Texas Instruments

Application Report

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TLC5924 Precharge FET Eliminates Ghosting in Time-Multiplexed LED Displays

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ABSTRACT

LED drivers are often used in visual applications that require time-multiplexing of numerous LEDs in the display. Time-multiplexing is a scheme that involves connecting the cathodes of multiple LEDs to each OUT pin of the LED driver. A time-multiplexed circuit is advantageous because it uses fewer LED drivers for a given amount of LEDs, which results in lower cost and smaller size. One major drawback to time-multiplexing is a side-effect called *ghosting*. The ghosting phenomenon is caused by stray board capacitance which can force time-multiplexed LEDs to flash when they should be off. This application report discusses the precharge FET feature on the Texas Instruments TLC5924 which eliminates the ghosting effect, allowing for cleaner imagery on the LED display. It should be read by users wishing to evaluate the differences between the TLC5923 and TLC5924 as well as users interested in time-multiplexed LED displays.

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1 LED Output Topologies

1.1 Single LED per Output

Most LED drivers are used in applications where only one LED is connected to each output of the LED driver. This type of scheme is ideal for applications where size is not a factor and a small number of LEDs are being used. One advantage of this topology is that the code used to program the LED driver can be relatively simple, because it does not have to switch external FETs as in a time-multiplexed system. The TLC5923 is an excellent choice of LED driver for a system using one LED per output. Figure 1 demonstrates a TLC5923 in this topology.

