Design Guide for Local Dimming Backlight System with TLC6C5748-Q1

Caryss Li ***caryss-li@ti.com***

To enhance LCD display performance, local dimming backlight is more and more popular especially in large screen size displays and automotive displays. In Local Dimming backlight, LEDs under the LCD panel are divided into many small zones. The luminance range of individual zones is dynamically adjusted to better align with the content. The individual current control is realized by LED drivers and each zone is controlled separately by each channel.

TLC6C5748-Q1 is the latest automotive LED driver designed for local dimming in automotive displays. The enhanced contract ratio perfectly fits the content with navigation, cluster, infotainment etc. in vehicles.

With dramatically increment of LED counts and dozens of LED drivers, the backlight system design is quite different from conventional design. This article is a design guide for fresh users to grounds-up build a local dimming backlight system.

1. Local Dimming System Architecture.

LED Position: In conventional LCD module, the backlight is "Edge-lit", which means the LEDs are placed at the edge of the LCD module and light is coupled into a light guide-plate [1]. While in local dimming applications, dense array of LEDs facing the viewer and coupled into a diffuser sheet[1], which called "Direct-lit". Fig 1 shows the basic structure of LCD panel and the place of backlight LEDs.

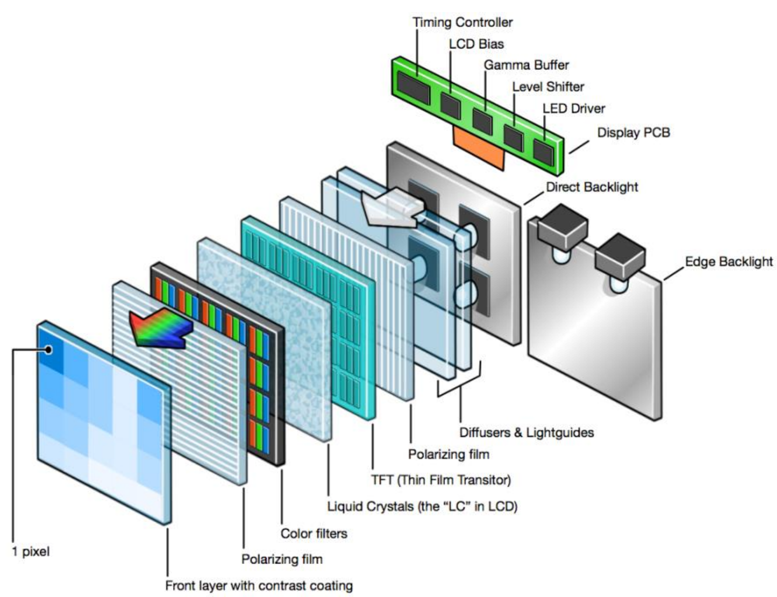

Fig 1, LCD panel structure and backlight LED placement [2]

Local Dimming System Architecture: the LCD module system is consist of three parts: 1. Timing controller (TCON), 2. LED backlight unit and 3. LED drivers. The SPI interface marked in red in Fig 2, is new in local dimming system. Since the backlight is dynamically changed according to display content, the dimming signal comes from TCON as well.

