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AN-8212

Designing for High Performance Commercial and Industrial Lighting Solution Using FL77904 Compact LED Direct AC Driver

Introduction

The FL77904 is a LED Direct AC driver. It integrates four constant current regulators, which can withstand up to 500 V on LED1 to LED3 pin and 200 V on LED4 pin. FL77904 is the ideal solution for driving string of series connected LEDs directly from the rectified AC line voltage of 80~305 V_{AC}. This application note provides practical guidelines for designing high performance commercial and industrial lighting solution using FL77904.

Operation

Figure 1 shows the internal block diagram of FL77904 and Figure 2 shows its principle of operation. FL77904 controls the LED's current to be in phase with the rectified AC line voltage via four constant current regulators within the IC. The LED currents that flow through each of the internal current regulator, I_{LED1}~I_{LED4}, are set by an external current sensing resistor (R_{CS}). The regulated current level through each channel as well as the total Root-Mean-Square (RMS) input current can be calculated as follow.

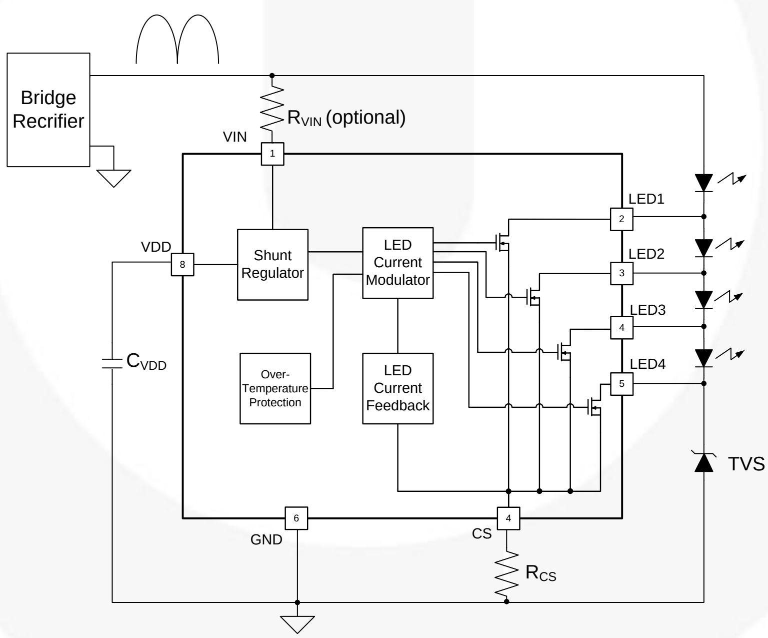

Figure 1. FL77904 Block Diagram

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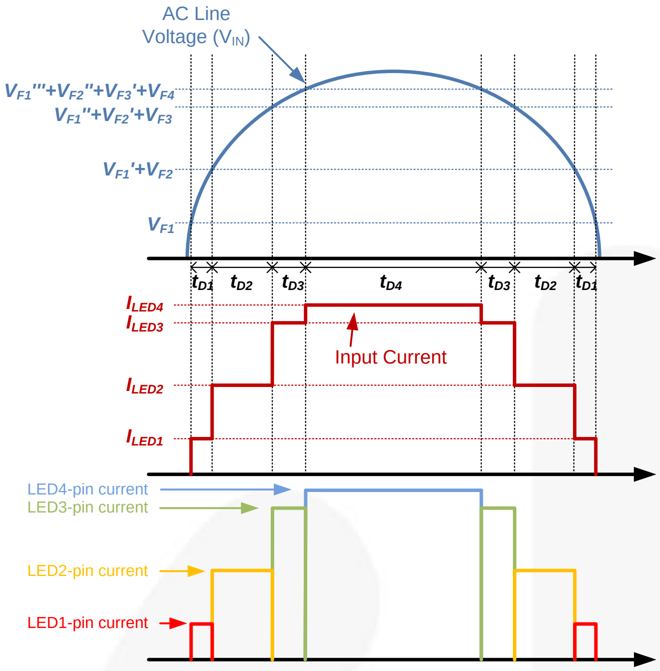


