



Addressable LEDs 101: Control, Design, and Implementation

Lighting technology has evolved significantly, and one of the most remarkable advancements is the introduction of addressable LEDs. These innovative light sources offer unprecedented control and versatility, allowing users to create dynamic and customizable lighting displays. Addressable LEDs, also known as digital LEDs or pixel LEDs, are revolutionizing the way we think about lighting design, enabling precise control over individual LEDs or groups of LEDs within an array. This article delves into the fundamentals of addressable LEDs, exploring their components, operation principles, and the factors to consider when designing and implementing these cutting-edge lighting systems.

Traditional LED arrays allow for a very limited control of the function of the LEDs within the array. The control is usually just an on / off, intensity or color variation of the entire array. The circuit would become very complex to allow control of each LED within an array of traditional LEDs. On the other hand, addressable LEDs allow for a simplified array of LEDs. They allow the user control over the array of LEDs to either act as a whole, in subgroups of LEDs, or for individual LEDs within the array to display independent functions.

An addressable LED system is comprised of five primary components (see Figure 1) LEDs, Integrated control circuits commonly embedded within the LED package, a circuit board either flexible or rigid, power supply, and primary LED controller.



Figure 1: Basic system components

In the basic operation of an addressable LED array, groups and sequential location within that group identify the individual LEDs. Connected to the LEDs there are three and sometimes four wires, power, ground, and data/clock for the three wire / one-control wire system. A four wire / two-control wire system will add a separate data and clock wires. More on that later.

With addressable LEDs, the signals to the LEDs are all

digitally controlled. The digital commands transmit from the primary controller to the addressable LED's embedded control chip. The control chip interprets the command; converting it to a digital pulse signal driving the appropriate RGB LED chips. The use of digital pulse signals allow for control of color and intensity output of the RGB array.

ADDRESSABLE LED DESIGN CONSIDERATIONS

- How many LEDs in my array?
- Do I need a 3-wire system or 4-wire system?
- Do I need a 5-volt or 12-volt supply?
- What are my system losses?
- What are my plans to mitigate circuit losses?

1-WIRE CONTROL SYSTEM

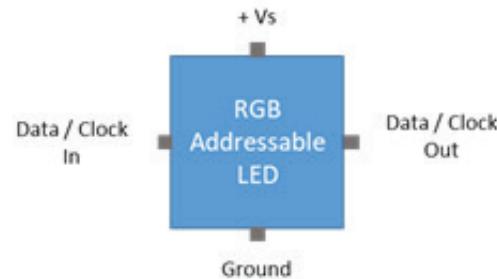


Figure 2: 1-Wire Control System Schematic

In the 1-wire control system (see Figure 2), 3 wires, a + Vs and ground connection for power and 1 single primary control wire that will supply all of the command signals to the initial LED in the group via the data / clock in terminal. This command signal will remain active in the first LED until the LED receives a new command. When receiving a new command the LED acts on that new command and will transfer previous command to the next LED in the string. This transfer of command repeats down the line for the entire array. The key is that the feed rate of commands is high enough that LEDs can appear to act as a group or as individual LEDs. For a typical 1-wire control system, the transfer time of commands from one LED to the next is typically 30 μ sec. The human eye generally cannot perceive this time so the command appears almost instantaneous in small quantity LED strings. It is not until about 30 msec

of delay for observation of a discernable difference. This delay limits a system, with 1-wire control, to a maximum LEDs count of 1000 LED in the array.

Three-wire addressable LED system are beneficial for smaller arrays with fewer connections made within the circuit. The downside of the 1-wire control system would be perceivable time delay potential in larger arrays and should an LED should fail in the array the function of the balance of the array stops as commands would no long be transferred out of the failed LED to the next LED in the array.

