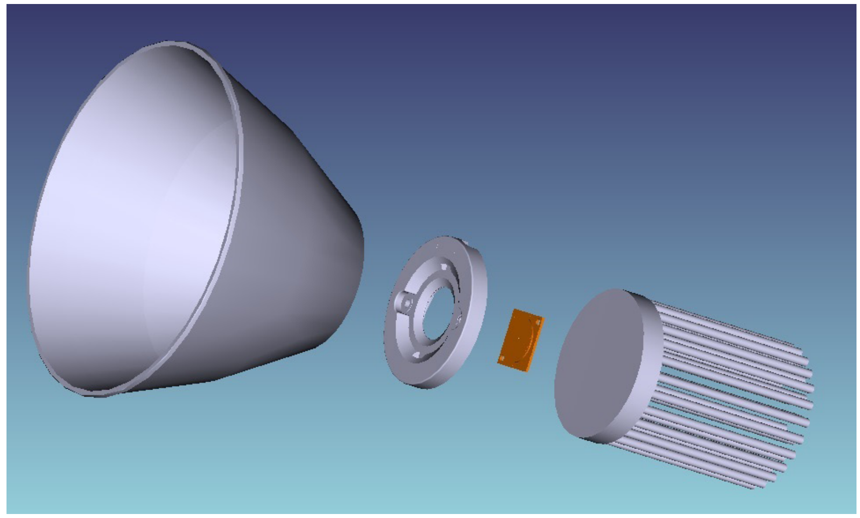
Application Note

Design Guidelines and Ecosystems for Luminus COB Arrays



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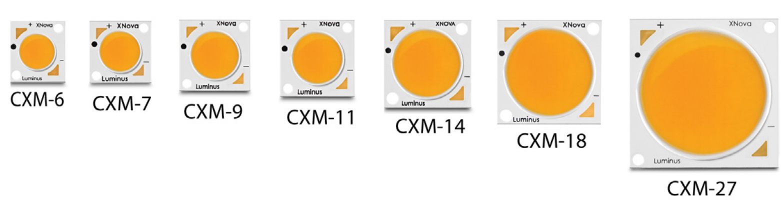
1.0 Introduction:

This document presents information about general physical principles related to solid state lighting (SSL) and guidelines for designs using elements commonly used in conjunction with chip on board (COB) arrays. COB arrays are designed to provide a reliable, long lived light source for a wide variety of illumination systems. COB arrays can be designed into systems featuring many types of reflector, TIR style lenses, collimating lenses, Fresnel lenses, bulk diffusers, and combinations of these elements. COBs arrays can be incorporated into flood lights, wall washes, narrow beam spot lights as well as numerous types of PAR, MR, BR, GU, A, E and festoon replacement bulbs. While these applications may vary a great deal in their performance and design, herein are contained some common attributes that should be considered when designing any lighting system featuring COB arrays.



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2.0 Performance Characteristics

2.1 Photometric Power and Flux Binning

The amount of illumination a lighting system can provide as well as the intensity of the beam it creates is directly proportional to the photometric power, or luminous flux produced by the light source. Luminous flux is measured in units of lumens and is the rate of energy radiated per unit time by the light source within the range of visible wavelengths. Lumens are calculated by integrating the product of the radiometric power per unit wavelength of the source (often referred to as the spectral response function or spectral distribution) and the human visual response curve (Fig. 1.) The human visual response curve (often referred to as the C.I.E. photopic response curve) is an experimentally derived function based on the perceptions of light by human subjects over a range of intensities and colors. The data were produced and are maintained by the Commission International l'Eclairage (C.I.E.), an international standardization organization whose protocols have become standard in the lighting industry. The mathematical relationship can be expressed as follows where S(λ) represents the spectral distribution and ȳ(λ) represents the photopic response curve.

$$\text{Luminous Flux} = \int S(\lambda) \cdot \bar{y}(\lambda) \cdot d\lambda$$

This integral is calculated from a range of 380nm to 730nm since it is in this wavelength range that the typical human observer is capable of perceiving light energy. This result assumes the radiation is emitted in all directions which can be described by spherical surface area surrounding the source.

