Application Report
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Use TLC59283 for LED Indication with Better Brightness Uniformity, Smaller Size, and Ghosting Elimination

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ABSTRACT

With the blossoming of AI (Artificial Intelligence) and IoT (Internet of Things), more and more end equipments use larger quantities of LEDs to show different statuses or functions. From the HMI (Human Machine Interface) perspective, LED indication, including LED-based seven-segment, dot-matrix displays, and a large quantity of LED indicators are bringing new dimensions of versatility and eye-pleasing visual effects to a growing number of applications. This application report showcases how to use the TLC59283 to drive seven-segment, dot-matrix displays or a large quantity of LEDs with the advantages of better brightness uniformity, smaller size, and ghosting elimination over current solutions.

Contents

List of Figures

List of Tables

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1 Introduction

When you take a look at the surrounding electronic equipment, seven-segment and dot-matrix displays are widely used as human machine interface. Seven-segment displays like Figure 1 are used in digital clocks, electronic meters, appliances, and other electronic devices to display numerical information while dot-matrix displays like Figure 2 are used to represent characters, symbols, and images.

Figure 1. Seven Segment Display

Figure 2. Dot-matrix Display

Since AI and IoT are quite popular nowadays, more and more end equipments use larger quantities of LEDs to show different statuses or functions. Taking a smart home as an example, you can find a lot of LEDs including LED indicators, seven-segments, and dot-matrix displays.

This tutorial takes a detailed look at the essential technical principles of seven-segment and dot-matrix displays and shows how to use the TLC59283 to achieve better display performance over current solutions.

2 LED Indication Application Analysis

Current solutions for driving LED indication including LED-based seven-segment, dot-matrix displays, and a large quantity of LED indicators can be categorized to three types:

- Directly driven by I/Os
- Controlled by shift registers
- Time-multiplexed using shift registers and transistors

If the total LED count is less than eight, controller I/O is usually applied to control the LEDs as in Figure 3. For the LED that only needs a several mill-ampere current, it can be driven directly through I/Os like (a) in Figure 3. If the LED needs several decades of mill-ampere current, transistors or MOSFETs can be used like (b) in Figure 3 to enlarge the current ability. Either of these configurations need a current limit resistor to set the current to a certain level and prevent the LED from blowing up.

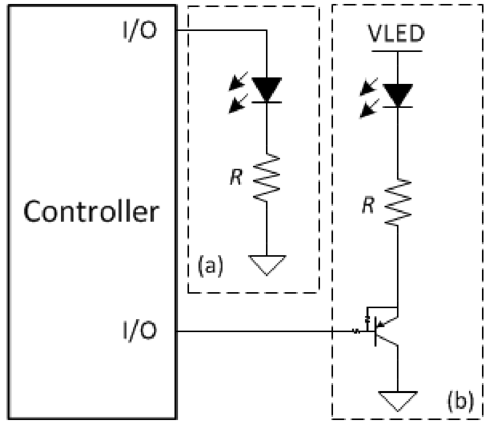

Figure 3. LEDs Directly Driven by I/Os

To drive seven-segment displays or LED count higher than eight, shift registers like 74HC595 or 74HC164 are used to save I/O count. Taking two seven-segment displays (16 LEDs) for example, can use two 74HC595 or 74HC164 plus 16 current limit resistors as in Figure 4.