- t_{D1}: Current is directed to LED1 pin through 1st LED group.
- t_{D2}: Current is directed to LED2 pin through 1st and 2nd LED groups.
- t_{D3}: Current is directed to LED3 pin through 1st, 2nd, and 3rd LED groups.
- t_{D4}: Current is directed to LED4 pin through 1st, 2nd, 3rd, and 4th LED groups.
- $V_{F1}/V_{F1}'/V_{F1}''/V_{F1}'''$: Forward voltage at forward current of $I_{LED1}/I_{LED2}/I_{LED3}/I_{LED4}$ in 1st LED group.
- $V_{F2}/V_{F2}'/V_{F2}''$: Forward voltage at forward current of $I_{LED2}/I_{LED3}/I_{LED4}$ in 2nd LED group.
- V_{F3}/V_{F3}': Forward voltage at forward current of I_{LED3}/I_{LED4} in 3rd LED group.
- V_{F4}: Forward voltage at forward current of I_{LED4} in 4th LED group.

Figure 2. Drawing of Principle Operating Waveform

$$I_{LED1} = \frac{0.23}{R_{CS}} \tag{1}$$

$$I_{LED2} = \frac{0.47}{R_{CS}} \tag{2}$$

$$I_{LED3} = \frac{0.86}{R_{CS}} \tag{3}$$

$$I_{LED4} = \frac{0.96}{R_{CS}} \tag{4}$$

$$I_{IN,RMS} = \frac{0.96}{1.35 \times R_{CS}} \tag{5}$$

$$R_{CS} = \frac{0.96 \times V_{AC,RMS}}{1.35 \times P_{IN}} \tag{6}$$

The number "1.35" in equation (6) is the AC input current crest factor which depends on the LED configuration. It is normally 1.35 for FL77904 when LEDs are configured to have identical forward voltages in each group. $V_{AC,RMS}$ is the RMS value of the AC input voltage, and P_{IN} is the input power. For different LED configuration, crest factor can be in the range of 1.3 to 1.6. In that case, fine tuning on R_{CS} value is required to have precise targeted P_{IN}.

Figure 3 shows the actual operating current waveform captured by an oscilloscope. Currents waveform of each LED group is shown in Figure 4. **Please refer to AN-5088 [1] for detailed operation, calculation formula for average and RMS currents, guidance of surge compatibility, and PCB layout considerations.**

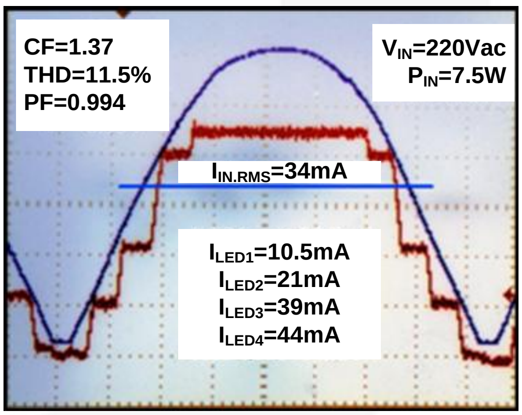


Figure 3. Input Voltage and Current (7.5 W Input Power, R_{CS}=22 Ω @ AC 220 V)