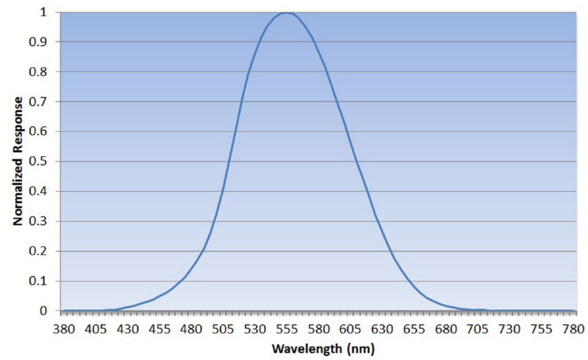

Fig. 1 CIE Photopic Response Curve

Fig. 2 Integrating Sphere

Physically, luminous flux is typically measured in an integrating sphere (Fig. 2.) An integrating sphere is a device which uses a spherical chamber coated on the inside with a material that is highly reflective and incurs very little absorptive loss when light from the source under test strikes it. The light is reflected back and forth within the sphere many, many times before it eventually falls on a detector. In this manner the light from the source is "integrated" and any directional component inherent to the source is removed. As a result the integrating sphere returns a measurement of the total flux as if it were emitted in all directions (like an Edison light bulb) even if the emission of the source is highly directional (like an LED coupled with a dome lens.)

The process of manufacturing LEDs results in devices that produce a range of luminous flux for a given drive current. For this reason finished parts are tested then sorted into bins based on their luminous flux at their rated drive current. Binning insures that designers are able to obtain a predictable output from the light source in their system. It also provides a measure of uniformity in across light sources if numerous LEDs are used in a system. The binning structure for each device is described in detail in the data sheet for each COB product.

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2.2 Spectral Distribution and Color Binning

LEDs produce light by means of a quantum mechanical process known as electroluminescence. This occurs when electrons move from one type of semi-conductor material to another. This movement happens when a voltage is applied across the two materials. Chemical dopants are added to the materials in order to facilitate the combination of electrons donated from one material with energy voids called holes in the other. Materials that contain an excess of electrons and thus contain an inherent negative bias are referred to as "N" type materials. Conversely materials that are apt to receive electrons and therefore have an inherent positive bias are called "P" type materials.

Any solid state diode, either light emitting or otherwise, requires the combination of P and N type materials. When a voltage is applied across the N and P materials, electrons and holes begin gathering in a region called the depletion layer and they combine at what is known as the junction. When the electrons combine with holes they emit a quantum of light known as a photon. Even in low output indicator LEDs billions and billions of holes and electrons are combining every second. Since there is a range of energies at which the electron-hole combination may occur, the light emitted by the LED also occurs across a range of wavelengths. This range is referred to as the spectral response or spectral emission.

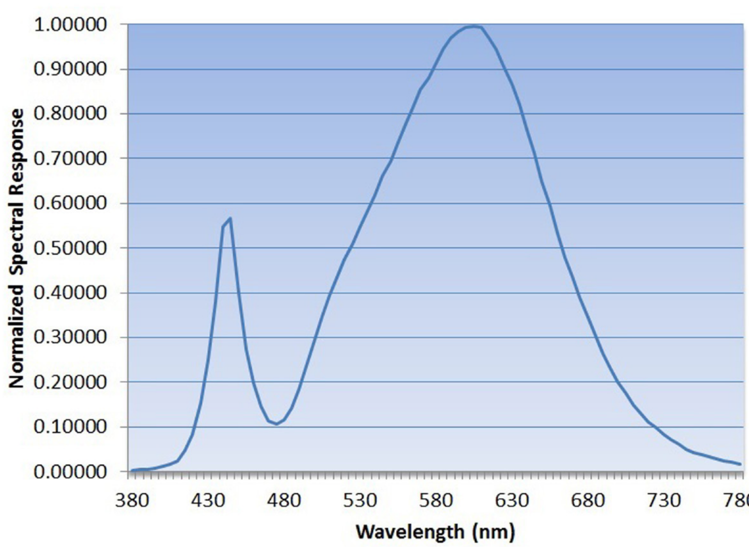

Fig. 3 Pumped Phosphor Spectral Distribution

By themselves doped semiconductor LEDs produce light that is perceived as a highly pure, saturated color. There are two methods by which LED devices produce white light. Individual red, green and blue LEDs may be assembled in a package small enough so that the combined emission appears as white light. This method has advantages in applications where it might be desirable to have the ability to change the color of the lighting such as in entertainment or photographic lighting. However in general lighting where high efficiencies are a more important performance parameter, LEDs are packaged with phosphors, either deposited directly on the LED die or remotely on a cover or lens.

In this arrangement the LED die "pumps" the phosphor and the phosphor emits light across a much wider emission band than the LED alone (Fig. 3.) Since phosphors produce light as a result of the internal molecular arrangement of the phosphor itself, no additional energy is required other than the radiated emission coming from the LED pump.

The spectral characteristics (i.e. color) of pumped phosphor LEDs will depend on the combination of the LED die used as a pump and the formulation of the phosphor packaged with it. Phosphors can be formulated to produce a wide variety of colors including many types of white light. White light is characterized by where it falls along the blackbody curve (Fig 4.) While pumped phosphor LEDs do not emit

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2.2 Spectral Distribution and Color Binning Cont.

light in the same way that blackbody radiators do (such as a bar of iron that is heated until it glows) their emission can be characterized in terms of the equivalent temperature that a blackbody radiator would have to reach in order to produce the same color of white light. Thus white LEDs are characterized in terms of what is known as "correlated color temperature (CCT)" which is given in units of degrees Kelvin.