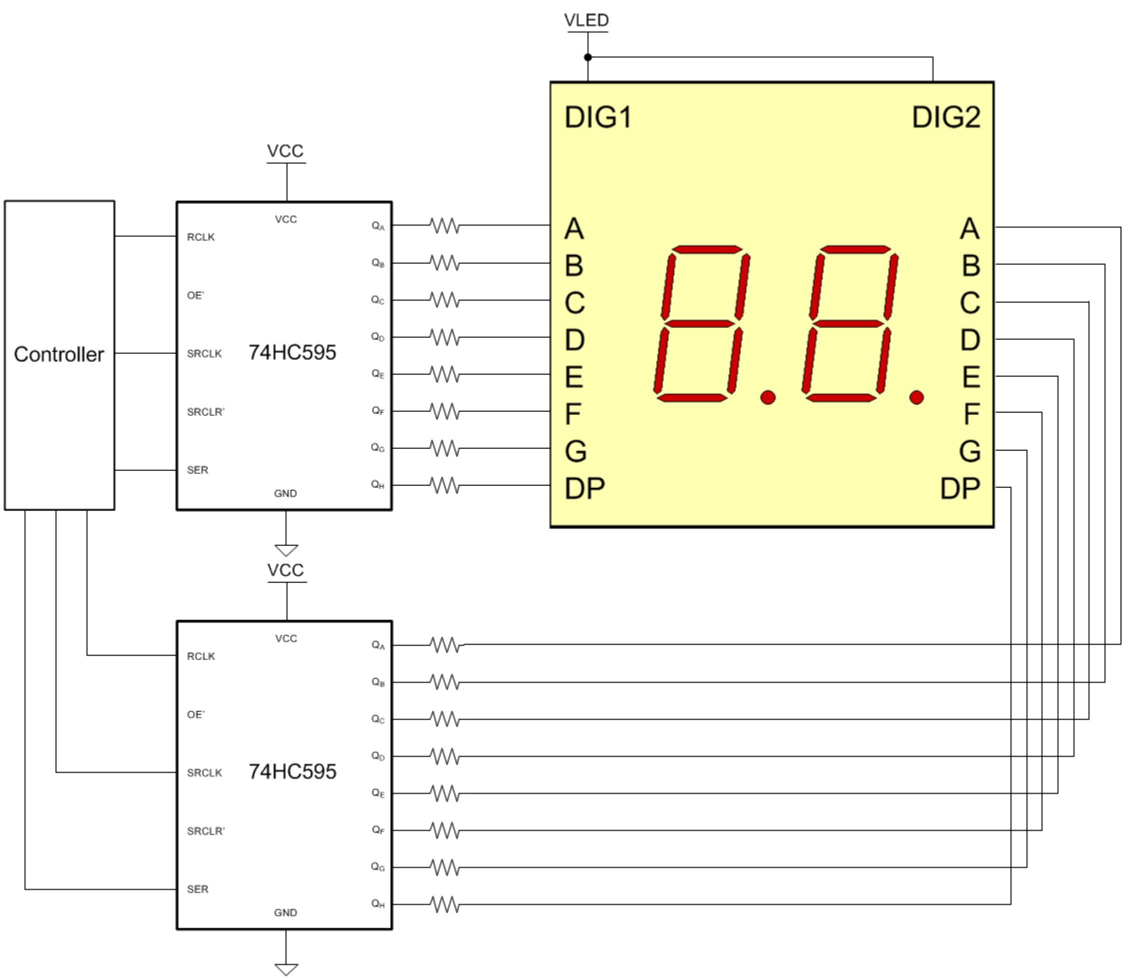

Figure 4. Two Seven-segment Displays (16 LEDs) Controlled by Shift Registers

Considering drive dot-matrix display or more than 20 LEDs, time-multiplexing is widely used to reduce system building cost. Usually the 74HC595 and ULN2003 are used to form this driving circuit as in Figure 5. In this circuit, one 74HC595 is used as current sources while the ULN2003 is used as common current sinks and each current sink turns on at a time so that each LED can be individually controlled. Since the switching frequency is higher than 60 Hz, the human eye does not identify the difference with static control or direct control.

