

1. Are traditional industrial-grade power supplies suited for LED applications?

Most typical industrial-grade power supplies are not suited for outdoor LED applications for several reasons. First, most traditional power supplies provide constant voltage output, while LEDs prefer to use constant current drivers. Second, most industrial power supplies are designed to operate up to 40°C ambient temperature without power derating, which the LED drivers are often required to operate up to 60-70°C ambient without derating for many indoor and outdoor applications. Also, most industrial power supplies do not have waterproof and lightning protection features which are required for most outdoor LED lamps.

2. What are the critical factors in selecting an LED driver?

The first issue is whether the application requires constant voltage or constant current. If the supply is to drive the LEDs directly, it will typically require constant current. Next, the output voltage and/or current must be specified as well as the overall output power rating. Then the input voltage range must be determined. Many lighting applications require operation up to 277 Vac and so Astrodyne offers products with a 90-305 Vac operating range. Also important is the operating temperature range and the ingress protection (IP) rating. For outdoor lighting applications lightning protection is often a critical factor. Finally, compliance to efficiency, safety and electromagnetic compatibility standards should be evaluated.

3. Which are the most common configurations for connecting multiple LEDs and what are the advantages and limitations of each configuration?

Most solid state lamps consist of a significant number of high-brightness LEDs. These LEDs may be wired in any of a variety of configurations, each with their own advantages

and limitations. Four of the most common configurations are discussed here.

Series

Perhaps the simplest configuration is to connect all of the LEDs in series, the anode of the second LED connected to the cathode of the first. A single, constant current source can then illuminate the entire string. This works very well with a limited number of LEDs in the string. However, as the string voltage is proportional to the number of LEDs in the string, long strings can generate rather high voltages. Assuming a forward voltage of 3.5V, a string of 24 LEDs would generate a voltage of about 84V. If any given LED fails short, there is limited impact on the operation of the lamp. However, if any LED fails open, the entire lamp will fail. Despite the high voltage, this is perhaps the most energy efficient way to power a lamp.

Parallel Strings

In order to minimize the operating voltage, multiple strings can be connected in parallel. Using the same 24 LEDs, one could form four series strings of six LEDs each and then connect these strings in parallel. The total voltage would now be only about 21V but it would require four times as much current to power the lamp. If any given LED failed open, one of the strings would fail but the other strings would remain lit. If any LED failed short, that string would carry much more current than the remaining strings. These situations will likely result in lower reliability as the remaining LEDs in the string with the failed LED are subject to significantly increased stress.

Matrix

In order to negate some of the disadvantages of the Parallel Strings configuration, it is possible to make additional connections in the configuration. In a Matrix configuration, multiple LEDs would be connected in parallel then multiple sets of these paralleled LEDs would be stacked in series. Using the above example of 24 LEDs, four LEDs could be connected in parallel and then stacked six high. The string voltage would still be 21V. The drive current would remain the same. The advantage is

that one LED failing short (the most common failure mode) would take four LEDs out of service but the remaining 20 would operate normally without additional stress. The disadvantage is that load sharing between the paralleled LEDs is a function of how well the LEDs are matched in their operating characteristics.

Independent Strings

Perhaps the most robust method is to utilize a multi-channel constant current driver. Using the same example, in this configuration a four output driver would drive four strings of six series-connected LEDs independently. This would eliminate the problem of a single LED failing short. In this case, all other LEDs would be unaffected. The driver in this case would be somewhat more expensive having four independently regulated channels.

4. What are the benefits of using high efficiency LED drivers?

There are several benefits to use high-efficiency LED drivers. The first is very simply energy savings. The driving force behind the conversion to solid state lighting is energy efficiency. It only makes sense then to use high efficiency drivers as well. Energy savings in high efficiency drivers can be quite significant over the life of the driver. For example, the power dissipation of a 100W LED driver is 11.1W if the unit is 90% efficient, but increases to 25W if the unit is only 80% efficient. Assume the lifetime of the LED light is 40,000 hours, the difference of energy saving between these two units over the lifetime would be 556 Kilowatt*hours. At 10 cents per kilowatt*hour rate, this translates into a cost saving of \$55.6 over the lifetime. In some applications, the cost saving can be more significant if taken into account the losses in the utility line and the reduced energy consumption of the air conditioning system (if the lamp is used indoor).

In addition, the lower temperatures associated with higher efficiency drivers can significantly improve product life and MTBF. The power dissipated in a 90% efficient driver is less than half that dissipated in an 80% efficient driver. Doubling the heat in the lower efficiency driver significantly increases component temperatures. The life of the electrolytic capacitors in the driver decrease by about 50% with each 10 degree C increase in temperature. Therefore, higher efficiency drivers can easily have a 2-4 times longer projected life. Reliability is also a function of temperature and lowering temperature increases the reliability of all components in the driver.

5. Why is it important to use long-life LED drivers? How are they different?

There are two primary factors in the justification of most solid state lighting systems. The first is energy savings. However, there are other alternative lighting technologies that offer high efficiency for lower initial costs. The second justification, lower maintenance costs, is therefore critical. LEDs have the advantage of much longer life than most other lighting technologies. Reduced replacement and/or maintenance costs can be a very significant factor. However, if the power electronics in the system does not match the life/reliability of the LEDs then the justification of the system is in jeopardy.