Luminus COB arrays are binned within a range of colors which can be described on a virtual area known as color space. In 1931 the C.I.E. published a methodology for assigning a value to colors based on a set of coordinates within a two dimensional color space. The area is referred to as the CIE 1931 Chromaticity Diagram (Fig. 4.)

This area provides a mathematical methodology for locating a given color within the color space. The x,y chromaticity coordinates of the color produced by an emissive or reflective source are derived by solving mathematical integrals weighted by the color response of a typical human observer.

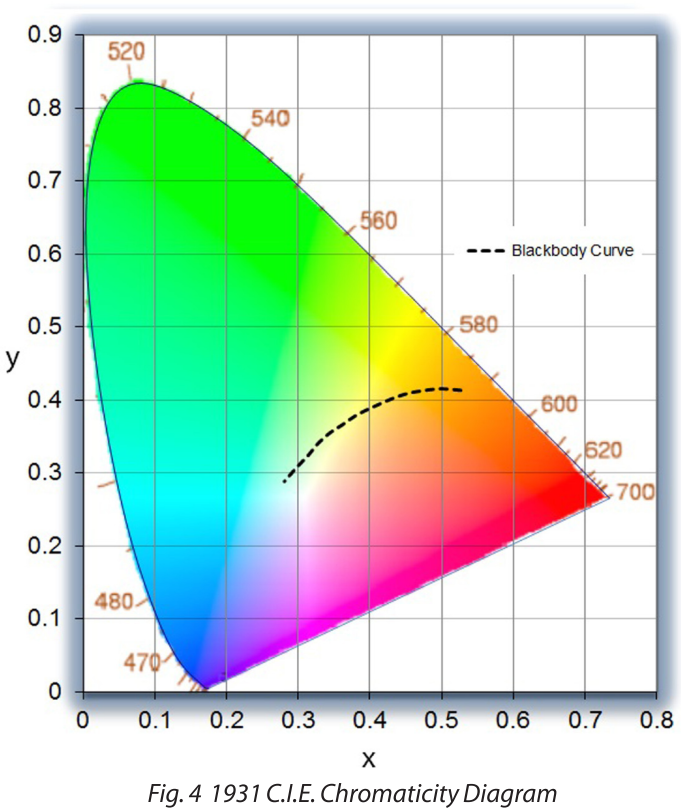

Fig. 4 1931 C.I.E. Chromaticity Diagram

The degree to which a human observer can differentiate one color, or shade of color, from another can be represented by elliptical areas of varying sizes on the 1931 chromaticity diagram. The MacAdam ellipse is a series of regions on the 1931 diagram that are used to describe how closely related a given set of points on the chromaticity diagram will appear to a standard observer. Since human vision is better at differentiating colors in greens and yellows (480 to 580nm,) and less sensitive to blues and purples (380 to 480nm), standard MacAdam ellipses vary in size throughout CIE 1931 color space. For white light binning of LEDs, these MacAdam ellipses fall along the blackbody curve according to the specified color temperature.

The total area covered by a MacAdam ellipse is referred to as the step size. Each step represents a standard deviation of the major and minor axis of the ellipse based on a statistical sample. Each standard deviation is based on the ability of a standard observer to differentiate a color difference.

COBs are binned according to two-step, three and five step MacAdam ellipses. To put this into perspective, a one-step MacAdam ellipse is defined as a range of chromaticity coordinates that is impossible for a standard observer to distinguish from one another. This binning structure allows designers a range of options when considering their color uniformity requirements.

In the binning of white LEDs, MacAdam ellipses are often shown in the context of areas on the 1931 CIE chart called ANSI quarangles (Fig 5.) The American National Standards Institute (ANSI) has provided a binning structure based on a 5 step MacAdam ellipse. Ellipses along the blackbody curve may have regions that are

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not covered by adjacent ellipses centered at commonly specified color temperatures. So in order to improve the efficiency of the binning process, quadrangles provide a means of insuring that any LED falls into some particular bin (Fig 5.)

Another way of characterizing white LEDs relates to how colors appear when illuminated by the white LED. Objects that do not themselves emit light can be seen because they are reflecting light provided by some illuminant. Therefore the color of that object may vary in appearance depending on the spectral characteristics of the illuminant. The accuracy with which the color of an illuminated object appears compared to that same object illuminated by a standard illuminant is known as the color rendering index (CRI.) Light sources that score a higher number on the color rendering index (high CRI) will provide illumination that causes objects to appear similar to some referenced color the Munsell hue/chroma scale. The Munsell scale assigns values based on how that color would appear in daylight. Higher CRI illumination light sources have ergonomic benefits for task lighting however low CRI illuminants can be advantageous for higher contrast or overall lumen output.