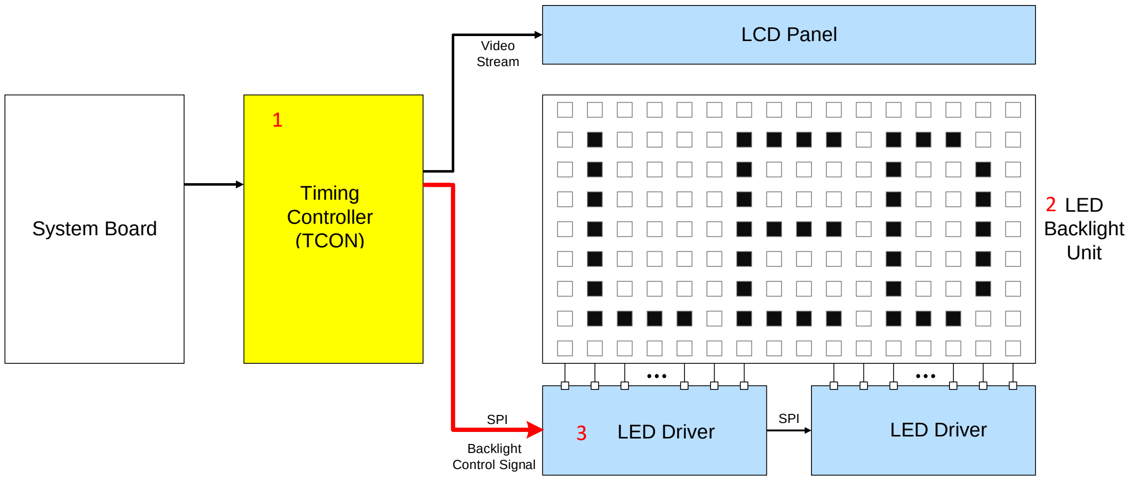

Fig. 2 Local dimming system architecture.

2. Local dimming design considerations:

1. Hardware construction:

As indicated above, there are 3 main elements in the system; there are several ways to place them:

1.1 Separated LEDs and LED drivers

This is a traditional way to place LED driver. The LEDs are mounted on its own board, which is usually the same size as the LCD panel. The LED drivers and TCON are placed on another board. This is used in global dimming application, the LED count for edge lit is small, usually there is flex PCB strip use to place LEDs.

1.2 LEDs and LED drivers on the same board.

This is the most cost-effective way to build the backlight system. In Local dimming design, the LED count is large and the LEDs are place behind the LCD panel and the LED PCB is the same size as the LCD panel. To save the cost, the other side of PCB could be used to place the LED drivers. Besides, with TLC6C5748-Q1, a simple 2-layer PCB is enough to accomplish circuit layout.

This is the way we recommended to build the LED backlight unit.

2. LED Driver Design

Bases on above definition about local dimming, there is some basic information about system requirements to design a new local dimming system.

First of all is the zone number in the LED Backlight unit and how is the LED configuration in each zone. The total LED current and LED forward voltage are also needed. Based on these requirements, the channel numbers are clear. TLC6C5748-Q1 is a 48CH device, for each channel, the maximum current could be as high as 31.9mA and supports up to 10V LED power supply. So the total LED driver counts could be calculated.

For example, a 480-zone local dimming system is required in a 15 inch cluster panel. Each zone is consist of four LEDs, which is two in serious in one string and two strings in parallel, shown as below. The LED Vf is 2.7V at the maximum current of 5mA. So each current sink in TLC6C5748-Q1 needs to driver 10mA and endure 5.4V+Vhr voltage, which is call VLED. As a result, there are total 10 pcs of TLC6C5748-Q1 in this system.

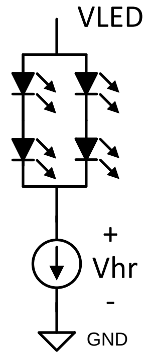

Fig3. LED configuration for each current sink

The endurable maximum voltage in this case would be higher than 5.4V. Vhr is the headroom voltage of each current sink which is the knee voltage needed to support desired constant current. In TLC6C5748-Q1, Vhr= 200mV could be used to estimate the headroom voltage when current lower than 20mA. Actually, 5.4V is usually the typical condition; the highest LED voltage shall be taken into account during low temperature and different LED bins. VLED comes from prior stage DC/DC converters. As you can see, the DC/DC converter must have the capability to drive at least 4.8A output current and keep the VLED ripple small during load transient.

3. Timing Controller (TCON) Selection

The interface of TLC6C5748-Q1 is quasi SPI interface. There are four terminals: GCLK/SCLK/SIN/LATCH. The detailed description is referred to datasheet. There are several mature TCONs in the market support the protocol of TLC6C5748-Q1. HX8880-D/E version from Himax and NT51360TT from Novatek are popular candidates.

4. LED Backlight Unit

According to the zone numbers and LED configurations, the total LED counts could be derived. Usually there will be hundreds of LEDs and several LED drivers. Since each TLC6C5748-Q1 could support 48 zones, it is the best way to place the related 48 zones of LEDs around the LED driver. And the LEDs could be on the top side and the LED driver is on the bottom side. In TLC6C5748-Q1, pin4 to pin 27 and pin 30 to pin 53 drivers each LED zone, they could be controlled individually.

