This user’s guide describes the characteristics, operation, and use of the TLC5924EVM-186 evaluation module (EVM). This EVM is designed to help the user evaluate and test the various operating modes of the TLC5923 and TLC5924 LED drivers. This user’s guide includes setup instructions for the hardware and software, a schematic diagram, a bill of materials (BOM), and PCB layout drawings for the evaluation module.

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1 Introduction

The Texas Instruments TLC5923 is a 16-channel, constant-current LED driver that is capable of driving up to 80 mA per channel. The integrated circuit (IC) contains integrated DOT correction circuitry that adjusts the DC current for each output channel to compensate for brightness difference among LEDs. DOT correction information can be written into internal registers. The TLC5924 is a device nearly identical to the TLC5923, with the exception of an added precharge FET. The precharge FET eliminates the ghosting, or spike current effect, that is associated with driving time-multiplexed strings of LEDs from a single IC.

This EVM contains a TLC5923 IC connected in parallel with a TLC5924 IC. The two ICs drive 16 red and 16 green light-emitting diodes (LED). The LEDs are separated into two banks, so that all red LEDs reside on bank A, while all green LEDs reside on bank B. Both the TLC5923 and TLC5924 contain 16 outputs each and every output is connected to a different pair of red and green LEDs. A switch on the EVM (S1) selects which IC to activate, so that only one IC is on during normal operation. Using the supplied software, the user individually controls the DOT correction and on/off values for each LED. Two modes of operation are present in the software: Single-Bank Mode and Multiplex Mode. In Single-Bank Mode, the user selects which bank of LEDs to activate, so that only the red or green LEDs are programmable. In Multiplex Mode, both rows of LEDs are programmed sequentially at a high rate, giving the appearance
Introduction

that both rows of LEDs are on at the same time. In reality, two FETs continuously switch the two banks of LEDs in and out of the circuit. Therefore, only the red or green LEDs are connected to the IC at any given time. Because this switching occurs hundreds of times per second, both rows of LEDs appear to be always on. To accomplish multiplexing, the selected LED driver has to be reprogrammed every cycle so that different patterns can be displayed on the two LED banks.

In both modes of operation, the software allows the user to enter the LED DOT correction and enable information for every LED. The software then communicates with the TLC5924EVM via an USB Interface Adapter. This interface board generates the individual data signals necessary to program the TLC5924EVM so that it properly drives the LEDs.

1.1 Requirements

In order to operate this EVM, the following components must be connected and properly configured. All components, software, and connectors are supplied in the EVM except for the host computer and the two DC power supplies.

1.1.1 Software

Texas Instruments has provided the software necessary to evaluate this EVM. Check the TLC5924 product folder on the TI Web site for the latest revision of the software.

1.1.2 Host Computer Requirements

- The host computer, or personal computer (PC), operating system must have either the Windows™ XP or Windows™ 2000 operating system installed.
- Must have a USB port
- Must have a minimum of 100 MB of free hard disk space for the EVM software installation
- Must have a minimum of 256 MB of RAM to run the LED Frame Designer program

1.1.3 Power Supply Requirements

- DC power source capable of supplying a minimum of 5.5 V at 2 A
- DC power source capable of supplying 3.3 V at 500 mA

1.1.4 Printed-Circuit Board Assembly

The TLC5924EVM-186 PCB contains a TLC5923 IC configured in parallel with a TLC5924 IC.

1.1.5 USB Interface Adapter

The USB Interface Adapter(1) is the communications link between the PC and the EVM. One end of the interface board connects to the PC with the supplied USB cable and the other end of the interface board connects to the EVM with the supplied SCSI-1 cable. When the user programs the LEDs to turn on or off, the PC sends the proper commands to the USB Interface Adapter. The USB Interface Adapter receives these USB commands, and its firmware converts the commands into the proper bit stream necessary to control the LEDs on the EVM.

(1) "USBINTERFACEADAPTEREVM" is the orderable part number for the USB Interface Adapter.

1.2 Setup

The following discussion describe how to set up the EVM software and hardware.