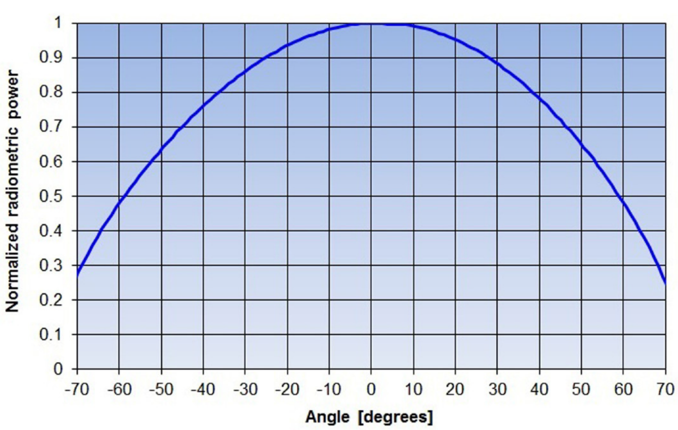

Fig. 6 Typical Angular Distribution Pattern for CXM Array

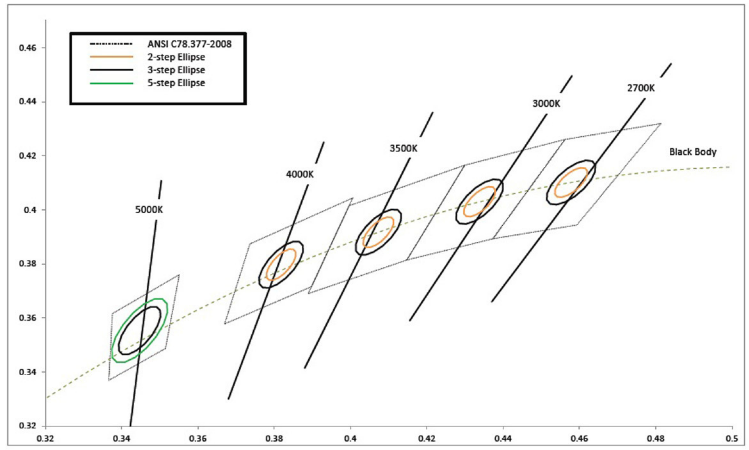

Fig. 5 MacAdam ellipses and ANSI quadrangles

2.3 Angular Distribution

Luminus COB arrays emit light in what is called a Lambertian pattern. As Lambertian emitters the intensity relative to viewing angle very nearly approximates a cosine curve where the maximum occurs at 0° (normal) viewing angle (Fig 6.) This results from the high degree of randomization to the emission angle of photons released by both the LED die and the phosphor. The highest intensity of light emission occurs at a 0° because it is at this angle that emitted photons are less likely to be reabsorbed by materials in the system. Photons emitted at high angles relative to normal must travel through more material, either in the LED die itself, or through the phosphor layer or in the packaging material such as the yellow resin.

Consequently they are more likely to be absorbed and converted to heat energy in a process known as quenching. The data sheet for each COB product will contain a plot describing the angular distribution for that device (Fig 6.) It is important to note that while the absolute intensity of the device will increase with increased drive current, the relative intensity vs. viewing angle curve will remain the same at any drive current.

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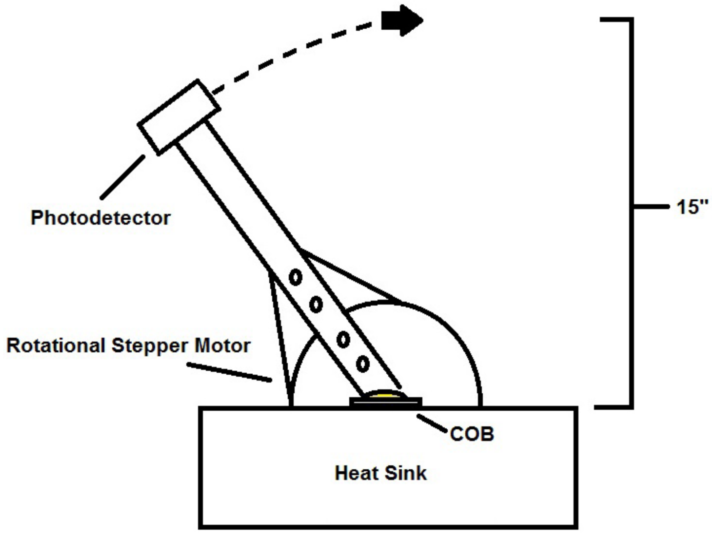

Fig. 8 Diagram of Goniometer Used for Far Field Angular Distribution Measurements:

COB device is mounted on a heatsink and power is applied. A photodectector is rotated over the device by means of a motion controlled stepper motor. Radiometric power readings are recorded by the photodetector at each angular position throughout a specified range of angles.