The life of an LED driver is mainly determined by the lifetime of the electrolytic capacitors employed. Therefore, to achieve long life of the LED drivers, it is critical to select long-life, quality electrolytic capacitors. Also, since the life of electrolytic capacitors drops by half for every 10°C increase in operating temperature, thermal management of these components is important. Two key factors for reducing the temperature of the capacitors are high efficiency design (dissipating less heat in the driver) and thermal design (effective conduction and/or convection of the heat into the ambient surroundings).

6. What are the differences between MTBF and Lifetime?

Mean Time Between Failure (MTBF) represents the statistical approximation of the cumulative hours a number of units should operate before a failure can be expected. It does not represent the expected life of any given unit. For instance, if 10,000 units operated in the field for 1000 hours with 10 failures, the MTBF would be 1 million hours. This does not suggest that any unit will be expected to operate for 114 years. As another example, if product is determined to have an MTBF of 250,000 hours and 1000 units are deployed in the field, on average a failure could be expected about every 10 days if the products are operated around the clock or about once a month if they are operated 8 hours per day.

Conversely, the lifetime of a product indicates how long a product should be expected to survive under normal operating conditions. It is the period of time between starting to use the device and the beginning of the wear-out phase. This is determined by the life expectancy of components used in assembly of the unit. The weakest component with the shortest life expectancy determines the life of the whole product. For power supplies, electrolytic capacitors typically have the shortest lifetime expectancy. MTBF is applicable only during the normal operating life of the product.

7. What are PF and PFC and why are they important in specifying LED drivers?

Power Factor (abbreviated PF) is the ratio of real power to apparent power in an AC power system and is expressed as a number between 0 and 1. Real power is the actual power drawn by the load whereas apparent power is the product of the load current and load voltage. Since the voltage and current may be out of phase this product may be significantly greater than the real power.

PFC is the abbreviation for Power Factor Correction. In order to maintain a high power

factor, switch mode power supplies (including LED drivers) must employ some form of power factor correction.

This is an important issue because a load with a low power factor draws more current than a load with a high power factor for the same amount of real power transferred. Low power factor therefore results in greater power losses in the utility lines. There are a number of standards now in effect requiring certain levels of power factor correction in switch-mode power supplies and/or LED drivers.

8. Why are LED drivers often potted? Is it necessary?

The purpose of potting is twofold. First, it enhances the ingress protection (IP) rating of the unit by providing a waterproof barrier protecting the components from the intrusion of water under most circumstances. This is critical for outdoor applications such as streetlights.

Second, since the potting compound normally has much better thermal conductivity than the air, the potting is used to conduct heat generated by the key power components to the surface of the enclosure. This helps to greatly reduce the thermal stress on these components and thus increases the lifetime and reliability of the drivers substantially. It is estimated that the potting can typically reduce the operating temperatures of some of the key power devices by 20-40°C.

9. How are waterproof levels specified for LED drivers?

Ingress Protection (IP) ratings specify the environmental protection the enclosure provides. The IP rating normally has two numbers with the first specifying protection from solid objects or materials and the second specifying protection from liquids (water). The first number is specified from 0-6 with 6 implying complete protection from dust. The second is specified from 0-8 with the following implications:

0	No protection.
1	Protected against vertically falling drops of water e.g. condensation.
2	Protected against direct sprays of water up to 15° from the vertical.
3	Protected against direct sprays of water up to 60° from the vertical.
4	Protected against water sprayed from all directions.
5	Protected against low pressure jets of water from all directions.
6	Protected against high pressure jets of water from all directions.
7	Protected against the temporary immersion.
8	Protected against prolonged immersion.

Most Astrodyne drivers are rated IP67 which implies that the products are completely protected from dust and protected against temporary immersion in water.

10. How are lightning protection levels specified for LED drivers?

IEC 61000-4-5 establishes a common reference for evaluating the immunity of electrical and electronic equipment when subjected to surges. The test method documented in this part of IEC 61000 describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.

Surge test standards for lightning protection as below, IEC61000-4-5 ranks:

Level voltage	Open-circuit test
1	0.5 kV
2	1.0 kV
3	2.0 kV
4	4.0 kV
X	Special

NOTE X can be any level, above, below or in between the other levels. This level can be specified in the product standard.

What are the key advantages of Astrodyne's LED drivers?

Astrodyne offers the widest variety of high power LED drivers available anywhere. As most LED lighting applications are justified on the basis of energy savings and reduced maintenance costs, Astrodyne accordingly focuses on providing high efficiency and long-life products. The Astrodyne portfolio offers products with up to 95% efficiency, power factor up to 0.99, robust lightning protection and IP67 waterproof levels. These products comply with global safety regulations and electromagnetic compatibility standards and feature over-voltage, over-current and over-temperature protection. They are widely used for LED street lamps, tunnel lights and architectural lighting.