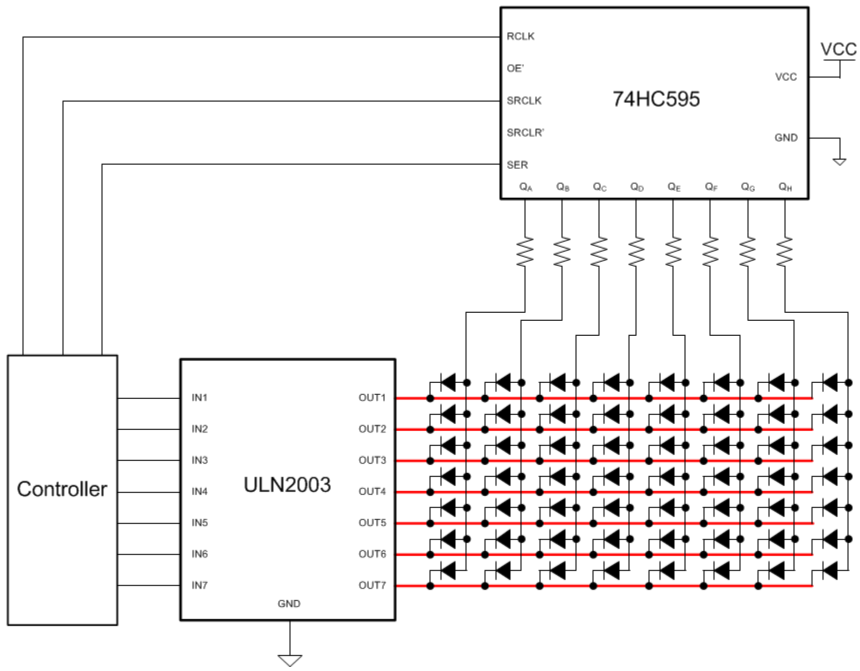

Figure 5. Time-multiplexed LED Matrix by Shift Registers and Transistor Arrays

The main challenges for the above three solutions come from three aspects:

- Non-constant current results to bad LED brightness uniformity
- Big size requires large PCB area
- Ghosting issues usually occur in time-multiplexing topology

It is well-known that an LED starts turning ON with enough forward voltage (V_F) and when the LED is ON, the forward current determines the brightness. As you can see from the LED I-V curve in Figure 6, a small shift of the forward voltage results in a big difference of the forward current and this causes brightness variation or can even blow up the LED. Due to the accuracy of the resistors and the variation of the LED forward voltage, the final current is not a constant value so it is hard to ensure the brightness uniformity.

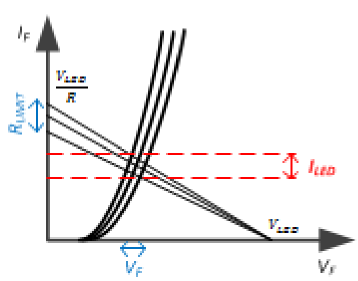

Figure 6. LED I-V Characteristics and Non-constant LED Current Solution

The size is another problem. As Figure 4 shows, it needs two shift registers and up to 16 current limit resistors, so the size is quite big which usually needs large PCB area and brings more cost.

Ghosting is very common in time-multiplexing LED displays. Figure 7 shows what ghosting looks like in seven-segment and dot-matrix displays. Ghosting is an unwanted side effect caused by LED Anode "float", which means the common lines are not discharged quickly due to parasitic capacitance and this causes the LED to briefly turn on. Refer to the 16-Channel, Constant-Current LED Driver with Pre-Charge FET Datasheet for the mechanism of this issue.

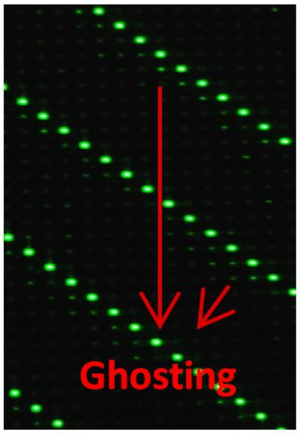

Figure 7. Ghosting Phenomenon in Time-multiplexing Circuit

To improve the display performance and solve the problems that were previously discussed, constant-current, small-size, and ghosting-elimination circuits are required, and the TLC59283 is a good choice.

3 Use TLC59283 to Get Better Brightness Uniformity with Smaller Size and Ghosting Elimination

This section introduces the TLC59283 and how to use it to avoid the problems in current solutions.

The TLC59283 is a 16-channel, constant-current sink LED driver. Each channel can be individually controlled with a simple serial communications protocol which can be controlled through SPI interface or GPIOs.

3.1 High Accuracy Constant Current Sinks Ensure Brightness Uniformity

Figure 8 shows a typical application. It uses one TLC59283 to drive two seven-segment displays (16 LEDs). The constant-current values for the 16 channels are determined by an external resistor (R_{IREF}) placed between IREF and GND. The current can be adjusted from 0 mA to 45 mA, which is enough for most LED indication applications.