3.0 Ecosystems

Designers who choose Luminus COB products can count on reliable, predictable performance from their light source. In order to utilize the power of COB arrays designers will also need to combine the light source with numerous optical and electronic elements. A typical solid state lighting system will require at the very minimum an electrical design, a mechanical design, a thermal design, and an optical design. The particulars of the design will depend on a number of parameters including the required illumination at various distances, beam angle, power limitations, ambient environment temperature just to name a few.

In order to provide resources to designers using COB products, Luminus Devices has teamed with Certified Solution Partners. Our Certified Solution Partners are manufacturers and distributers of equipment necessary to develop solid state lighting systems based around COB products. Listed in section 3.7 Ecosystems at a Glance are a wide variety of options for design solutions across many different lighting applications. The Preceding sections 3.1 through 3.6 provide a very general description of how these options may be applied in SSL systems.

3.1 Reflectors and Diffusers

In any application, a reflector is designed to redirect light that is emitted at directions where it is not useful, to directions where it is useful. Since COB arrays emit light in a Lambertian pattern, a reflector is required in applications that demand a beam narrower than 180°. The most common types of reflector geometry used in SSL systems are parabolic, hyperbolic, elliptical zonal. Each of these geometries is suited for particular illumination patterns.

For example parabolic reflectors typically generate a narrow beam pattern and hyperbolic reflectors produce a wider beam. Elliptical reflectors work by placing the light source at one focus of the ellipse which then concentrates the light down to a point located at the other focus of the ellipse.

In terms of performance reflectors are characterized in two ways, their beam width and their beam efficiency. Beam width simply describes the angular distribution of the light emerging from the system.

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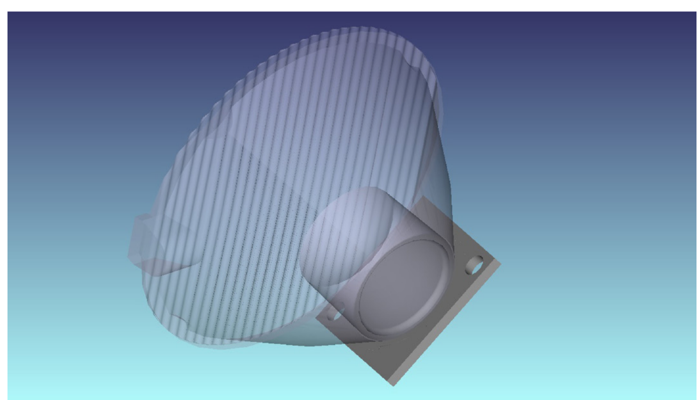
A reflector's efficiency describes how much light from the source is directed into the beam at a particular angle. Lighting designers specify reflector efficiency in units of candelas per lumen (cd/lm.) The candela is the base unit of photometry and is defined as 1 lumen per steradian and quantifies the intensity of beam of light emanating from a source. The definition of the candela can also be stated as photometric power per solid angle. So a reflector's efficiency can be thought of as the ratio of how many lumens end up in the beam to how many lumens are provided by the source per degree of solid angle. For this reason the beam efficiency will change over the angular distribution of the beam. Typically the beam efficiency is specified at the 0º viewing angle.

Typical categories used in general lighting are spot, flood and medium. These categories are defined by the width of the beam produced by the combination of light source and reflector. Typically this definition depends on the angular width of the beam at 50% of maximum intensity. Again the metric of "full width at half maximum" (FWHM) is used however this definition is not to be confused with the FWHM of the intensity vs. wavelength description of the LED's spectral distribution.

To some degree, all materials scatter light in various directions as photons travel through. Diffusers are materials used in lighting systems that are particularly suited for serving this function. Diffusers help to "soften" lighting by directing light in random directions which results in a wider dispersion of light, and a less defined appearance to the lighting source. Diffusers also come at a significant cost to the lumens budget of the lighting system. However designers often deem this cost worthwhile in order to improve the appearance and visual appeal of the lighting.

3.2 Lenses

A lens is an optical element that uses curved surfaces to refract light. They can be made of glass or plastic and in very high performance applications lenses made of quartz or sapphire may be employed. There are an immense variety of lenses suited for a host of applications. Lenses are most commonly used in imaging systems such as cameras and projectors but are also used in many types of illumination system. In SSL systems lenses are often used to concentrate light into a narrow beam where all the rays emerging from the system are nearly parallel. This process is known as collimating and can be useful when the application requires a highly controlled light. Parabolic reflectors can produce beams as narrow as 8º to 12º but typically a lens is required to produce collimated light. Lenses can also be used to perform the opposite function and disperse light over a wide area of illumination. The performance of the lens and beam it produces will depend on several factors such as the focal length, diameter and thickness of the lens as well as the position of the lens relative to the light source. In some systems combinations of lenses are used in order to produce the desired illumination pattern.



