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## **White Paper:**

### **About LED Lighting**

Halco Lighting Technologies has spent a significant amount of effort in the development of effective LED lighting, and is committed to only provide the highest quality LED products in our ProLED division.

We are committed to studying and monitoring the current state of LED technology, and applying this technology *where it makes sense*. Part of the problem with LED lighting is a lack of understanding of the strengths and weaknesses associated with the use of LEDs as well as the misapplication of current technology (or using the wrong LED technology).

Applying the technology where it takes advantage of the strengths while minimizing the weaknesses of LED lighting may limit the number of LED products that we will carry, but it will ensure that if you buy a ProLED product, it is of the highest quality and will provide the desired results.

### **Operating Characteristics**

What is an LED? An LED is a semiconductor chip that generates light when current is applied in the right conditions, which is very different from any other technology currently used in lighting. These chips (known as *dies*), are assembled in a structure that helps support and protect the dies and the electrical connections. This structure is generally known as a *package*. Depending on the type of LED package and the desired characteristics, there may be one or more LED dies per package. The different types of LED packages have different strengths and weaknesses that impact the package's applicability in lighting. Of note, LEDs are more sensitive to operating temperature than other types of lighting, and anything from lifetime to acceptable current to chromaticity can be impacted by the operating temperature.

### **Low Power LEDs**

Low Power LEDs come two main categories, and in each category there are available in a number of different shapes, power levels, and sizes. These are distinguished and referred to as low power because they typically run very low

current levels, in the tens of milliamps rather than hundreds of milliamps that the *high power* LEDs run at. This means that they will, by nature, produce less light, but also will have different applications in lighting. Of the two categories of low power LEDs, there are the *lamp type* and the *surface mount type* (also known as an *SMD* LED).

Lamp-type LED packages are the type that most people are already familiar with, and are used in numerous applications as indicator lights or other applications where the requirement is that light must be seen. They use a low power LED die which is placed in a tiny reflector, and then encased in a transparent plastic material. The reflector extracts much of the light generated by the LED die and then the shape of the plastic encasement acts as a lens to give a light distribution, which varies depending on the shape of the encasement. Partially due to the plastic encapsulation (which has poor heat transfer properties), many of these LED packages will depreciate from their initial light output quickly. In some cases these LED packages can fall to 50% of their initial brightness within a few thousand hours. These LED packages are appropriate for indicators, and very minor backlighting applications (such as buttons or switches), but do not generate or maintain enough light for use in a general lighting application. Some companies market LED “bulbs” with large quantities of this type of LED package that are contained in a standard lamp shape (such as a glass PAR shell), but these products will almost always result in disappointment if they are expected to produce usable light over an extended period of time. It is simply a misapplication of the technology.

Surface Mount LED packages have more in common with high power LEDs in form factor and properties than they do the lamp type LED packages. These LED packages consist of one or more LED dies (still low power) in a single, typically flat, package. The package typically consists of either a ceramic or plastic reflector, and they are encapsulated in a protected substance, and the package is mounted to a PCB board. The orientation on a PCB board, as well as the configuration of the electrical contacts within the package, allows much better heat transfer properties in this type of configuration. This allows these low power LED dies to operate cooler, and reduce their light depreciation over time to levels more appropriate for use in lighting. This type of low power LED package has the potential to be useful in lighting where large arrays of them can be combined together to produce significant, usable light. This is also an economical alternative, as while SMD type packages can be more expensive than the lamp type packages, they are much less expensive than high power LED packages.

## **High Power LEDs**

High Power LED packages are always of surface mount form factor (meaning single or multiple high power dies in a package) and get their name from running hundreds of milliamps per chip and generate a much more useful amount of light. Whereas Low Power LEDs generate comparatively little heat, these higher power

versions do generate enough heat to make its management a concern. This is why the surface mount configuration, with better heat transfer properties, is essentially a requirement in using high power LED dies. These LED packages are more expensive, as they require a larger portion of semiconductor and require a very high grade of semiconductor material to operate effectively and efficiently at high currents. Despite this premium high power LEDs also have the most potential for use in replacing less efficient sources of lighting in general (and specialized) lighting applications.

The increased current through these devices increases heat management importance over that of low power products, which is why most high power products will be mounted in a structure that will help dissipate heat. This is why all of the High Power ProLED products use a complex aluminum heat sink as housing for the LED lamps, and why Halco has chosen to mount them on a metal core printed circuit boards.