1.2.1 Software Installation

To install the software, insert the enclosed CD into the CD-ROM drive of your computer. Browse the contents of the CD for the Setup.exe file. Run this file to start the software installation process.
1.2.2 Hardware Setup

See Figure 1 when setting up the TLC5924EVM hardware.

Attach the 10-pin ribbon cable between the USB Interface Adapter and the TLC5924EVM board (the connectors on the boards and the ribbon cable are keyed to only allow connection with the proper orientation).

Attach the 5.5-V (2-A) power supply to the LED board between J4 (VLED) and J5 (GND).

Attach the 3.3-V (500-mA) power supply to the LED board between J4 (VIN) and J7 (GND).

Connect the host computer to the USB Interface Adapter using the provided USB cable. If the computer is running, you may see a message about installing new hardware. Follow the on-screen instructions and allow Windows™ to install the default drivers for this device. Note that the USB board appears to Windows as a generic Human Interface Device (like a keypad or a mouse), so there is no custom driver to install.

![Quick Connection Diagram USB Interface Adapter](image)

Figure 1. Hardware Setup

1.3 Input/Output Connector Descriptions

1.3.1 J1 – Interface Connector

This connector is used to connect TLC5924EVM to the USB Interface Adapter. The connector specifications are shown in Table 1. For a more detailed description of each signal, see the TLC5923 data sheet (SLVS550) and the TLC5924 data sheet (SLVS626).
Table 1. J1 – Interface Connector

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Pin Symbol</th>
<th>Signal Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SIN_IN</td>
<td>Serial data input</td>
<td>Used to input data into the TLC5923 and TLC5924 ICs</td>
</tr>
<tr>
<td>2</td>
<td>ENA_IN</td>
<td>Enable A</td>
<td>Controls bank A LEDs. When ENA_IN is high, the anodes of all bank A LEDs (red) are connected to VLED via Q1. When ENA_IN is low, the anodes of all bank A LEDs are disconnected from VLED.</td>
</tr>
<tr>
<td>3</td>
<td>ENB_IN</td>
<td>Enable B</td>
<td>Controls bank B LEDs. When ENB_IN is high, the anodes of all bank B LEDs (green) are connected to VLED via Q2. When ENB_IN is low, the anodes of all bank B LEDs are disconnected from VLED.</td>
</tr>
<tr>
<td>4</td>
<td>SCLK_IN</td>
<td>Serial data input clock</td>
<td>Shifts SIN data into internal registers of TLC5923 and TLC5924</td>
</tr>
<tr>
<td>5</td>
<td>3.3V</td>
<td>3.3V</td>
<td>This pin is the 3.3V bus from the interface board. It is not connected to the VIN pins on the PWB.</td>
</tr>
<tr>
<td>6</td>
<td>GND</td>
<td>Ground</td>
<td>Signal ground</td>
</tr>
<tr>
<td>7</td>
<td>BLNK_IN</td>
<td>Blank input</td>
<td>Activates/Deactivates all OUTx signals.</td>
</tr>
<tr>
<td>8</td>
<td>MODE_IN</td>
<td>Mode select</td>
<td>Controls whether SIN programs ON/OFF control logic or dot-correction logic.</td>
</tr>
<tr>
<td>9</td>
<td>XLAT_IN</td>
<td>Data latch</td>
<td>Rising edge latches data from shift registers into ON/OFF registers or dot-correction registers.</td>
</tr>
<tr>
<td>10</td>
<td>N/A</td>
<td>N/A</td>
<td>This pin is floating and is not connected to any signals on the board.</td>
</tr>
</tbody>
</table>

**Note:** The extension _IN is simply used to refer to the signals that arrive at the EVM via connector J1. Each signal on Table 1 is accessible through its corresponding test point. For example, attaching a voltage probe to TP4 would allow the user to observe the signal SCLK_IN. The test points and their corresponding signals are clearly labeled on the schematic and PCB.

1.3.2 J2, J3, J4, J5 – Power Connectors

These connectors provide power to the ICs and LEDs on the EVM. Table 2 shows pin assignment and Table 3 shows the power requirements of the EVM. Ensure that the power supplies connected to VIN and VLED have the required current capability.

