**TI Designs: TIDA-01615**

*10×16 Full-Color RGB LED Matrix Reference Design*

**Description**

This reference design showcases a solution using a 48-channel LED driver TLC5957 to drive a 10×16 full color (R/G/B) LED matrix with a 1/10 multiplexing rate. This design enables you to drive 160 RGB LEDs with only one TLC5957 LED driver and five dual P-MOSFETs. The design provides selectable PWM grayscale bits from 9-bit to 16-bit, which results in a fine and smooth display effect. Because the TLC5957 LED driver provides 512-step adjustments for each color, it is easy to get a desired white balance. Also, the LED open detection and thermal shutdown functions help to ensure high system reliability.

**Features**

- 1/10 Multiplexing Ratio
- Pre-Charge FET for Ghosting Reduction
- PWM Grayscale Selectable From 9 bit to 16 bit
- 512-Step Adjustment for Each Color Group
- LED Open Detection for Caterpillar Cancelling
- Multiple Modules Cascading Support

**Applications**

- Keyboards
- Smart Speakers
- Set-Top Boxes
- Sound Bar
- Vacuum Robot
- Air Conditioner
- Air Purifier
- Kitchen Solution

**Resources**

- TIDA-01615
- TLC5957
- SN74LV1T04
- SimpleLink™ MSP432P401R
- LaunchPad™ Development Kit

**ASK Our E2E™ Experts**

![Diagram of 10x16 RGB LED Matrix Reference Design](image)

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1 System Description

1.1 Key System Specifications

Table 1. Key System Specifications

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SPECIFICATIONS</th>
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<tbody>
<tr>
<td>Input voltage range</td>
<td>3.0 V to 5.5 V</td>
</tr>
<tr>
<td>Current sinks accuracy</td>
<td>±1% channel-to-channel and ±1% device-to-device current accuracy</td>
</tr>
<tr>
<td>PWM dimming control</td>
<td>Up to 16-bit PWM grayscale control, 9-bit to 16-bit PWM selectable</td>
</tr>
<tr>
<td>Data transfer rate</td>
<td>Up to 33-MHz data transfer rate</td>
</tr>
<tr>
<td>Protection</td>
<td>LED open detection (LOD), thermal shutdown (TSD)</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>−40°C to +85°C</td>
</tr>
<tr>
<td>Patterns</td>
<td>8 Patterns: Scan, static pictures (smile, gradient, flower), animations (Doraemon, rainbow, pulse), words</td>
</tr>
</tbody>
</table>
2 System Overview

2.1 Block Diagram

Figure 1. TIDA-01615 Block Diagram

2.2 Highlighted Products

This reference design uses the following highlighted products. The key features of selecting the devices for this reference design are outlined in the following subsections. For the complete details of the highlighted devices, see their respective product data sheet.

2.2.1 TLC5957 48-Channel, 16-Bit ES-PWM LED Driver With Pre-Charge FET, LED OPEN Detection, and Caterpillar Cancelling

The TLC5957 is a 48-channel constant current sink driver. Each channel has an individually-adjustable, 65536-step, pulse width modulation (PWM) grayscale (GS) brightness control.

The output channels are divided into three groups, and each group has a 512-step color brightness control (CC); CC adjusts brightness between colors. The maximum current value of all 48 channels can be set by an eight-step global brightness control (BC). BC adjusts brightness deviation between LED drivers. GS, CC, and BC data are accessible using a serial interface port.

The TLC5957 has one error flag: LED open detection (LOD), which can be read using a serial interface port. Each constant-current has a pre-charge field-effect transistor (FET), which can remove ghosting and improve display performance on the multiplexing LED. In addition, the TLC5957 has an enhanced circuit that can cancel the caterpillar effect caused by LED open.
The TLC5957 has a poker data transmission mode. GS data length can be configured from 9 bit to 16 bit, according to PWM bits in each sub-segment. Poker mode can significantly increase visual refresh rate in multiplexing applications.

2.2.2 SN74LV1T04 Single Power Supply INVERTER Gate logic level shifter
SN74LV1T04 is a low voltage CMOS gate logic that operates at a wider voltage range for industrial, portable, telecom, and automotive applications. The output level is referenced to the supply voltage and is able to support 1.8V/2.5V/3.3V/5V CMOS levels.

2.2.3 SimpleLink™ MSP432P401R LaunchPad™ Development Kit
The SimpleLink MSP432P401R LaunchPad development kit is an easy-to-use evaluation module for the SimpleLink MSP432P401R microcontroller (MCU). This device contains everything needed to start developing on the SimpleLink MSP432™ low-power + performance Arm® 32-bit Cortex®-M4F MCU, including onboard debug probe for programming, debugging, and energy measurements. The MSP432P401R device supports low-power applications requiring increased CPU speed, memory, analog, and 32-bit performance.