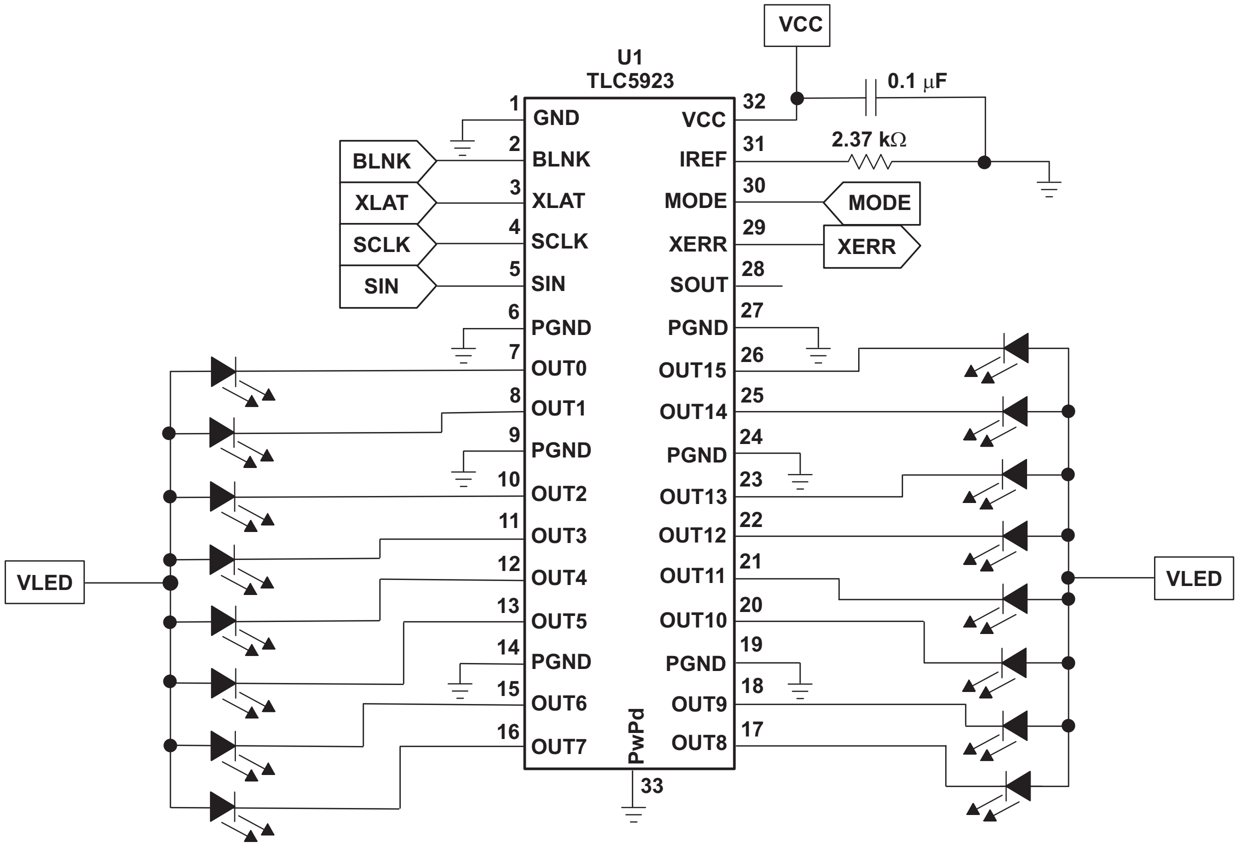

Figure 1. TLC5923 With Single LED per Output

As shown in Figure 1, the cathode of each LED is connected to a different output pin on the TLC5923, and the anodes of the LEDs are connected to a single voltage source (VLED). Each TLC5923 output controls the current flowing through each LED and therefore the brightness of all 16 LEDs. The input control pins (BLNK, XLAT, SCLK, SIN, MODE) program the current for each of its 16 outputs. See the TLC5923 data sheet for a more detailed description of its programming.

1.2 Time-Multiplexing

Using one LED driver per 16 LEDs may not be a practical solution in display systems that require a large amount of LEDs. Instead, the concept of time-multiplexing can be used so that multiple LEDs are connected to each LED driver's output. Figure 2 demonstrates this concept:

