

LED Configurations

As the efficiency and brightness of LEDs improve and their cost decreases, the number of consumer and industrial applications using LEDs continues to increase.

Applications such as traffic lights, car lamps, LCD backlighting, and architectural lighting take advantage of the high efficiency and long operational lifetime of high brightness LEDs.

Constant Current LED Driver

A constant current driver is normally used to accurately control brightness and color of a LED. A Constant Current driver regulates the current through the LED independently of external factors, such as variations in LED forward voltage (V_f), power supply drift, etc. Once a current value is selected, the LED will continually be driven by that current, regardless of operating conditions. An internal feedback network monitors the current flow in a given LED or string of LEDs and continuously adjusts the output to maintain the desired current level. The output will support a single LED or series/parallel combinations of LEDs, maintaining the desired current on each output string.

Aimtec constant current LED drivers are available in models with universal AC voltage input, as well as models with DC voltage input.

LED Lighting

The Constant Current driver offers a versatile power solution for a wide variety of LED lighting products. For super-bright LEDs, the forward voltage range may be 3 to 3.5 V and the same constant current driver can be used. The selected current will be maintained regardless of the forward voltage of the LED.

LED lighting applications typically utilize many 1W to 3W LEDs operating together. There are three possible configurations for powering multiple LEDs. This article discusses each configuration accompanied by a simple schematic diagram along with a brief operational description, its main advantages and disadvantages.

Most often when LEDs fail they create a short from their anode to their cathode. For the purposes of this discussion this will be known as a “fail short”. Also possible is a “fail open” when an open circuit is created from the anode and cathode.

Configuration options: Series or Parallel or Matrix

There are two main options when connecting multiple LEDs together, parallel or series. Both architectures have their own advantages when considering the key parameters – efficiency, brightness matching, and LED failure immunity. The third option is a hybrid of the series and parallel configuration known as a matrix.

Series Configuration

When LEDs are connected in series, brightness matching is maximized; meaning the variation of brightness of one LED compared to another LED is not visible. The brightness matching results from the same current flowing through each LED and is independent of the variations of forward voltage of each LED; this is the main advantage for series configuration.

Series Configuration

When LEDs are all connected in series, the cathode of the first LED is connected to the anode of the second and so on, as illustrated in Figure 1.

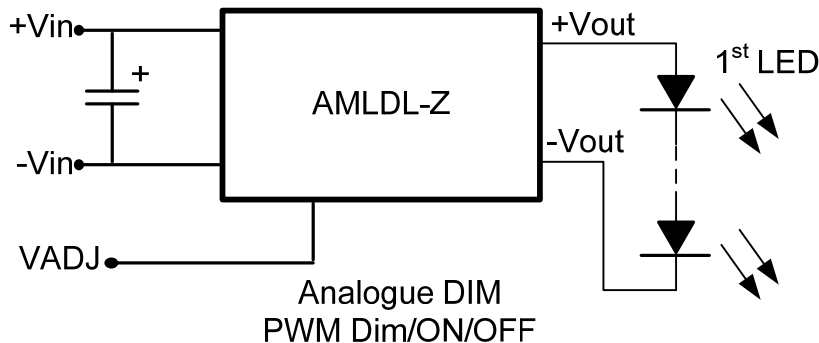


Figure 1 Series Configuration

The total string voltage is a function of the number of LEDs in the string, and the typical forward voltage (V_f) of each LED.

If 20 LEDs with a V_f of 3.5VDC are used, the total string voltage would be 70VDC. A single constant current driver provides power to each of the LEDs. In this configuration all LEDs receive the same current.

Advantages

- The configuration is simple with only a single circuit.
- There are no current imbalances as all LEDs in the string receive identical current.
- The efficiency of the system is high because no current limiting resistors are required.
- If one LED fails short the remaining LED's will operate normally, the string voltage will drop by the V_f of the failed LED and the power consumption will decrease. The overall lamp brightness will dim by one LED.

Disadvantages

- Output voltage can become very high when large numbers of LEDs are used, posing a possible safety issue.
- If an LED fails open the entire string of LEDs in the lamp will stop operating. In this case a simple by-pass circuit can be connected in parallel with each LED that will short out (by-pass) the failed LED minimizing the affect of the open fail LED.

How to calculate what LED driver parameters are needed

Calculation of Maximum number of LEDs connected in series

EXAMPLE 1: To calculate the maximum number of LEDs that can be safely connected in series to a constant current LED driver use the maximum output voltage of the driver divided by the forward voltage of each LED.

If $V_{out\ max} = 30VDC$, and the $V_{forward} = 3.0V$, then the maximum number of LEDs is $30/3 = 10$. A total of 10 LEDs can be connected in series with the constant current LED driver.

To select the required output current of the driver, consult the specification sheet for the LED used for the optimal current. Simply select an LED driver with the same optimal LED current.

Parallel Strings Configuration

Connecting strings of LEDs in parallel will reduce the maximum string voltage as well as adding some fault immunity.

Taking an example where 10 LEDs were used in a lamp, the LEDs could be arranged in 2 paralleled strings of 5 LEDs each. This configuration is illustrated below in Figure 2.