2.3 System Design Theory
This reference design uses multiplexing topology to drive 10-line by 16-column RGB LEDs. The 48-channel TLC5957 controls the 16 columns while five dual P-MOSFETs control the 10 lines by a 1/10 multiplexing ratio.

Taking the advantages of TLC5957 features, this reference design provides the following benefits.

2.3.1 Flexible PWM Bit
The TLC5957 offers a flexible PWM bit, from 9 bit to 16 bit, which is configured by an internal Poker Mode register. In high multiplexing applications, Poker Mode can significantly increase visual refresh rate.

A higher PWM bit achieves better grayscale performance. For different application requirements, it can be configured to a different PWM bit by balancing the refresh rate and performance.

2.3.2 Ghost Removal
For multiplexed LED modules, ghost is a common phenomenon. For a detailed description, see the Build a High-Density, High-Refresh Rate, Multiplexing Panel With the TLC5957 User’s Guide.

One cause of this is the charging current for parasitic capacitance of the OUTXn through the LED, when the supply voltage switches from one common line to the next common line. To prevent this unwanted charging current, the TLC5957 uses an internal FET to pull OUTXn up to VCC-1.4V during the common line switching period. Thus, no charging current flows through the LED and the ghosting is eliminated.

Another cause of the ghost is that the line voltage is not discharged quickly due to parasitic capacitance of the line. Thus, a Zener diode is added to discharge each line when the line MOSFET is off.

By combining these two methods, the ghost phenomenon is removed in this reference design.

2.3.3 Caterpillar Cancelling
The caterpillar effect is a phenomenon caused by broken LEDs. The TLC5957 has an internal circuit to remove caterpillar issues in multiplexed LED modules. One cause of this phenomenon is the electric charge on the parasitic capacitor of the line goes through an LED when the OUT is pulled down to GND, due to LED open of another line. This makes all the LED multiplexing with the open LED turn on during the special time.

To prevent the caterpillar issue, the TLC5957 integrated internal circuits for LED open detection. When LED open is detected, the output channel is turned off for this specific line and then the caterpillar effect is eliminated.
2.4 System Schematic

Figure 2. TIDA-01615 System Schematic 1
Figure 3. TIDA-01615 System Schematic 2
3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

3.1.1 Hardware

To get started with this reference design, connect the MSP-EXP432P401R LaunchPad and the LED panel through the BoosterPack™ connector.

Plug in the USB wire for the LED panel to power up the TLC5957. Then, plug in the USB wire for the MSP-EXP432P401R LaunchPad, and the patterns run automatically.

There are also VCC and VLED power connectors to separate these two power rails or use an external DC supply.

3.1.2 Software

The firmware for designed patterns are downloaded to the MSP432P401R LaunchPad.

The source code is compiled in Code Composer Studio™ (CCS). To edit the code or design new patterns, install the CCS Integrated Development Environment (IDE) to the PC first.

3.2 Testing and Results

3.2.1 Test Setup

Connect the MSP-EXP432P401R LaunchPad and the LED panel through the BoosterPack connector.

Then, plug in the USB wires for the LED panel and the MSP-EXP432P401R LaunchPad by order. The patterns run automatically.
3.2.2 Test Results

Figure 4 shows the ghost removal effect through the Scan pattern. Figure 5 and Figure 6 are captures of Rainbow and Pulse animation patterns.

From the display results, there is no ghost issue when applying a stripe and the LED panel works normally with designed patterns.

Figure 4. Ghost Removal Effect—Scan Pattern
Figure 5. Rainbow Pattern
Figure 6. Pulse Pattern
4 Design Files

4.1 Schematics
To download the schematics, see the design files at TIDA-01615.

4.2 Bill of Materials
To download the bill of materials (BOM), see the design files at TIDA-01615.

4.3 PCB Layout Recommendations

4.3.1 Layout Prints
To download the layer plots, see the design files at TIDA-01615.

4.4 Altium Project
To download the Altium project files, see the design files at TIDA-01615.

4.5 Gerber Files
To download the Gerber files, see the design files at TIDA-01615.

4.6 Assembly Drawings
To download the assembly drawings, see the design files at TIDA-01615.

5 Software Files
To download the software files, see the design files at TIDA-01615.

6 Related Documentation
1. Texas Instruments, TLC5957 48-Channel, 16-Bit ES-PWM LED Driver with Pre-Charge FET, LED OPEN Detection and Caterpillar Cancelling Data Sheet
2. Texas Instruments, Build a High-Density, High-Refresh Rate, Multiplexing Panel With the TLC5957 User's Guide

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