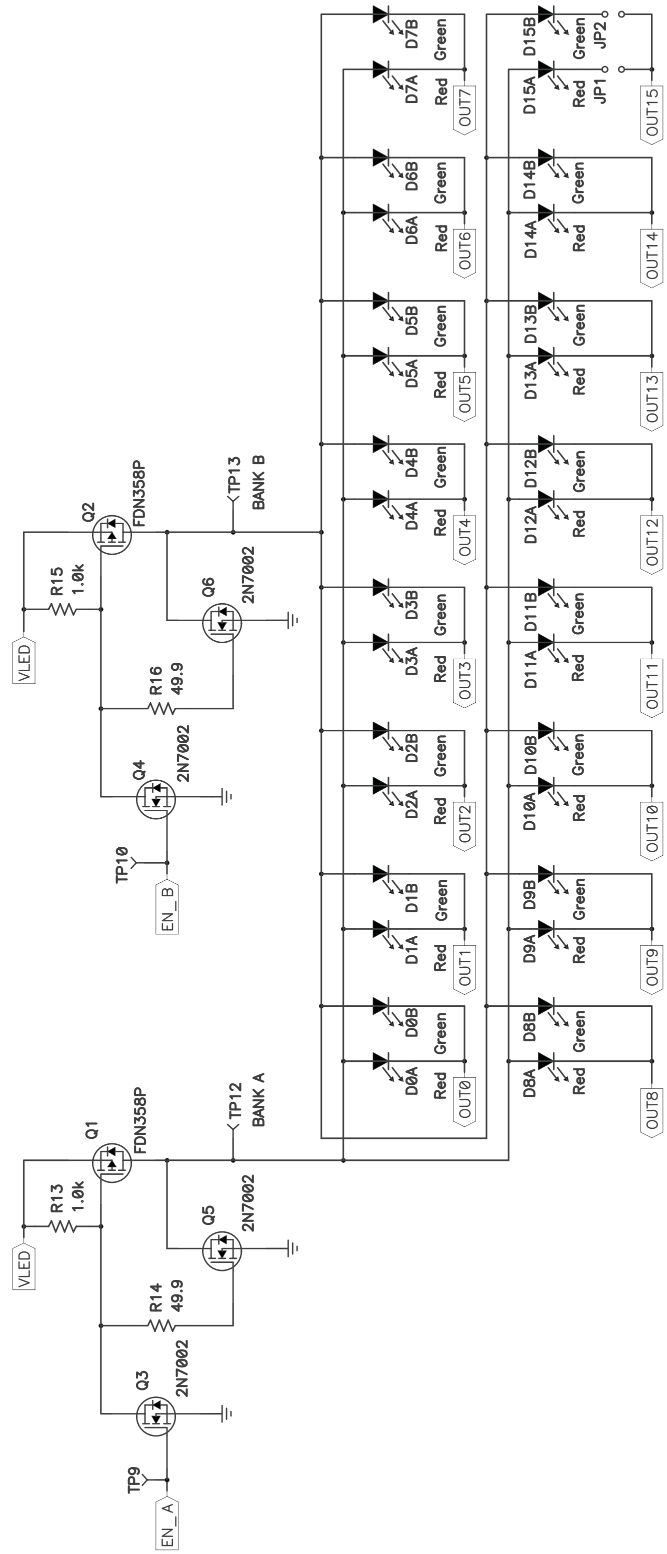

Figure 2. Time-Multiplexing Topology

In Figure 2, two LEDs are connected to each LED driver output (the LED driver is not shown in the figure). In this system, a microcontroller controls the EN_A and EN_B signals so that the VLED voltage is only applied to one LED on each output. Because EN_A and EN_B are never active at the same time, only the red or green LEDs are controlled by the IC at any given instant. The other set of LEDs are turned off by transistor Q5 or Q6, which ties the anodes of the disabled LEDs to ground. If the LED driver is programmed to multiplex between the two rows of LED fast enough, the user does not see the LEDs turn on and off, resulting in the illusion of both red and green LEDs being on at the same time. Multiplexing between the red and green LEDs faster than 100 Hz is fast enough that the switching is not visible. If a single LED per output topology had been used to drive the 32 LEDs in Figure 2, then two LED drivers would have been necessary instead of only one. In an application where hundreds or thousands of LEDs are required, time-multiplexing offers obvious benefits, because the time-multiplexed topology is cheaper and smaller than a nontime-multiplexed topology where each LED requires a separate driver output. However, a time-multiplexed topology requires more complicated programming of the LED driver, as well as additional external parts such as the switching MOSFETs.

2 Ghosting Effect

2.1 Description

A time-multiplexed topology has another disadvantage called the *ghosting effect* if the proper LED driver is not selected for the application. This ghosting phenomenon causes time-multiplexed LEDs to emit a brief flash of light when they should be off. In display applications, the images on the display appear illuminated at improper times, resulting in poor image quality. This phenomenon is caused by several factors, mainly the differences in the forward voltage drops of the LEDs coupled with the stray capacitance on the PCB and cabling. Figure 3 illustrates this parasitic capacitance.

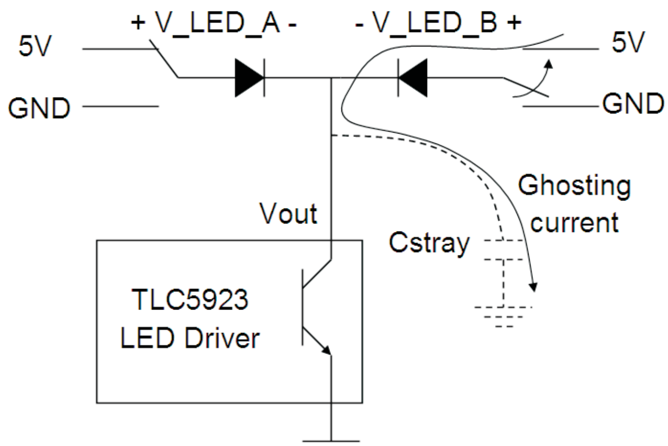

Figure 3. Time-Multiplexing With the TLC5923

For simplification, only one output pin and two LEDs are shown in the Figure 3. Additionally, the six transistors in Figure 2 are replaced with two switches that serve the same function. The value of VLED in Figure 2 is assumed to be 5 V in Figure 3. Figure 4 illustrates the timing waveforms and highlights the ghosting effect.

