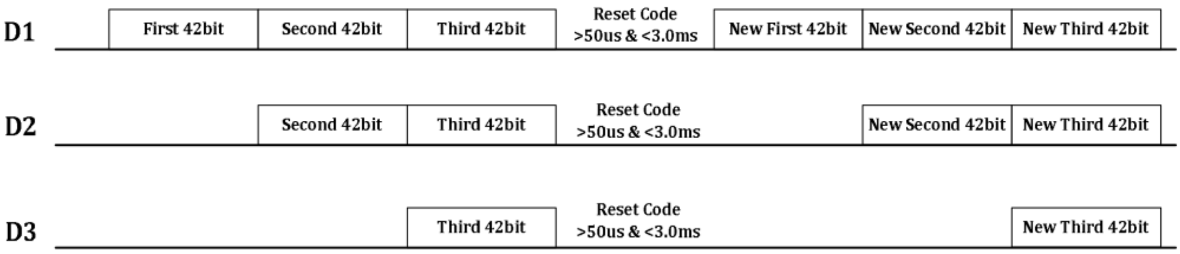


Fig. 1 Data Communication

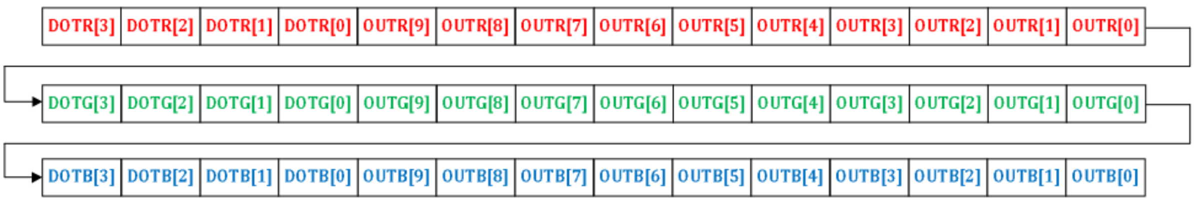


Fig. 2 Single Data in 42-bit for RGB

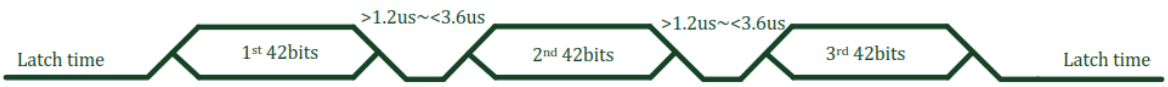
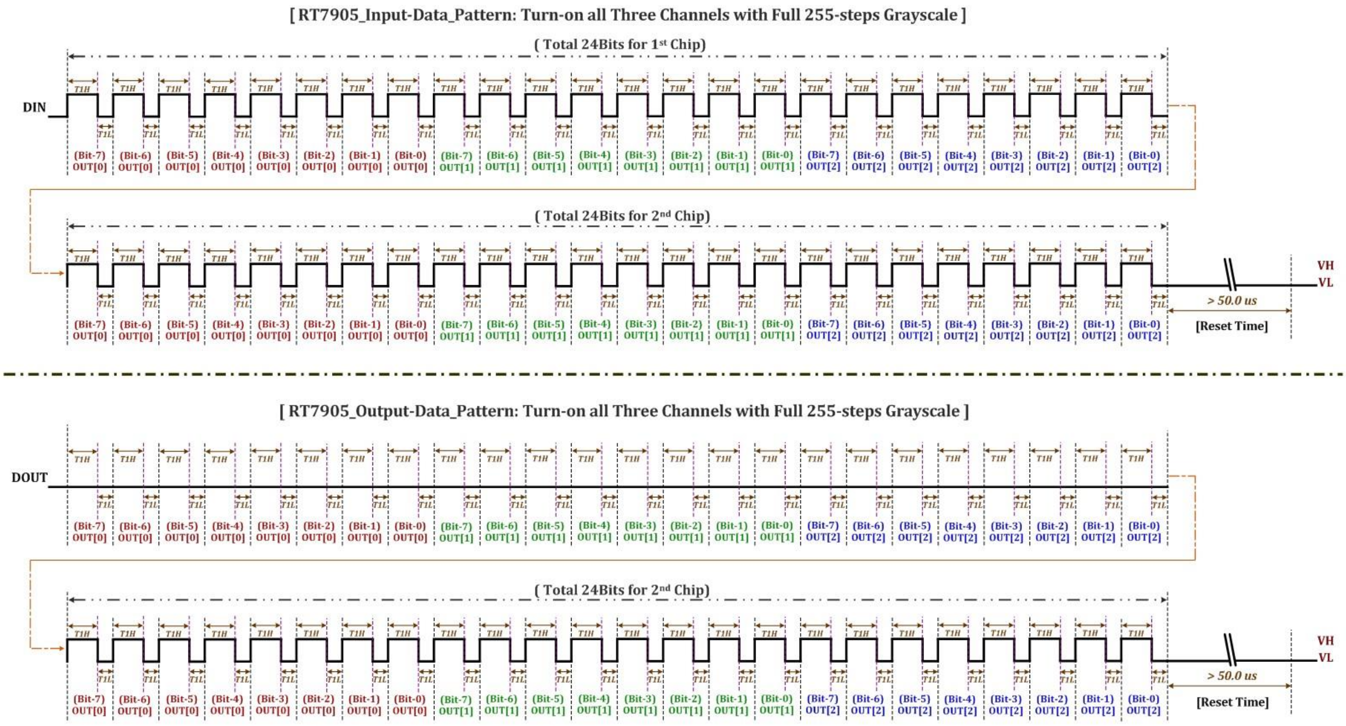