### **Other Operating Characteristics**

Of note is that LED chips run on a very low voltage (3V-4V) and need a well regulated voltage and current. Each of the ProLED products is made with integrated drivers and transformers (appropriate to the application) in order to safely drive the LED components and achieve a long lifespan. The low voltage products are designed for 12VDC current, and will operate on 90% of 12VAC applications. Some low voltage fixtures operate lamps on 12VAC electronic transformers, which can cause problems with any LED product not working properly due to incompatibility related to differences in frequency.

### ***Lighting Characteristics***

#### **Directionality**

Unlike a filament from an incandescent lamp, an arc-tube from a HID lamp, or the phosphor on a fluorescent tube, the emission of light from an LED is not omnidirectional; that is it does not radiate in all directions uniformly. It is difficult to project light through a circuit board and heat sink, so the light from an LED is emitted from the top of the chip. This means at a theoretical best, an LED can project light in a hemispherical pattern, in reality most bare LED chips project light in a 120 to 140 degree cone. While there are some experiments in laboratories utilizing transparent substrates that may be able to further expand this distribution, these are not commercially available at this time and if and when they are, there would still be the limitation of the mounting surface and heat sinking attachment. This is why there is not currently a true "A" lamp replacement using LED technology. There are some novel methods that are producing more acceptable distributions for an omni-directional light source out of an LED, they are difficult and still suffer limitations in how much light is possible and can suffer in efficiency, depending on the approach. The most that

is typically possible of an “A” lamp like LED is a distribution pattern similar to an R-type reflector lamp, directional but broad and relatively even. Despite these limitations, there are uses for a higher efficiency, long lived directional light source, and products can be made to take advantage of this.

To better direct light coming from an LED, our products use what is called a *secondary optic*. This is a lens (although there are reflectors available) that attaches to the chip holding the LED package mechanically or through adhesive and directs the light into a different pattern (such as a narrow or a wide flood pattern). The quality of this optic affects the optical efficiency, or the amount of light that is actually projected compared to the amount of light generated by the LED. By taking advantage of the directional characteristic of LEDs, and using high quality optics, effective general lighting can be achieved with ProLED lamps.

## **Light Quality**

There are no true white LEDs that are commercially viable. Every type of material used in the chip part of the LED that produces light generates a color, but none of those colors are white. All LEDs produce a color, red, green, yellow, or blue (note that IR and UV LEDs do exist as well). The two methods for generating white light are to either use multiple LED chips and mix the light (such as our PAR20/8RGB25/LED), or to use a phosphor with a single color light (usually blue) to generate white light.

The color mixing method is (with current technology) less efficient, particularly in a high power setting, but through the use of advanced controls does allow virtually any color to be produced by varying the intensity of the multiple LEDs. If the efficiency gap of utilizing green LED die material at high currents is solved, there is significant potential in this method.

The phosphor coating method is currently much more efficient at producing light, and is the one that is used to produce the white light in our ProLED series. This coating process does have limitations as well, and that is in the variation in color temperature and chromaticity. The phosphor coating composition and thickness affect the color temperature, color rendering, and light output. In addition to this, the phosphors have a ‘response curve’, which means that the exact wavelength of the blue LED die used in this package will have an impact on the final light output as well. Generally speaking, warmer color temperature LED packages will have more of the phosphor coating than a cooler color temperature LED. Additionally, some companies use the addition of a red phosphor as well to help with the color quality and color rendering. Increasing phosphor thickness and adding an additional phosphor will lower the output of the LED package, as while these phosphors are very efficient, they are not 100% efficient, do produce some losses, and can have an impact on thermal management. To deal with these manufacturing variations, manufacturers of LED packages will divide their products up into “bins” which will have a defined range of characteristics. By selecting a bin, the resulting product will fall within a reasonably predictable

range of color and performance characteristics. While the bins offered by manufacturers of LED packages are getting smaller, there can still be variation in the color characteristics between production runs. These are the trade-offs of using phosphors to produce white light.

Some light quality advantages they have are that the spectrum of a white phosphor based LED is much smoother than a compact fluorescent lamp (providing light emission over a broad range of spectrum), and is capable of providing high quality light. In additional comparisons to CFL technology, an LED product can achieve instant full brightness, and is unaffected by switching, all without the use of mercury. RGB based white lights can be used to create dramatic color changing effects. An advantage that LED products have over equivalent halogen lamps is significant energy savings, and a beam that projects neither heat nor UV radiation, making LEDs a safe product to use when highlighting without concern of overheating or fading of the product.