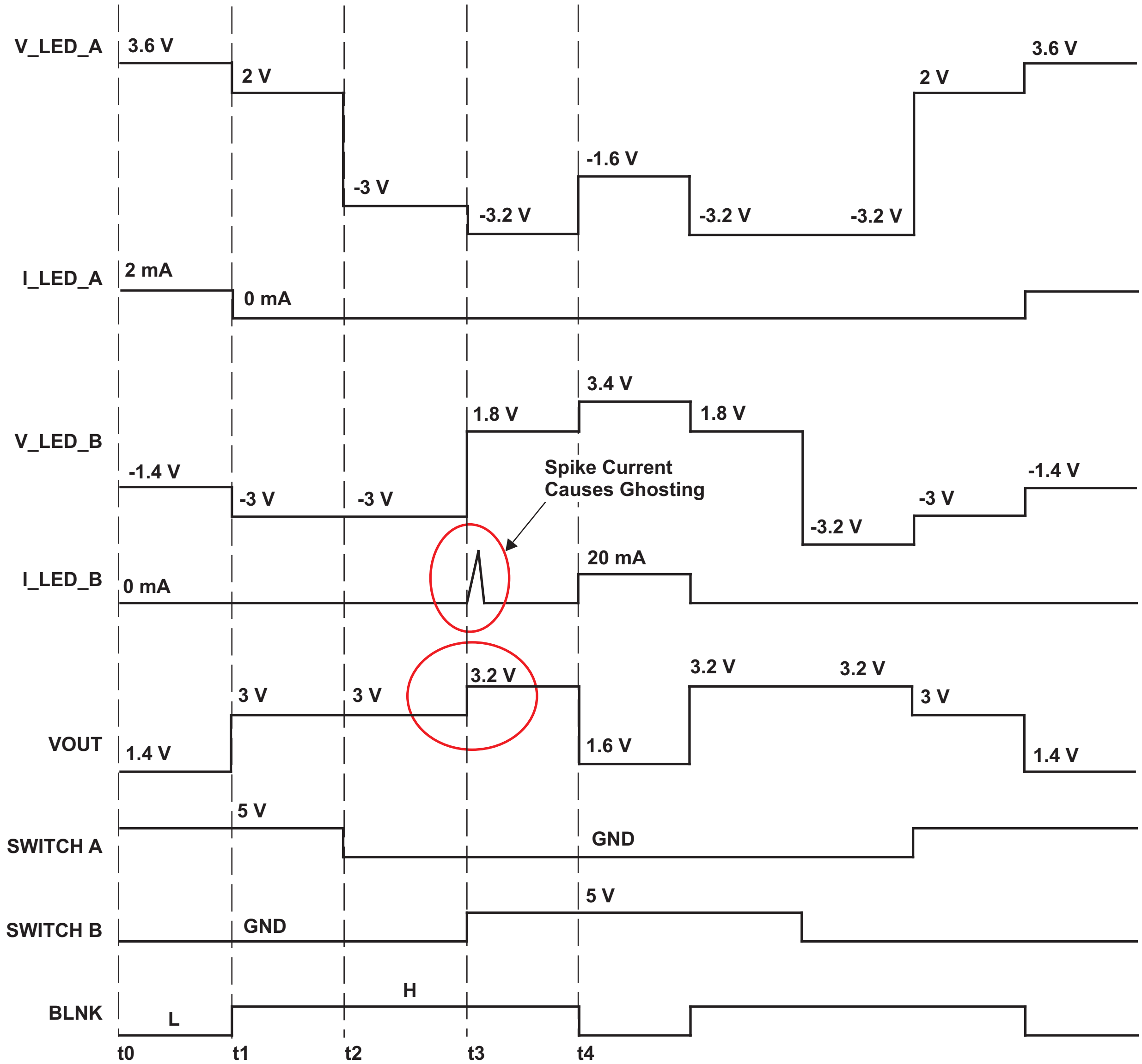

Figure 4. Time-Multiplexing Waveforms

The following assumptions were made for Figure 4.