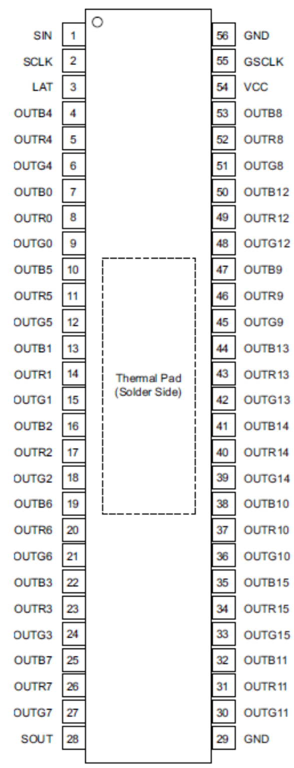

Figure 5-1. DCA Package HTSSOP-56 (Top View)

Fig. 4, TLC6C5748-Q1 pin out.

For example, there are 3 TLC6C5748-Q1 in one row and each control 48 zones, shown as below. The numbers in each rectangle represents the pin number of TLC6C5748-Q1. The number around the rectangle is the LED zone matrix, they consist of 8 rows and 18 columns, together 384 zones.

8	6	5	4	53	52	51	6	5	4	53	52	51	6	5	4	53	52	51
7	9	8	7	50	49	48	9	8	7	50	49	48	9	8	7	50	49	48
6	12	11	10	47	46	45	12	11	10	47	46	45	12	11	10	47	46	45
5	15	14	13	44	43	42	15	14	13	44	43	42	15	14	13	44	43	42
4	18	17	16	41	40	39	18	17	16	41	40	39	18	17	16	41	40	39
3	21	20	19	38	37	36	21	20	19	38	37	36	21	20	19	38	37	36
2	24	23	22	35	34	33	24	23	22	35	34	33	24	23	22	35	34	33
1	27	26	25	32	31	30	27	26	25	32	31	30	27	26	25	32	31	30
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Fig. 5 top view of LED zone matrix on LED Backlight unit.

Then the next thing is allocate the LED drivers. Usually there are more than 3 LED drivers in one backlight unit, it is recommended to place the LED drivers clockwise or counterclockwise in U shape. Avoid placing the LED drivers in Z shape. Sometimes there are some mechanical constrains brought by connector, but make sure the LED drivers shall be goes with one direction. Below is an example of 6 TLC6C5748-Q1 in one LED backlight unit, seen from bottom view. The connector is on the left, then the first unit is U101, and goes to U102, U103… U106. This is good for layout, which will be described later.

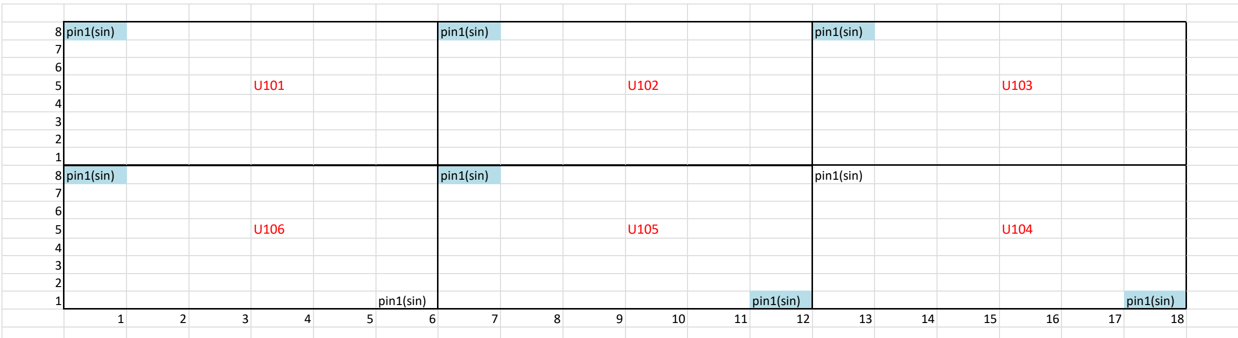

Fig. 6 Bottom view of 6 TLC6C5748-Q1 allocations.

Please note that, this LED zone matrix and LED drivers' placement shall be designed before the software. Each LED zone is dimmed individually, all the LED drivers are in daisy chain, so the sequence of each LED driver and LED zones are very important to software engineer to control the dimming signal sequence.