2-WIRE CONTROL SYSTEM

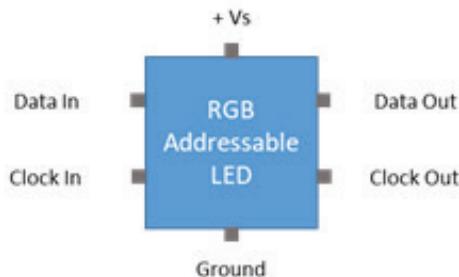


Figure 3: 2 Wire control system

A 2-wire addressable LED control system (see Figure 3) operates very similar to a 1-wire control system but as the name implies there is a 2nd control input wire to the LEDs to optimize control. In the 2-wire control system, separate control wires send the synchronized data and clock signals to the addressable LED. The embedded control chip interprets the signals then direct the LEDs what to do. The signals then pass to the next LED faster as the embedded chip can interpret the data and clock signals separately and simultaneously. The date transfer rate from one LED to the next is typically 1.9 μ sec. vs. 30 μ sec. for the 1-wire control system. The faster communication time results in potential LED arrays of up to 15,000 LEDs for the 2-wire control system as opposed to 1000 LEDs for the 1-wire control system, before any perceived perceptible delay from the first LED to the last LED in the array.

WIRING AN ADDRESSABLE LED ARRAY

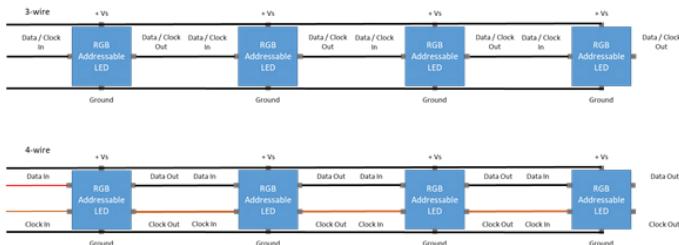


Figure 4: Addressable LED Array with 3-wire (2 power + 1 control) and 4-wire (2 power + 2 control) Circuit Schematics

Addressable LED systems are typically powered by either 5-volt or 12-volt control specifications (see Figure 4). Depending on the length of the array, the circuit designer must also consider the losses in the system not only for the individual LEDs but also in the wires and board traces. The power to the individual addressable

LED package remains constant so a 5-volt system would require 2.4 time the current of a 12-volt system.

In terms of wire loses, as an example, assuming the uses of a 20 AWG copper wire the wire loses at 25°C would be roughly $0.1 \Omega/\text{foot}$ of wire at 20°C. Additionally this resistance will increase approximately $0.39\%/\text{°C}$ increase in temperature. This number needs to double, as there are losses in both the positive wire and the ground wires. Many factors will determine the resistances of the traces in the circuit board, the major factors being the weight of the copper traces and the width of the copper traces on the board. Once you know this then the losses can be evaluated by considering the cross sectional area the same as round wire gauge.

The overall power consumption, hence current draw, of an addressable LED, only varies with changes to the programmed brightness of the LEDs. With maximum current consumptions around 36 mA for the 5 volt system. This is important to understand, as this determines the input current need to the LED array. The number of LEDs in the array would multiply this 36 mA current requirement. For example, a 50 LED array would require 1800 mA at the input.

To generate a very simplified calculation using the above example of a 50 LED array, if you assume 10 LEDs per foot and the trace resistance of the board is similar to the 20 AWG wire begin used than the losses between the power supply and LED 50 would be, assuming 20°C operation

1. $R \text{ wire } 20 \text{ ft.} * .01\Omega/\text{ft.} = 0.2\Omega$
2. Board at LED 50 R trace $(5\text{ft} * 2) * .01\Omega/\text{ft.} = 0.1\Omega$
3. Total 0.3Ω

The loss at LED 50 would be then be

1. $36\text{mA}/\text{LED} * 50 \text{ LEDs} = 1.8 \text{ amps (1800 mA)}$
2. Voltage loss at LED $1.8\text{A} * 0.3\Omega = 0.54 \text{ volts.}$

Actual losses would be slightly less as the full 1800 ma trace currents reduce by 36 ma at each LED further down line. If we assume for simplicity that the current is constant in the array, based on the above calculation with a 5-volt input the actual voltage at LED 50 would approximately be 4.46 volts. While this reduced voltage may or may not pose issues at the furthest LED in a 50 LED array, it is easy to see in much larger arrays that the voltage could easily drop below the proper operation of the addressable LEDs the further they are away from the power supply. You calculate the losses in a 12-volt system in the same manner. The losses would be inherently less as the current consumption per LED in the 12V systems are less than that of the 5-volt system. However, in very large arrays of the system losses are still a consideration of the design.

MITIGATING WIRING LOSSES

There are several methods to mitigate the losses in an addressable LED array. Including, but not limited to use of larger gauge wires, use of larger circuit board traces, and injecting additional power at points further down in the array or a combination of several of the above

Increasing the input wire sizes would only address a portion of the system losses, additionally the larger the size the more difficult it may be to route the wire from a remote power supply / controller to the addressable LED array.