- LEDA has a forward voltage drop of 3.6 V at approximately 20 mA.
- LEDA has a forward voltage drop of 2 V when OUT is open drain (no current flowing through LEDA).
- LEDB has a forward voltage drop of 3.4 V at approximately 20 mA.
- LEDB has a forward voltage drop of 1.8 V when OUT is open drain (no current flowing through LEDB).

At time t0, switch A is tied to 5 V so that current flows through LEDA (switch B is tied to GND). BLNK goes high at t1, forcing the LEDs off. The voltage on VOUT rises to 3 V because V_LED_A equals 2 V at 0 mA. At t2, switch A is tied to GND, forcing V_LED_A to –3 V. At time t3, switch B turns on while the BLNK signal is high. This causes the voltage on VOUT to jump from 3 V to 3.2 V, because the forward voltage drop of LEDB is 1.8 V and the anode of LEDB is switched to 5 V. Because the OUT pin is open drain as a result of BLNK being asserted, the voltage on VOUT can only be raised to 3.2 V by the charging of the stray capacitance. In order for this to happen, current must flow into the stray capacitance, and the only path available for this current is through LEDB. Therefore, LEDB flashes briefly (even though BLNK is asserted). This flash is the unwanted ghosting effect. The red circles in Figure 4 highlight the moment at which the ghosting effect occurs.

To summarize, the ghosting effect occurs when VOUT transitions from a lower voltage to a higher voltage while BLNK is asserted. The exact amplitude, duration, and timing of the ghost current spike in LEDB depends on the amount of stray capacitance in the circuit, the forward voltage characteristics of the LEDs, and the timing characteristics of the second switch.

2.2 Solution

The Texas Instruments TLC5924 contains an innovative precharge FET feature which eliminates the ghosting effect from multiplexed LED displays. Figure 5 illustrates this feature.

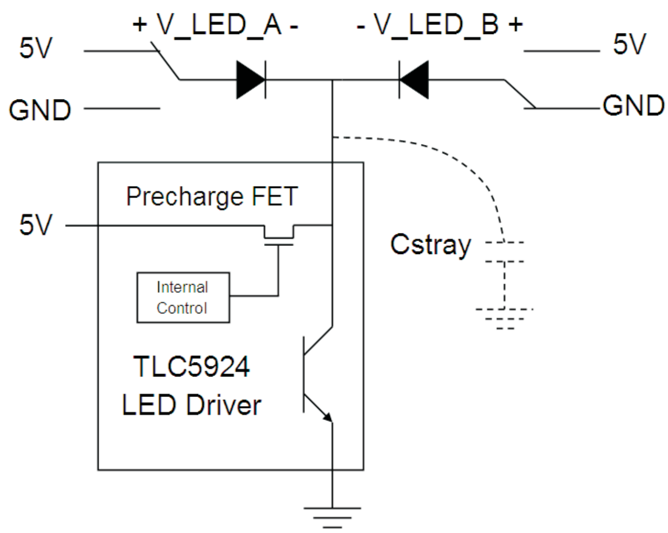

Figure 5. TLC5924 Precharge FET

Each output pin of the TLC5924 is connected to an external voltage source (VUP) through its own internal precharge FET. This FET is switched on when BLNK is asserted so that OUT is pulled up to the voltage on the VUP pin. Therefore, the FET provides an alternate path for the current to charge the stray capacitance. Instead of flowing through LEDB, the current flows through the precharge FET from the VUP pin. This prevents the current spike from flowing through LEDB, which eliminates the ghosting effect.

3 Conclusion

Time-multiplexing LEDs reduce system level cost and minimize board area by reducing the number of LED drivers in a display. However, it also introduces a problem called ghosting that can degrade video quality. The TLC5924 contains precharge FETs that eliminate ghosting and help maintain high video quality in time-multiplexed systems.

4 References

1. Day, Michael, *Time Multiplexed LED Display Architecture—Improving Image Quality by Reducing Ghosting*. The 1st International Conference on Display LEDs. February 2007.
2. *TLC5924, 16-Channel LED Driver With DOT Correction and Pre-Charge FET* data sheet (SLVS626).
3. *TLC5923, 16-Channel LED Driver With DOT Correction* data sheet (SLVS550)