Table 2. J2, J3, J4, J5 – Power Connectors

<table>
<thead>
<tr>
<th>Connector</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>J2</td>
<td>VIN</td>
<td>Supplies bias power for the ICs on the EVM board.</td>
</tr>
<tr>
<td>J3, J5</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>J4</td>
<td>VLED</td>
<td>Supplies power to drive the LEDs. VLED is connected to the anodes of all LEDs via Q1 and Q2.</td>
</tr>
</tbody>
</table>

Table 3. EVM Power Requirements

<table>
<thead>
<tr>
<th>Connector</th>
<th>Symbol</th>
<th>Voltage Range</th>
<th>Max. Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>J2</td>
<td>VIN</td>
<td>3.3V ± 0.1V</td>
<td>&gt; 500mA</td>
</tr>
<tr>
<td>J4</td>
<td>VLED</td>
<td>4.0V – 17V</td>
<td>&gt; 2000mA</td>
</tr>
</tbody>
</table>

1.4 Jumper/Switch/Test Point Descriptions

1.4.1 S1 – IC Select

S1 is a 3-pin switch that allows the user to activate either the TLC5923 or TLC5924. Moving the switch to the right applies power to the TLC5923 and deactivates the TLC5924. Moving the switch to the left applies power the TLC5924 and deactivates the TLC5923.
1.4.2 JP2, JP3 – LED Current Measurement

These jumpers provide an easy place to measure the current flowing through D15A (JP2) and D15B (JP3). To measure the current through an LED, remove the corresponding shunt and connect a current meter across the jumper pins. Note that no current can flow through the LEDs if the shunts are removed and a current meter is not installed. Therefore, a shunt should be placed on JP2 and JP3 when they are not being used to measure current, or the IC may activate the error LED because it would be detecting an open circuit on its OUT15 pin. The IC considers this event an LOD fault (LED open detect).

1.4.3 TP1 to TP11 – Voltage Test Points

The EVM contains 11 test points labeled from TP1 to TP11. These connections are used as convenient locations to attach oscilloscope probes or voltmeter leads when performing measurements. Each test point is connected to its corresponding signal. For a detailed description of each signal, see Table 1 or the TLC5924 data sheet.

1.5 EVM Operation

1.5.1 Turning on the EVM

After the software is installed and the hardware is connected as described earlier in this document, the EVM is ready for use. The start-up procedure for the EVM is as follows:

1. Connect all hardware.
2. Turn on the 3.3-V and 5.5-V power supplies
3. If not yet running, run the TLC5924EVM software program on the PC. To do this, click on the Start menu, then under Programs, navigate to Texas Instruments Incorporated. Click on the TLC5924EVM Software to run the program. A message appears that states Verifying Applications Requirements. This may take a few moments. At this point, the software may load an update message. If it does, click ‘Install’ and wait for the program to update and then load. The program may also ask you to update the firmware. If it does, click OK and then Yes. After it updates the firmware, follow the instructions to unplug the USB adapter and plug it back in. Then click OK.

If the USB cable is removed and reinserted while the software is running, or if power is removed from VCC, the DOT correction data may become corrupted. To correct this problem, click on the triangular PLAY button in the software.

The default state at start-up is to program the LED drivers to 100% DOT correction and all LEDs enabled. The Help section of the software details the operation of the program.

1.5.2 Software Operation

The TLC5924EVM software allows the user to control the operation of the evaluation module. The user interface displays the current values of DOT correction and enable for each LED. A tab allows the user to select between Single-Bank Mode and Multiplex Mode.

In Single-Bank Mode, only one bank of LEDs can be controlled at a time. The user can choose which bank to activate and can adjust DOT correction values for each LED on the chosen bank. Using the switch S1 to change the activated IC is not recommended in Single-Bank Mode, because the software updates the data only when a change is made in the user interface; so, switching ICs causes the newly activated IC to turn on a random number of LEDs. This can be easily corrected, however, by changing any value (DOT correction or on/off) in the program so that the software updates the data. Also, both the TLC5924 and TLC5923 operate identically in Single-Bank Mode, so using the switch to change ICs results in no discernible difference in operation.