Fig. 3 Time Interval between 42bits signal

E. Reference Waveform Timing

i. Take 8-bit IC for example: (DIN / DOUT) – Serial Connection for Two LEDs



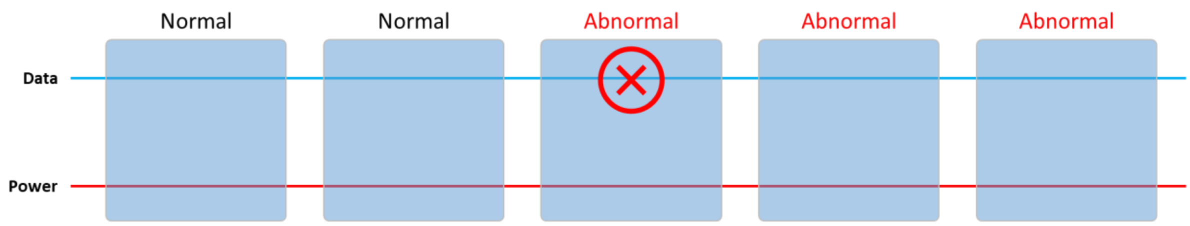
Notes:

LITEON P/N	T0H	T0L	T1H	T1L	Allowance
8-bit IC	300ns	900ns	900ns	300ns	80ns
14-bit IC	300ns	900ns	900ns	300ns	80ns

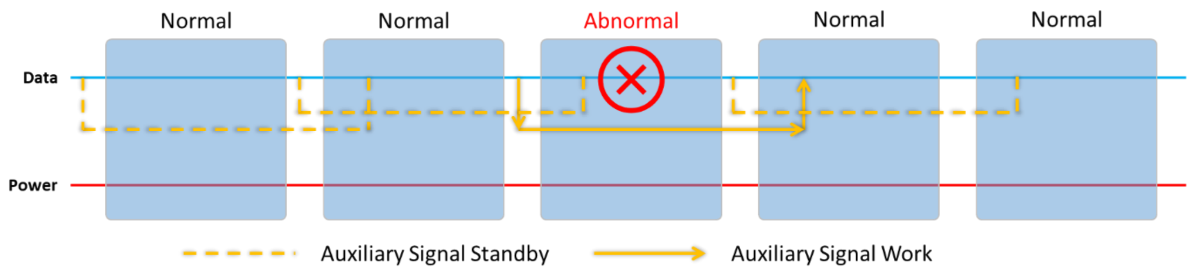
Appendix

i. Bypass Function Brief Introduction

For normal IC embedded LEDs, all LEDs of matrix or strip are controlled by the signal output from MCU and transmitted from beginning to end. If anyone has a problem, all LEDs behind will be affected. Out of control phenomenon may be flickering, colors abnormal, or even not light up.