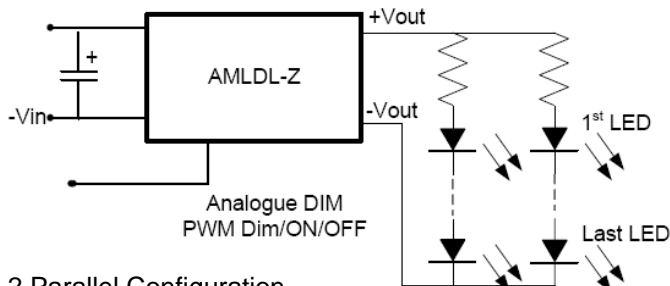


Figure 2 Parallel Configuration

The total string voltage is reduced from the Series Configuration by a factor equal to the number of paralleled strings.

Current is divided between the various strings based on how well each limiting resistor of the strings is matched. Variations in the V_f of the various LEDs can cause significant current imbalances in each string. A resistor in each string is commonly utilized to help balance the current.

Features of Parallel Configurations:

Advantages

- Only a single driver is required in the configuration.
- The total output voltage is relatively low.
- With proper selection of the resistance value reasonably equal current sharing can be achieved between the paralleled LED strings.

Disadvantages

- The improvement in current sharing comes with the disadvantage of higher power consumption in the resistors and lower system efficiency.
- If a single LED fails short, the remaining LEDs in the same string will be exposed to a higher stress level as they are forced to handle a larger share of current resulting in the likelihood of another LED failure in that string. The LEDs in the other strings will be noticeably dimmer because the total current is fixed by the current rating of the driver.
- If any LED fails open the LEDs in the same string will stop operating, and the current in the other strings will increase depending on the number of strings. In this case a simple by-pass circuit can be connected in parallel with each LED that will short out (by-pass) the failed LED minimizing the affect of the open fail LED.

Calculation of Maximum Output Voltage of LED Driver

EXAMPLE 2: In a parallel configuration the total forward voltage is V_{forward} multiplied by the number of LEDs in each string. If there are 2 strings of 5 LEDs, and the V_{forward} is 3.5V, the total forward voltage is $5 \times 3.5 = 17.5\text{Vdc}$.

To determine the output of the constant current LED driver take the optimal current for the LED used, and multiply it by the number of strings. If 350mA is the optimal current for the LED and there are 2 strings, the LED drive must have a current rating of $350 \times 2 = 700\text{mA}$

Matrix Configuration

The Matrix configuration attempts to eliminate some of the problems with Parallel Strings configuration by adding more connections between the LEDs.

A diagram of this configuration can be found below in Figure 3.

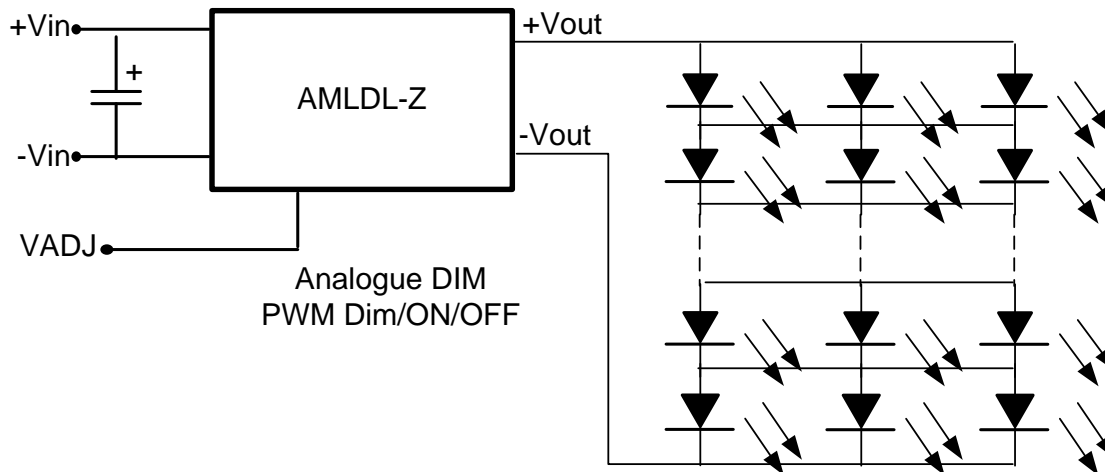


Figure 3 Matrix Configuration

The topology of this configuration is similar to that of the Parallel Strings configuration with the exception that there exists a connection between each of the strings.

The first LED in each string is effectively connected in parallel with the first LEDs in all of the other strings. Each subsequent LED is in parallel with its neighboring LED.

With this configuration, the LEDs are now arranged into a matrix of rows and columns.

Advantages

- This configuration also requires only the use of a single output driver, while the output voltage is relatively low, comparable to that of the Parallel Strings configuration shown in Figure 2.
- Generally, this configuration has higher fault-tolerance.
- Higher efficiency as current sharing resistors are typically not used.

Disadvantages

- Current imbalances are still an issue. Adding resistors to aid in current sharing is not as straightforward as in the parallel configuration.
- Uneven current sharing causes non-uniform light distribution and thermal distribution.
- If any LED fails short all LEDs in the same row will stop operating. The other rows will continue to operate normally but the brightness of the lamp will decrease.
- If any LED fails open the LEDs in the same row will be exposed to higher current increasing the chance of another LED in that row failing. All other LEDs will operate normally. In this case a simple by-pass circuit can be connected in parallel with each LED that will short out (by-pass) the failed LED minimizing the affect of the open fail LED.

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