In Multiplex Mode, both banks of LEDs are driven using time-multiplexing. Two FETs continuously switch the two banks of LEDs in and out of the circuit. Therefore, only the red or green LEDs are connected to the IC at any given time. Because this switching occurs hundreds of times per second, both rows of LEDs appear to be always on. Using switch S1 to change the activated IC allows the user to better observe the advantage of the precharge FET on the TLC5924.
Board Layout

Both modes of operation also allow the user to create and play multiple frames. A frame is a particular configuration of DOT correction data and on/off values for all LEDs. Creating and configuring multiple frames allows the user to select which frames to activate or play the frames sequentially.

For a more detailed description of software operation, see the Help section of the software.

### Note:
When the EVM is in operation, the LEDs may flash briefly. This is normal and is caused by an interrupt on the USB connection; it is not a malfunction of the EVM or LED drivers.

#### 1.5.3 Signal-Conditioning Buffer

The TLC5924EVM PWB contains a buffer to condition the input signals to the EVM. This buffer, SN74AVC16244, eliminates any noise on the input signals, generates fast, clean rise and fall times, and improves the drive capability of the signals. Due to a weak pullup capability on the USB Interface Adapter, all input signals on J1 are connected to 3.3V via 10-kΩ pullup resistors to improve signal integrity. The buffer also controls which IC receives the input signals, so that only the selected IC receives the signal inputs, while the deactivated IC’s inputs are floating. For these reasons, SCLK24 and SCLK23 are clean versions of the SCLK_IN signal.

2 Board Layout

This section provides the TLC5924EVM-186 board layout and illustrations.

2.1 Layout

![Figure 2. Assembly Layer](image-url)

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Figure 3. Top Layer Routing

Figure 4. Layer 2 Routing
Figure 5. Layer 3 Routing

Figure 6. Bottom Layer Routing
3 Schematic and Bill of Materials

This section provides the TLC5924EVM-186 schematic and bill of materials.

3.1 Schematics

![Schematic Diagram]

Figure 7. TLC5924EVM-186 Schematic (a)
Figure 8. TLC5924EVM-186 Schematic (b)
### 3.2 Bill of Materials