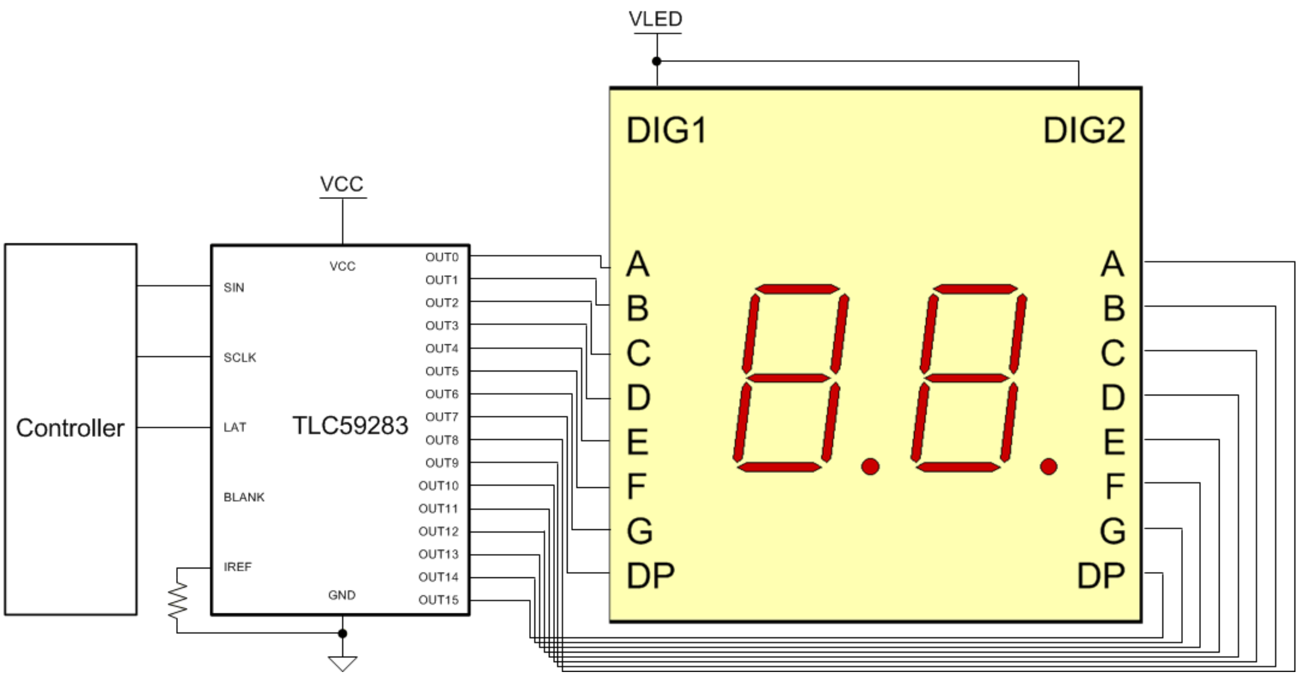

Figure 8. Use TLC59283 to Drive Two Seven-segment Displays (16 LEDs)

The TLC59283 has high accuracy current sinks and the current error between each two channels is less than 3%. As a benefit of the high accuracy current sinks, all 16 LEDs have the same forward current so the brightness uniformity is ensured regardless of the LED forward voltage variation, which is shown in Figure 9.

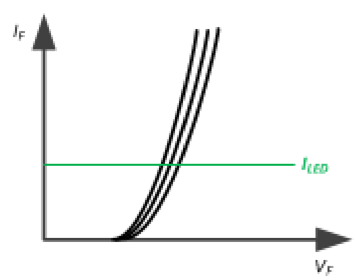

Figure 9. TLC59283 Ensures Constant Current for Fetter LED Brightness Uniformity

3.2 High Integration Saves PCB Size

One TLC59283 can drive up to 16 LEDs directly, so it can replace two 74HC595 and the current limit resistors if driving two seven segment displays. Figure 10 makes a simple comparison and the PCB size is 65% smaller using the TLC59283. If you are using the QFN package, the size is even smaller.