5. Layout Guidance for Backlight Unit

5.1 LED layer:

It is recommended to place more copper on LED cathode to help LED thermal dissipation. Below is two kinds of layout, but the lower one is preferred. There are two LEDs in series and the yellow part represents PCB copper area.

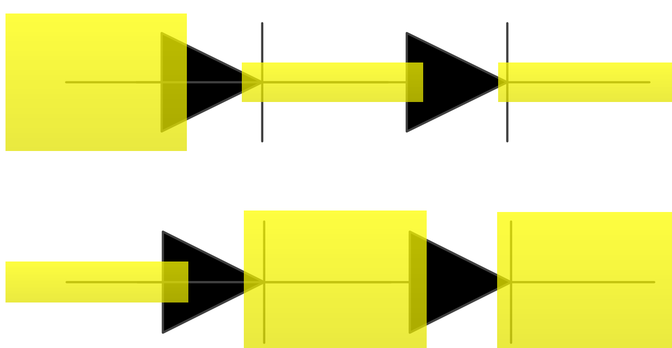

Fig.7. LED layout

5.2 LED driver layer

Fig 8 provides an example of six TLC6C5748-Q1 layout. The input connector is at the top-left corner, then six LED drivers are cascaded. The signal traces from top to bottom is GSCLK, SIN, SCLK. LAT, SOUT. There are two basic rules of the layout:

1) Leave enough space for GND copper as much as possible for each LED driver

2) Less branches from signal BUS such as GSCLK, SCLK, LAT. Especially for GSCLK , it is usually in tens of MHz. More branches will lead to bad signal integrity.