#### Table 4. TLC5924EVM-186 Bill of Materials

<table>
<thead>
<tr>
<th>Count</th>
<th>RefDes</th>
<th>Value</th>
<th>Description</th>
<th>Size</th>
<th>Part Number</th>
<th>MFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>C1, C3–C6, C8</td>
<td>0.1μF</td>
<td>Capacitor, Ceramic, 50V, X7R, 10%</td>
<td>0805</td>
<td>C2012X7R1H104K</td>
<td>TDK</td>
</tr>
<tr>
<td>1</td>
<td>C2</td>
<td>10μF</td>
<td>Capacitor, Ceramic, 25V, X5R, 10%</td>
<td>1210</td>
<td>GRM32DR61E106KA12L</td>
<td>Murata</td>
</tr>
<tr>
<td>1</td>
<td>C7</td>
<td>22μF</td>
<td>Capacitor, Ceramic, 25V, X5R, 10%</td>
<td>1210</td>
<td>STD</td>
<td>STD</td>
</tr>
<tr>
<td>16</td>
<td>D0A, D10A–D15A, D1A–D9A</td>
<td></td>
<td>Diode, LED, Red, 1.8-V, 40-mcd, Sm</td>
<td>1210</td>
<td>SML-LX1206SWR-TR</td>
<td>Lumex</td>
</tr>
<tr>
<td>16</td>
<td>D0B, D10B–D15B, D1B–D9B</td>
<td></td>
<td>Diode, LED, Green, 4-V, 25-mcd, Sm</td>
<td>1210</td>
<td>LNJ316C83RA</td>
<td>Lumex</td>
</tr>
<tr>
<td>1</td>
<td>D16</td>
<td></td>
<td>Diode, LED, Red, 2.6-V, 40-mcd</td>
<td>0.114 × 0.049</td>
<td>LN1271RTR</td>
<td>Panasonic</td>
</tr>
<tr>
<td>1</td>
<td>J1</td>
<td></td>
<td>Connector, Male Right Angle 2x5 pin, 100mil spacing, 4 Wall</td>
<td>0.607 × 0.484</td>
<td>86479-3</td>
<td>AMP</td>
</tr>
<tr>
<td>4</td>
<td>J2–J5</td>
<td></td>
<td>Header, 2-pin, 100mil spacing, (36-pin strip)</td>
<td>0.100 × 2</td>
<td>PTC36SAAN</td>
<td>Sullins</td>
</tr>
<tr>
<td>2</td>
<td>JP1, JP2</td>
<td></td>
<td>Header, 2-pin, 100mil spacing, (36-pin strip)</td>
<td>0.100 × 2</td>
<td>PTC36SAAN</td>
<td>Sullins</td>
</tr>
<tr>
<td>2</td>
<td>Q1, Q2</td>
<td></td>
<td>MOSFET, P-ch, −30V, −1.5A, 125mΩ</td>
<td>SOT23</td>
<td>FDN358P</td>
<td>Fairchild</td>
</tr>
<tr>
<td>4</td>
<td>Q3–Q6</td>
<td></td>
<td>MOSFET, N-ch, 60V, 115-mA, 1.2Ω</td>
<td>SOT23</td>
<td>2N7002DICT1N</td>
<td>Vishay-Liteon</td>
</tr>
<tr>
<td>9</td>
<td>R1–R9, R11</td>
<td>10k</td>
<td>Resistor, Chip, 1/16W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>R10</td>
<td>121</td>
<td>Resistor, Chip, 1/16W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>2</td>
<td>R13, R15</td>
<td>1.0k</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0805</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>2</td>
<td>R14, R16</td>
<td>49.9</td>
<td>Resistor, Chip, 1/10W, 1%</td>
<td>0805</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>2</td>
<td>R8, R12</td>
<td>2.37k</td>
<td>Resistor, Chip, 1/16W, 1%</td>
<td>0603</td>
<td>Std</td>
<td>Std</td>
</tr>
<tr>
<td>1</td>
<td>S1</td>
<td></td>
<td>Switch, SPDT, Slide, PC-mount</td>
<td>0.457 × 0.157</td>
<td>EQ1218</td>
<td>E_Switch</td>
</tr>
<tr>
<td>11</td>
<td>TP1, TP3, TP4, TP6–TP13</td>
<td></td>
<td>Test Point, Red, Thru Hole Color Keyed</td>
<td>0.100 × 0.100</td>
<td>5000</td>
<td>Keystone</td>
</tr>
<tr>
<td>2</td>
<td>TP2, TP5</td>
<td></td>
<td>Test Point, Black, Thru Hole Color Keyed</td>
<td>0.100 × 0.100</td>
<td>5001</td>
<td>Keystone</td>
</tr>
<tr>
<td>1</td>
<td>U1</td>
<td></td>
<td>IC, 16-Channel LED Driver w/Precharge FET</td>
<td>TSSOP-32</td>
<td>TLC5924DAP</td>
<td>TI</td>
</tr>
<tr>
<td>1</td>
<td>U2</td>
<td></td>
<td>IC, 16-Channel LED Driver w/Precharge FET</td>
<td>HTSSOP-32</td>
<td>TLC5923DAP</td>
<td>TI</td>
</tr>
<tr>
<td>1</td>
<td>U3</td>
<td></td>
<td>IC, 16-Bit Buffer Driver, 3-State Out Outs</td>
<td>48P TSSOP (DGG)</td>
<td>SN74VC16244DGG</td>
<td>TI</td>
</tr>
<tr>
<td>1</td>
<td>—</td>
<td>PCB, 5.9 In × 2.95 In × 0.062 In</td>
<td>HPA186</td>
<td>Any</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>—</td>
<td>Shunt, 100mil, Black</td>
<td>0.100</td>
<td>929950-00</td>
<td>3M</td>
<td></td>
</tr>
</tbody>
</table>
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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 3 V to 5.5 V and the output voltage range of 0 V to 17 V. Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User’s Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 60°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User’s Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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