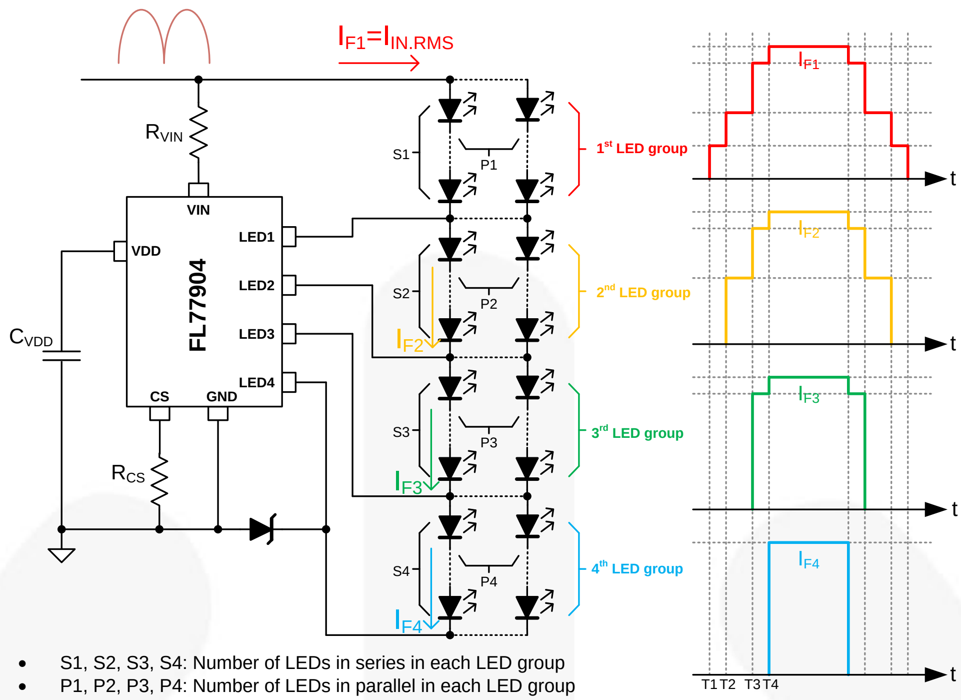


Figure 4. LED Current for each LED Group during a Half Cycle of the AC Line

Design LED Configuration

Referring to Figure 4, LEDs driven by FL77904 are arranged as four groups. Each group has its series quantity (S1~S4) and parallel quantity (P1~P4). Key point of a design process is to decide these quantities.

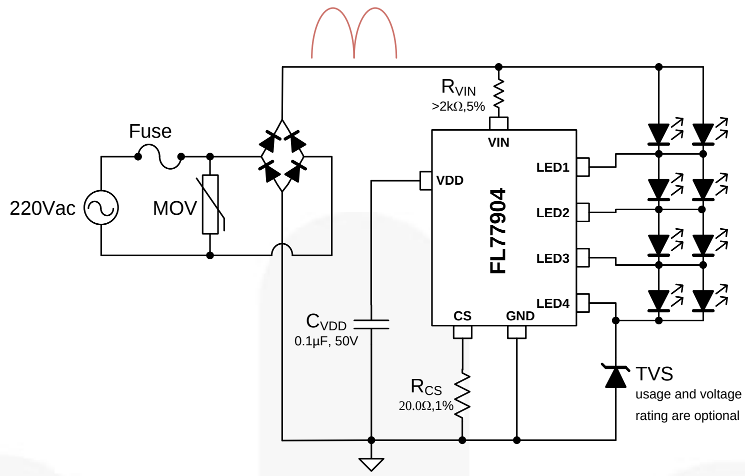
To decide S1~S4, the total forward-drop voltage (V_F) across the series connected groups of LEDs is the key design consideration. A good starting point is 1.2 times of RMS value of the input voltage. For example, a design may have approximately 250 V~270 V of total V_F for 220 V_{AC} input and 130 V~140 V of total V_F for 120V_{AC} input. V_F across each LED group can be adjusted for performance tuning while keeping the same total V_F. As the total V_F increases, efficiency goes up and Total Harmonic Distortion (THD) improves, but line regulation becomes worse. If the total V_F decreases, line regulation becomes better but efficiency decreases.

P1~P4 is basically decided by current rating and power rating of the LEDs. With a fixed R_{CS} value, peak current flowing through each LED group can be got form equation (4), and average current in each LED group can be calculated from equations in the AN-5088 [1]. Start with using just rated forward voltage multiplied by pre-decided S1~S4 in the equations, how many LEDs need be put in parallel can be estimated.

When all these quantities are decided, going through the equations as the design example helps confirming if the design target can be met.

Compact-Size Design

The total V_F needs to be about 260 V at 220 V_{AC} and 130 V at AC 120 V_{AC}. Assuming P1=P2=P3=P4=1, minimum LED quantity is S1+S2+S3+S4, which can be got from dividing total V_F by V_F of a single LED. For compact size, as quantity of LEDs is limited, high-V_F LEDs are recommended. As shown in Figure 5 each LED has 65 V of V_F. If conventional low-voltage LEDs are used, such as 0.06 W LEDs (V_F=3 V, I_F=20 mA) or 0.2 W LEDs (V_F=3 V, I_F=65 mA), a long LED array is needed, which may not be acceptable since it takes too much of PCB real estate.