To improve the situation, bypass function is developed. It can skip the abnormal and make behind LEDs work normally(The prerequisite is normal power supply). When LEDs work normally, the control signal is transmitted via the data wire. If any LED cannot receive control data, the auxiliary pin FDIN will be active and get normal data from the one in front of the abnormal LED. So that the LEDs behind can work normally.



The bypass function has some limitations. When two consecutive LEDs fail, the function will be invalid. If the source signal is abnormal, the problem cannot be solved by the feature, either. Even so, this feature is very useful. The module-level abnormal can be reduced to point-level as long as the LEDs have the bypass function.

ii. Sample Code for 8-bit Driver IC

```
int main (void)
{
        PE12 = 0;
        GPIO_SetMode(PE, BIT12, GPIO_PMD_OUTPUT);        //set pin to GPIO mode
        8bitIC_RGB_Data(0xFF, 0x00, 0x00);               //R
        8bitIC_RGB_Data(0x00, 0xFF, 0x00);               //G
        8bitIC_RGB_Data(0x00, 0x00, 0xFF);               //B
        HighSpeedReset();
}

void HighSpeedReset(void)
{
        PE12 = 0;
        for(int i = 0; i< 250; i++)                      //delay time setting   <50us
        {
            __nop();                                     //should follow clock rate
        }
}
```

```
void 8bitIC_RGB_Data(char r, char g, char b)
{
	char RGB_Data[3] = {r, g, b};
	char Data_out[8] = {0x80, 0x40, 0x20, 0x10, 0x08, 0x04, 0x02, 0x01};
	for(int RGB_count = 0; RGB_count<=2; RGB_count++)		//R->G->B
	{
		for(int out_count = 0; out_count<=7; out_count++)
		{
			if(RGB_Data[RGB_Count] & Data_out[out_count] == out[out_count])
			{
				PE12 = 1;			//T1H: 900ns   follow DS spec of data transfer time
				__nop();__nop();__nop();	//amount of __nop() should follow clock rate
				PE12 = 0;					//T1L: 300ns
				__nop();
			}
			else
			{
				PE12 = 1;					//T1H: 300ns
				__nop();
				PE12 = 0;					//T1L: 900ns
				__nop();__nop();__nop();
			}
		}
	}
}
```

About LITEON

Founded in 1975, LITEON Technology is the longest running and largest-scale optoelectronic components supplier in Taiwan; based on the strong R&D resources, LITEON has been able to cover extensive optoelectronic product lines including White LEDs, SMD LEDs, Lamp LEDs, LED Displays, Photo-couplers, Infrared Components etc. And it's proven to be the leader in total optoelectronic components solutions.

Optoelectronic components from LITEON have been highly acclaimed and used by leading brands of information products, consumer electronics, and communication equipment. LITEON optoelectronic components are widely used for applications ranging from indicators and displays of household electronic appliances, backlights of personal handheld devices and IT products, to active and passive lights in car electronics, industrial optoelectronic sensors, and light sources for all purposes.

Building on its professional packaging designs and sophisticated manufacturing experiences, LITEON Technology not only has been able to provide customers with high-quality optoelectronic components solutions, but also has been constantly pursuing for high-performance and low-pollutant light sources as its major goal.

As one of the world's leading producers of optoelectronics, LITEON OPTO has sustained stable growth since it was founded in Taiwan in 1975. The key to our success is to monitor the market trends closely and develop products ahead of our competition. Most importantly, we delight our customers with expedient, reliable services around the globe.

As one of the worldwide major suppliers of opto- devices supplies, LITEON OPTO is forging ahead with new product development. We are developing visible opto- products such as ultra-bright LEDs for outdoor applications, full color displays, and a variety of surface mount LED devices. For product outside the visible range, we offer infrared emitters, detectors, photointerrupters, and photocouplers.