Increasing the copper trace size on the circuit board sound easy, but comes at a price. The larger copper trace on the board will add substantial cost to the board and may require the board to be larger, rendering it impracticable for the desired installation location.

The most common method of mitigating the circuit losses in addressable LED arrays is to “inject” the power at the end of the array for shorter arrays, or at additional points within the array (see Figure 5a), by connecting additional set(s) of wires from a single power supply source. This would require that the single power supply output be capable of providing 100% of the current, plus any safety margin, to the LED array. Alternately, for very large arrays, accomplish power injection further downstream with the use of an additional supply located closer to the injection point. With this solution, the number of power supplies is increased but the output of the individual power supplies is reduced vs using a single power supply. When using the multiple power supply mitigation technique it is best to break the + power trace at the injection point to make the connection of the new power supply. Do not break the ground trace, as that is also the return trace for the data and clock signals. While the length of the array prior to needing to inject power will vary based on the design and wiring factors mentioned above, the length for a typical array with 30 LEDs per meter would normally be about every 5 meters.

Note: In some designs that incorporate large quantities of addressable LEDs there may also be a need to add amplifiers in the design to boost the data / clock signals, compensating for the attenuation of the signals over long distances.

Hint – Some designers have taken a different approach to help determine where to make an additional power injection. They run the addressable strip at full power in the cool white mode. Then scan the array looking for the point where the white starts to shift to a more neutral white and inject power at that point (see Figure 5b). The

theory behind this approach is that the green and blue LED chips in the array have a higher forward voltage than the red LEDs. When the voltage starts to drop too much in the circuit the current flow in the green and blue LEDs will start to drop before the current in the red LED chip and start to shift the color to warmer white tones.

DRIVERS FOR ADDRESSABLE LEDS

A Serial Peripheral Interface, or SPI, controller controls the performance of addressable LEDs. SPI controllers. These controllers are widely available from a variety of sources. Additionally if a system was initial set up to utilize a Digital Multiples, or DMX controller, that can easily be changed over to utilize addressable LEDs with the addition of a DMX to SPI decoder / converter between the DMX control and the addressable LED strips.

EXPERT GUIDANCE AND SUPPORT

Addressable LEDs have opened up a world of possibilities in lighting design and control. Their ability to individually control each LED within an array allows for remarkable creativity and flexibility, enabling stunning visual effects and dynamic lighting displays. While the implementation of addressable LED systems requires careful consideration of factors such as power requirements, wiring losses, and control systems, the benefits they offer are undeniable. As technology continues to advance, we can expect even more innovative applications and improvements in addressable LED systems, further expanding their potential in various industries, from entertainment to architectural lighting, and beyond. Embracing this cutting-edge lighting technology unlocks a realm of possibilities for designers, artists, and lighting professionals alike, ushering in a new era of illumination. If you need assistance in finding the right addressable LED solution for your project or have any questions, don't hesitate to contact the LED experts at Dialight. Their knowledgeable team can guide you through the process and ensure you get the perfect lighting solution tailored to your specific needs.



5a: Array Schematic with power “injection” point

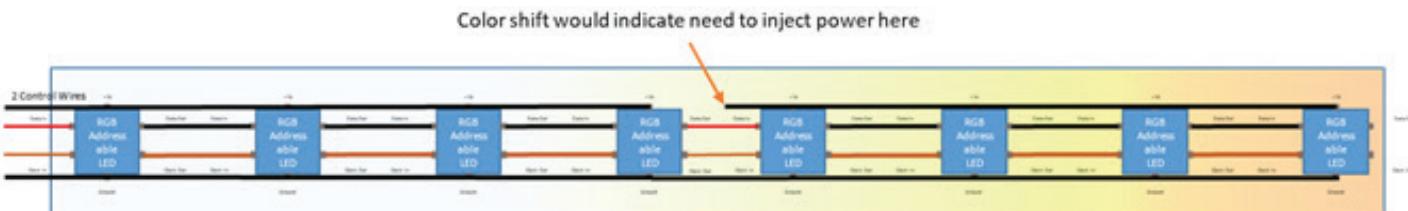


Figure 5b: Array Schematic showing point of color shift