- LED: High-voltage LED, V_F=65V@I_F=20mA
- Total number of LEDs: 8

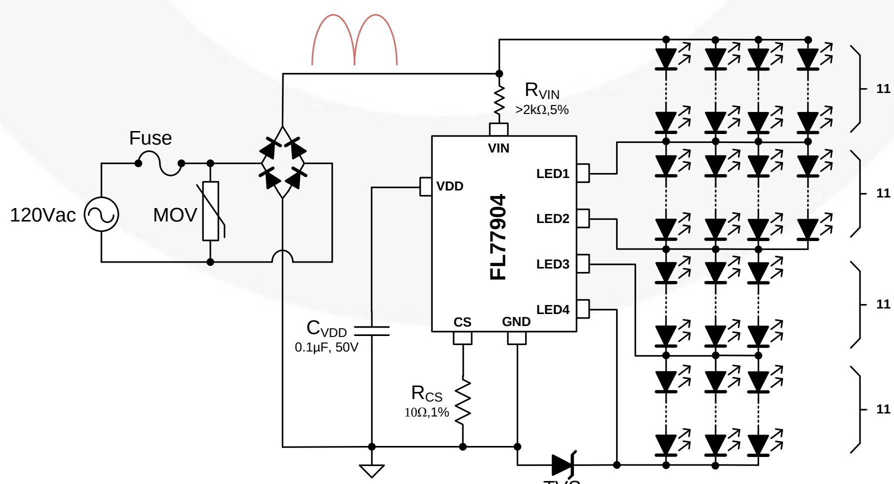
Figure 5. 20-V$_{AC}$ 8-W Down Light Design for Commercial Lighting Application using 65-V$_F$ LEDs

Long-String LED Design

When conventional low-voltage LED are implemented in a direct AC driving system, a long LED string will be presented in the schematic. It is optimum for designs requiring LEDs to be spread to larger areas.

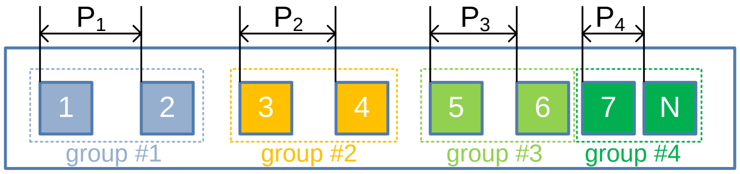
An example is tube-type design. Tube type LED lighting design requires tight balancing of light output at each part of the tube. FL77904 sequentially turns on each LED group thus current imbalance is inevitable. Possible ways to reduce the current imbalance are discussed below.

- Use different number of parallel LED string for each of the LED groups. For example, 1st LED group has the highest current and 4th LED group has the lowest current, so the 1st LED group will have the most number of parallel LED strings and 4th LED group will have the least number of parallel LED strings, as shown in Figure 6.
- Use different spacing between different LED groups based on their average current, as shown in Figure 7.
- Spread LEDs of each group evenly throughout the area. For example, if it's chosen to use 3X parallel LEDs (such as 5050 LED) in one package and have equal lighting distribution across light fixture, it is recommended to skip LED1, use only LED2~LED4, and arrange group connection as shown in Figure 8. In this configuration, the FL77904 still provides the decent performance such as power factor of 0.95, 15% THD.



- LED: V_F=3V@I_F=20mA
- Total number of LEDs: 154

Figure 6. 120-V$_{AC}$, 8-W LED Configuration having Different Number of Parallel LED Strings for Light Balancing



$P_1:P_2:P_3:P_4 = I_{F1.AVG}:I_{F2.AVG}:I_{F3.AVG}:I_{F4.AVG}$

In design example, $I_{F1.AVG}:I_{F2.AVG}:I_{F3.AVG}:I_{F4.AVG}$ = 1.88:1.79:1.54:1

Figure 7. Spacing LEDs Based on Normalized Current Ratio

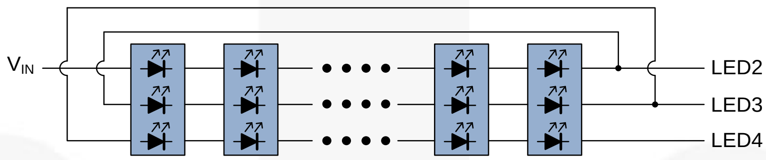


Figure 8. LED Configuration for Tube Type Lighting Design using 3X LEDs

References

[1] *"AN-5088 Designing for High Performance Commercial and Industrial Lighting Solution Using FL77944 High Power LED Direct AC Driver," Fairchild Semiconductor, July 2016.*

Related Datasheets

FL77904 –Phase-cut Dimmable Compact LED Direct AC Driver Data sheet

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