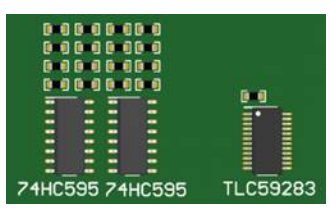

Figure 10. TLC59283 Offers a Smaller PCB Size than Shift Registers

3.3 Pre-Charge FET Circuit Eliminates Ghosting

Ghosting phenomenon, spike noise, or phantom noise are unwanted side effects caused by LED Anode "float" which may occur in time-multiplexing LED driving circuits. Since LEDs (PN junction of diodes) have relatively high levels of capacitance, their residual charge can keep triggering capacitive charge transfers between the floating nodes. Every time there is forward electron flow through a PN junction, it is forward-biased and emits light.

The situation where this phenomenon is most obvious is a diagonal line image. The TLC59283 employs a "pre-charge FET" circuit which eliminates these ghosting effects in Figure 11. As explained earlier, the root cause of ghosting is stray charges on the anode of the LED which forward-bias its PN junction and cause it to light at unwanted times. These pre-charge FETs are designed to ensure the LEDs remain reverse-biased so that the ghosting is eliminated.

Figure 11. TLC59283 Eliminates Ghosting with Pre-charge FET

4 TLC59283 Design Example for Time-multiplexing LED Matrix Display

This section show how to use the TLC59283 to drive the LED matrix using time-multiplexing topology.

Table 1. TLC59283 Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
LED count	64
Average current per LED	5 mA
Display frame rate	60 Hz

To form a time-multiplexing topology, it is necessary to add external switching MOSFETs or transistors.

If there is enough I/Os in the system to control the transistors, a block diagram like Figure 12 can be used to drive 64 LEDs. It uses four PNP transistors to switch the common lines and forms a 4-multiplexing scheme. Each transistor turns on for 4 ms and it can realize a 60 Hz frame rate. Since it is 4-multiplexing, to get 5 mA average current, the output current of the TLC59283 can be set as 20 mA by the R_{IREF}.

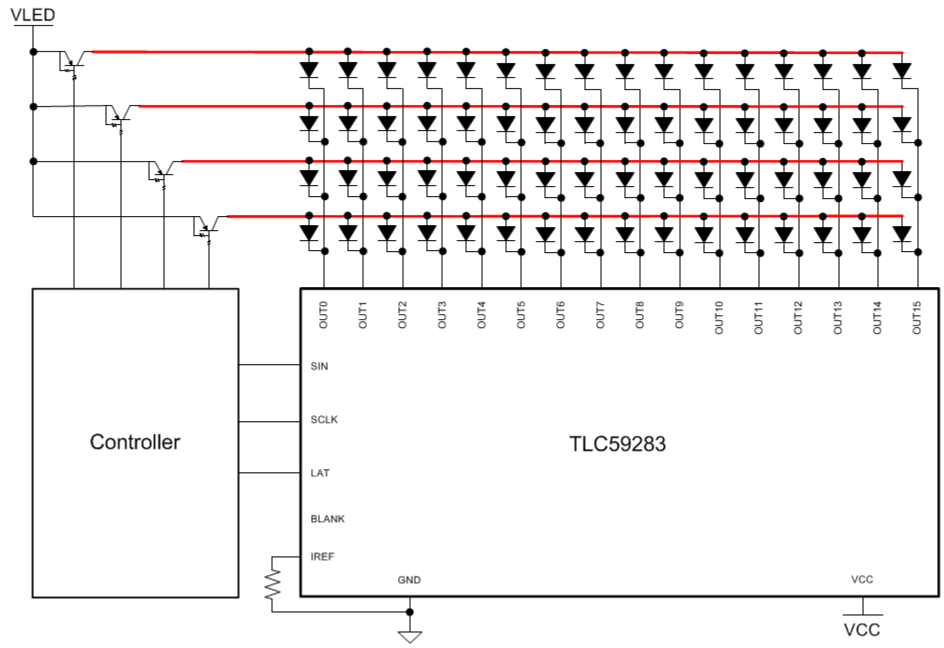

Figure 12. Time-multiplexing Circuit Using TLC59283 and Enough I/Os

If there are not enough I/Os in the system to control the transistors, a block diagram like Figure 13 can be used to drive 64 LEDs. It uses eight PNP transistors to switch the common lines and forms a 8-multiplexing scheme. The eight transistors are controlled by the outputs of the TLC59283 so it reduces the I/O count. Each transistor turns on for 2 ms and it can realize a 60 Hz frame rate. Since it is 8-multiplexing, to get 5 mA average current, the output current of the TLC59283 can be set as 40 mA by the R_{IREF}.