### ***Where to use LED products***

LED products, at their current state of development, do have some limitations, and are expensive compared to some other technologies, so where can the advantages of LED products best be used?

### **Lifespan**

The long life of *properly designed* LED products makes them ideal for a situation where light failure can cost a lot of time, effort, and money. Examples of such are high-mounted recess and track lighting, where changing the bulb could be both dangerous and time consuming (such as in a hotel lobby, or in the atrium of a building). Given our 40,000 hour useful lifespan of our products, years of trouble free lighting can be achieved, easily saving money in labor and replacement costs for the equivalent of three to four CFL changes, or ten to fifteen halogen lamp changes. Please note that we define useful life as when the LEDs depreciate to 70% of their initial output, in lumens. The lamp will continue to operate far beyond that, but with additional lumen depreciation.

### **Energy Savings**

One of Halco's more powerful lamps to date is a PAR30 shape that uses a mere 14 watts of power spread through 12 LED packages to produce up to 1080 lumens of light in a compact PAR30 shape. Compare that to a 75 watt PAR30 or a 75W BR30 producing equivalent or less light, the LED will outlast 10 of these bulbs, and you can see the savings.

### **Product Presentation**

The last thing you want when using light to highlight a point of interest is for that light to damage or impair what you are highlighting. Whether the product is a delicate food that is sensitive to heat, a painting whose vivid details could be

dulled by UV, or a diamond ring that has to be comfortable when it comes out of the case, an LED directional light is a great solution.

## **Safety**

There is no glass in our ProLED line to break, very little heat compared to a searing halogen reflector, and no mercury to poison the environment. When the safety of your environment (working and natural) matters to you or your customers, a ProLED lamp is a great choice to suit your lighting needs. A lamp that won't be in the landfill for years, won't poison drinking water, and won't shatter sending slivers of glass flying.

## **Fixture Requirements**

All of the LED products come with a mention of not using them in totally enclosed fixtures, which causes some confusion and concern. To clarify, the term "totally enclosed" in this instance means that there is no airflow around the LED lamp, and the reason goes back to thermal management. LEDs do generate some heat, and while not as much as any of the other types of light, in a fixture with zero airflow, the aluminum body is unable to act as a heat-sink, and reduces the life of the electrical components in the LED lamp. It should also be noted that currently, the only ProLED lamp that is rated for outdoor use is the PAR36.

## ***LED Drawbacks***

All of the aforementioned benefits of LED based lighting products do not come without a price.

One of the largest drawbacks of LED based products is literally the price. High quality LED packages, with predictable and reliable color quality and output, are still very expensive when considering their initial cost on a lumen per watt basis. Using more LED packages will generally result in a better efficiency, but is then tempered by the fact that it adds considerably to the product cost. An LED lighting product is essentially an electrical appliance that produces light, and is more complex than many other sources. In addition to the LEDs themselves, the aluminum heat sinks, printed circuit boards, drivers, and optical control devices are all relatively expensive components to produce. Improvements in LED efficiency has the potential to reduce the overall initial cost, and as demand increases, economies of scale will likely bring the initial cost of LED products down over time, but they are unlikely to ever be as initially inexpensive as older, simpler, but much less efficient incandescent technology. Their long life requires a different approach to considering cost, where cost of ownership over time considering energy and maintenance is taken into account.

The second main drawback of LED based products is that they are much more sensitive to heat buildup than many other technologies. There are many applications where LEDs may still be inappropriate at the current time, where the ambient temperature is high enough that the long life of an LED product would be

compromised significantly. Most LED products cannot be totally enclosed unless very low wattage or specifically designed for this application, and this includes many of the insulated recessed can lights.

Despite the drawbacks or challenges in LED lighting technology, they have significant potential to change the landscape of lighting forever, and in dramatic ways that far exceed the flexibility of any other commercially available lighting technology.

### ***Conclusion***

LEDs have great applications in lighting ahead, and as technology improves, so will our products. The current limitations of LEDs can be turned into strengths, with the right knowledge and application, and we have years of expertise in lighting. When used in the appropriate application, Halco Lighting Technologies' ProLED PAR and MR style lamps offer a safe, long lasting, and energy saving alternative to any other technology available. For additional technical details or information, please contact Halco Lighting Technologies or visit our website at [www.halcolighting.com](http://www.halcolighting.com).

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