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All lenses come with a cost to the optical power of the system. Even lenses equipped with thin film coatings designed to improve light transmission will incur at a very minimum a 2% loss due to reflection at each surface to the initial lumens provided by the light source. Furthermore, lenses can be affected by interference effects or geometric imperfections that may introduce unwanted artifacts such as hot spots, rings, or non-uniform illumination.

Compound Lenses are arrays of smaller lenses arranged in such a way as to correct for aberrations and defects that may occur in simpler lenses. One type of compound lens commonly used with LEDs is the so called total internal reflection (TIR) lens. TIR lenses are typically only used in SSL applications because LEDs offer much more flexibility for thermal management than any other light source. Since LEDs produce far less heat that incandescent lights sources, and most of the heat an LED does produce can be made to flow in the opposite direction of light emission, optical elements can be placed in very close proximity to the source without degradation to the optic or the source. In many cases the TIR lens completely envelopes the light source. In so doing TIR lenses act as both reflector and lens as they gather up a very high percentage of emitted light and like a fiber optic cable guide the light into the desired direction. TIR lenses have another significant advantage in that total internal reflection is 100% efficient and does not incur any absorptive loss at the reflective surfaces. Light that is internally reflected within the TIR lens exits through the output face which is often made up of many small shaped surfaces forming the compound lens.

3.3 Power Management

To emit light a direct current (DC) must flow through the LED. If an AC voltage is applied across the LED if will not only fail to produce light but it will also be likely to suffer permanent damage. In order to maximize the efficiency of an electrical grid, AC power must be distributed at voltages that are destructive to LEDs. So for SSL systems to function properly there must be some electronic interface between the AC power lines and the LEDs that converts the current from AC to DC and also steps the voltage down to a level that is safe for the LED.

There are two general types of power supplies used in lighting; constant voltage and constant current. In incandescent and fluorescent lighting systems, power supplies must hold a constant voltage across the terminals of the light source in order to produce consistent lighting. However LEDs produce light in a very different manner. LEDs generate light as electrons and holes combine within the molecular lattice of the semiconductor material. Since electrical current is nothing more than the flow of electrons, in order for the amount of light to remain consistent, the power supply must deliver a constant current to the LED.

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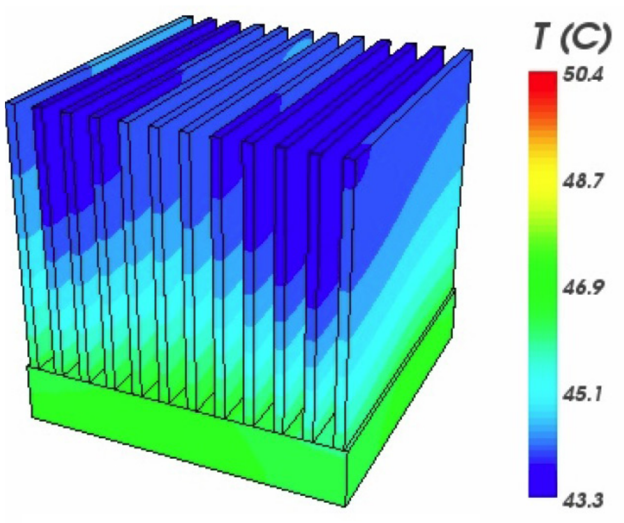
Designers who want the greatest amount of flexibility and customization in their electronic interface will design their own power supply around a particular integrated circuit (IC.) Functions such as dimming, timing, temperature monitoring, and fault detection can be based on the parameters of a particular IC. Since this chip ultimately controls the performance of the lighting source, they are often referred to as LED driver IC's.

An LED driver board typically contains a driver IC assembled on a circuit board along with other control and interface components. So the functions of a driver board are particular to a design based around the driver IC used on that driver board. However driver boards do not come potted or mounted in a frame or fixture which allows designers a wider range of choices for the mechanical design of their SSL system.

A lighting ballast consists of a driver board along with a housing and interface connectors. A ballast serves as an off the shelf interface between the source power and the output to the LED. A ballast requires minimal design or assembly after purchase however few if any modifications or customizations can be made to the part.



3.4 Thermal Management

Two processes occur within an operating LED that result in the production of heat energy. The first is the result in collisions between flowing electrons and atoms bound within the semiconductor materials. Semiconductors like LEDs could also be termed "semiresistors" and while their resistivity is low compared to materials like ceramic, they do result in a small voltage drop across the terminals and therefore produce some heat. However most of the heat produced by the LED emanates from the junction as electrons and holes combine. In this small area heat generation can be very large and if not managed properly can lead to a significant drop off in light production and eventual failure of the device. LEDs are packaged so that heat produced in the junction can be drawn away from the junction and dissipated elsewhere in order to allow the continued operation of the device. COB products are packaged with an aluminum core board that serves as the first means of drawing heat away from the junctions within each LED in the array. However by itself the core board is not sufficient to keep the LEDs within the range of safe operating temperatures.