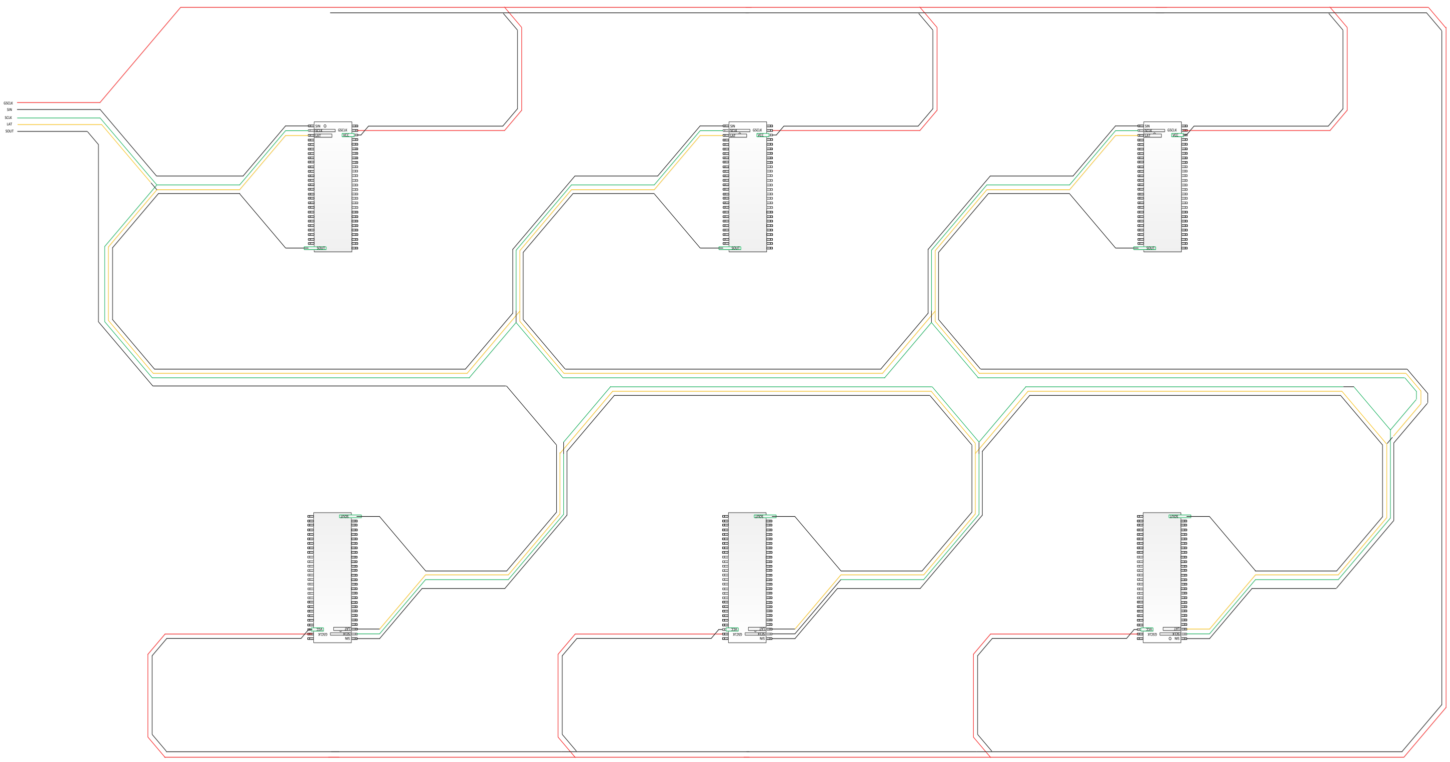

Fig. 8 Layout example for six TLC6C5748-Q1 cascaded.

As shown in Fig.8, all the signal traces are placed away from LED drivers, and there are planty of spaces for GND copper. The GSCLK is at the outer side, the SCLK/LATCH/SIN(SOUT) are at the inner side.

The current sink pin is connected to LED cathode on the other layer through via. It is recommended to place vias close to LED drivers, and using the top layer to place LED traces.

6. Check Single Integrity

When the backlight unit is quite large, especially in cockpit applications, the aspect ratio of the LED screen is large, so the GSLCK trace will be very long. When the signal frequency is very high, the signal integrity is impacted. The CLK signal is no long in square shape, and it will interference LED driver logic. Below is an example of bad signal integrity.

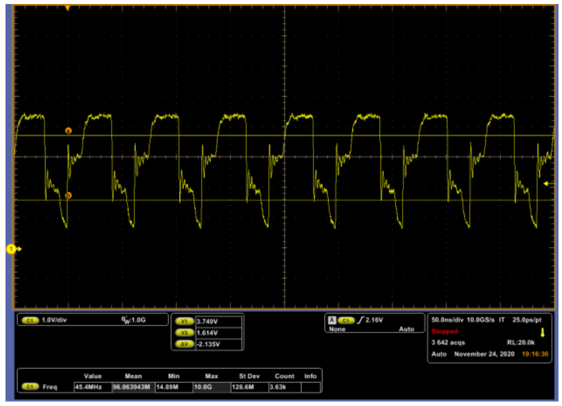

Fig. 9 Bad signal integrity.

There are some termination technologies to solve this problem, either put a resistor in series and close to the source or put two resistors at the end of the trace. It is recommended to put a buffer right after the connecter to give enough drive capability and with some termination resistors, the signal could be good and the DC voltage is not impacted too much. Fig. 10 shows the GSCLK with buffer added.

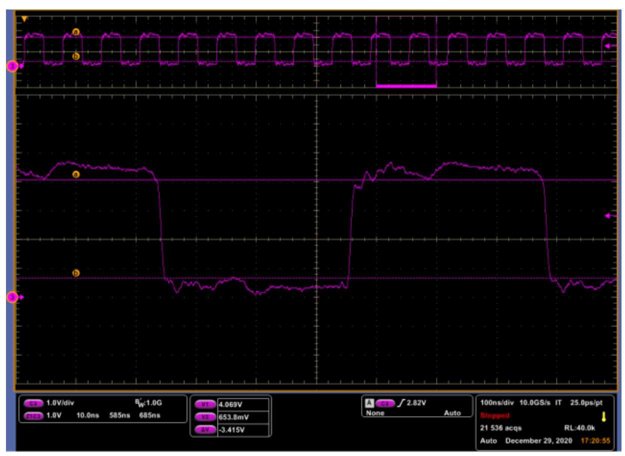

Fig. 10. Good signal integrity with buffer used for GSCLK

7. Reference Code

TI provides reference code with MSP432 lauchpad. Please contact TI for support.

Reference:

1. MiniLED Displays 2019 Market and Technology Report 2019—Yole Development

2. https://www.dealmoon.com/cn/materials-understanding-tv-features/784279.html