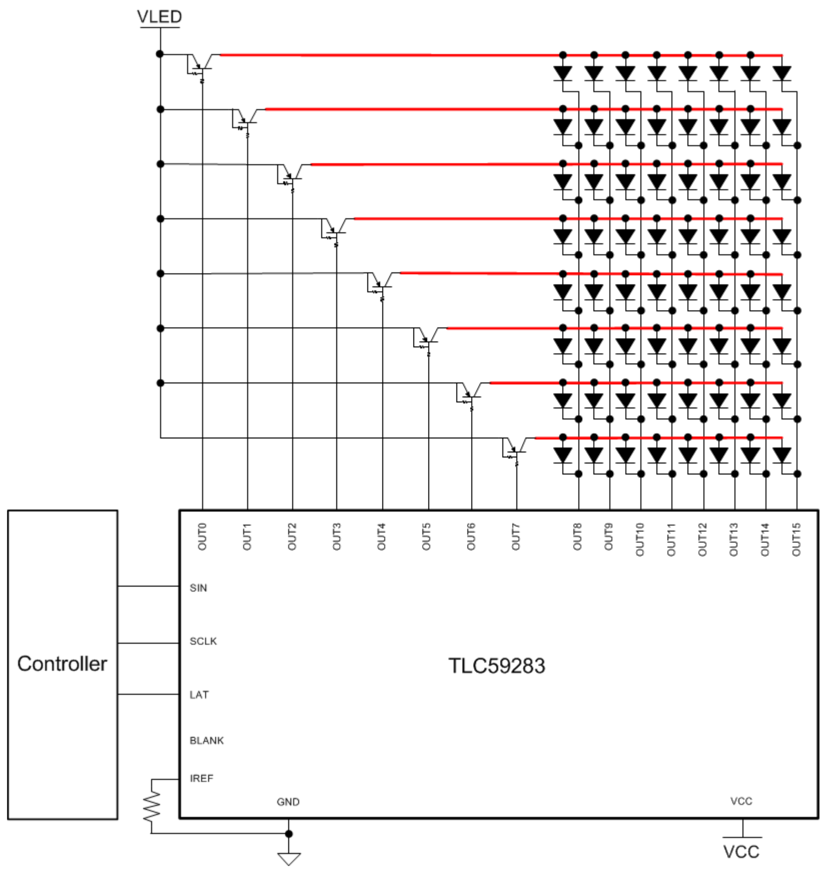

Figure 13. Time-multiplexing Circuit Using TLC59283 and Less I/Os

The transistors can also be replaced by P-MOSFETs, as shown in TIDA-01617. It uses one TLC59283 plus 16 P-MOSFETs to drive a 16×16 LED matrix display with high refresh rate and no ghosting.

5 Summary

This application report describes how to use the TLC59283 to drive seven-segment and dot-matrix LED displays or large quantities of LEDs. Compared to current solutions using GPIOs or shift registers, the TLC59283 provides constant current sinks to get a better brightness uniformity and saves the PCB size at the same time. Examples are provided to use the TLC59283 to form a time-multiplexing topology. Since the TLC59283 integrates pre-charge FETs, ghosting phenomenon is eliminated.

In other words, the TLC59283 is a good fit to drive LED indicators, seven-segments, and LED dot-matrix for LED indication purpose.

6 References

- Texas Instruments, *TLC59283, 16-Channel, Constant-Current LED Driver with Pre-Charge FET Datasheet* (SBVS199)
- Texas Instruments, *TIDA-01617, 16 × 16 Mono Color LED Matrix With Fast Refresh Rates and Ghosting Reduction Reference Design*
- *How to Design LED Signage and LED Matrix Displays*

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