In order for heat energy to move from the junction to the heat sink and interface material must be used in order to eliminate thermally resistive air gaps that occur on a microscopic scale. A thermal interface material (TIM) fills in voids that arise due to the surface roughness and contours of the COB and heat sink. A thermal interface material increases the surface contact by a significant degree and thereby allows for the efficient removal of heat from the LED package. All COB products require an effective TIM in order to function properly. The TIM should contact the entire back surface of the aluminum core board. Likewise the otherside of the TIM should be in complete contact with he heatsink. Voids, poor adhesion, or insufficient amount of TIM can result in low light output and failure of the device.

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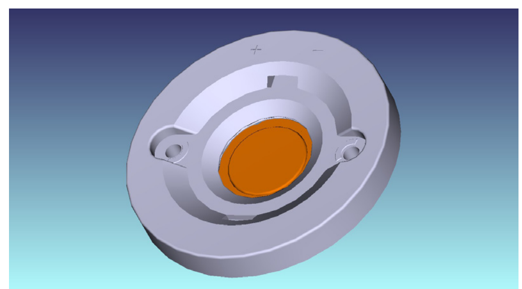
Once heat is removed from the LED package, it must be dissipated quickly and efficiently in order to prevent the junction temperature from rising to levels that could be destructive to the device. In SSL systems this function is served by the heat sink. Due to cost and manufacturability, aluminum is the most commonly used material for heat sinking of LEDs. Heat sinks are often formed into rays or fans in order to maximize the surface area of the heat sink within a certain volume and mass of material. A passive heatsink relies only on overall mass and surface area to remove heat from the LED package and dissipate the heat out into the environment. Active heat sinks use additional means such as a fan or thermo-electric cooler to perform these functions. Designers can calculate the junction temerature based on the thermal conductivity and thermal dissapation of the heat sink. For additional information for calculating junction temperature based on heatsink temperature, see APN-001443 Thermal Management of Big Chip LEDs

3.5 Solderless Connectors

As a requirement for proper operation, COB arrays must be firmly affixed so that at no time the core board separates from the TIM and heat sink. There are numerous methods by which this may be accomplished. The aluminum core board of each COB product is provided with two through holes for the purpose of mounting the device in the SSL system. The through holes can be used to either pass screws or receive holder pins in a holder, clamp or solderless connector. Section 4 below contains further information for handling and mounting requirements related to solderless connectors.



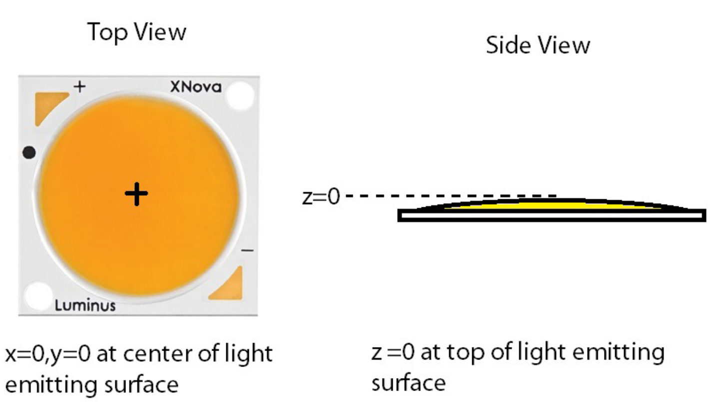


Fig. 8 Reference Plane for Optical Models

3.6 Mechanical and Optical Models

Many designers of SSL systems utilize 3D modeling software in order to virtually assemble their lamp, bulb or luminaire and simulate its performance. Virtual modeling provides a fast an inexpensive way of making changes to design iterations without having to wait for new prototypes to be built. Luminus Devices provides raytrace files for COB arrays in formats suitable for commonly used optical modeling software like Light Tools, Zemax and Trace Pro. Also provided are solid model files in .iges format which can be used by programs such as Solid Works and Pro Engineer. The files can be downloaded from the Resource Center section of the Luminus web site and can be accessed at the following URL:

http://www.luminus.com/resource/design.html

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4.0 Ecosystem Tables

4.1 Secondary Optics

COB/Reflector/Connector Compatibility Table

Manufacturer	COB p/n	Manufacturer	Reflector p/n	Diameter (mm)	Height (mm)	Manufacturer	Connector/Holder p/n
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-24R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-33R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-45R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	LedLink	LL01CIOT-24R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	LedLink	LL01CIOT-33R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	LedLink	LL01CIOT-345R3-P	50	30	LedLink	LL01A00SULB2
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Luminus Devices	CXM-7	LedLink	LL01ED-AKY38R49	50	30	LedLink	LL01A01STYB2
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Luminus Devices	CXM-7					Molex	180555-0001
Luminus Devices	CXM-9	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
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Luminus Devices	CXM-9	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-9	Ledlink	LLO1CIOT-20R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-14	Ledil	F13659_Angelina-S	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13379_Angelina-M	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13381_Angelina-W	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13379_Angela-S	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13380_Angela-M	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13664_Angela-W	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14					Molex	180414-0001
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13659_Angelina-S	82	36.04	TE Connectivity	2213254-1
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13379_Angelina-M	82	36.04	TE Connectivity	2213254-1
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13381_Angelina-W	82	36.04	TE Connectivity	2213254-1

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COB/Reflector/Connector Compatibility Table

Manufacturer	COB p/n	Manufacturer	Reflector p/n	Diameter (mm)	Height (mm)	Manufacturer	Connector/Holder p/n
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-24R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-33R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM/CLM/CHM-6	LedLink	LL01CIOT-45R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-7	LedLink	LL01CIOT-24R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	LedLink	LL01CIOT-33R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	LedLink	LL01CIOT-345R3-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-7	LedLink	LL01ED-AKY24R49	50	30	LedLink	LL01A01STYB2
Luminus Devices	CXM-7	LedLink	LL01ED-AKY38R49	50	30	LedLink	LL01A01STYB2
Luminus Devices	CXM-7	LedLink	LL01ED-AKY55R49	50	30	LedLink	LL01A01STYB2
Luminus Devices	CXM-9	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-9	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-9	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Ledil	C13083_PF_Socket
Luminus Devices	CXM-9	Ledlink	LLO1CIOT-20R2-P	50	30	LedLink	LL01A00SULB2
Luminus Devices	CXM-14	Ledil	F13659_Angelina-S	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13379_Angelina-M	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13381_Angelina-W	82	36.04	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13379_Angela-S	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13380_Angela-M	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14	Ledil	F13664_Angela-W	119.5	79.31	TE Connectivity	2213130-2
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13659_Angelina-S	82	36.04	TE Connectivity	2213254-2
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13379_Angelina-M	82	36.04	TE Connectivity	2213254-2
Luminus Devices	CXM-14-AC00/CHM-9-XH00/CXM-11-XH00	Ledil	F13381_Angelina-W	82	36.04	TE Connectivity	2213254-2
Luminus Devices	CXM/CHM-18	LedLink	LL01ED-AKA60R49	85	23.5	LedLink	LL01A01STZB2
Luminus Devices	CXM/CHM-18	LedLink	LL01ED-AKX24R49	116	32	LedLink	LL01A01STZB2

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COB/Reflector/Connector Compatibility Table

Manufacturer	COB p/n	Manufacturer	Reflector p/n	Diameter (mm)	Height (mm)	Manufacturer	Connector/Holder p/n
Luminus Devices	CXM-18	LedLink	LL01ED-AKX38R49	116	32	LedLink	LL01A01STZB2
Luminus Devices	CXM-18	Ledil	CN12721_Lena-S-DL	111	85.6	Ledil	C12153_LENA-STD-BASE
Luminus Devices	CXM-18	Ledil	CN12722_Lena-M-DL	111	85.6	Ledil	C12153_LENA-STD-BASE
Luminus Devices	CXM-18	Ledil	CN12723_Lena-W-DL	111	85.6	Ledil	C12153_LENA-STD-BASE
Luminus Devices	CXM/CHM-18/CHM-14-XH00					Bender & Wirth	453
Luminus Devices	CXM-27					Bender & Wirth	454
Luminus Devices	CXM-9					Bender & Wirth	461
Luminus Devices	CXM/CHM-18/CHM-14-XH00	LedLink	LL01LU-BRS24R49			LedLink	LL01A00BVFB2-M2
Luminus Devices	CXM-9-AC00					LedLink	LL30A00SUNBx-Mx
Luminus Devices	CXM-14-AC00/ CHM-9-XH00/CXM-11-XH00					LedLink	LL38A00SUQBx-Mx
Luminus Devices	CXM-22					LedLink	LL01A27BUYMx-Mx
Luminus Devices	CXM/CLM/CHM-6	Darkoo	DK35xx-REF				
Luminus Devices	CXM/CLM/CHM-6	Darkoo	DK2824-REF				
Luminus Devices	CXM/CLM/CHM-6	Darkoo	DK30XX-JC-B				
Luminus Devices	CXM-7	Darkoo	DK-42XX-REF				
Luminus Devices	CXM-7	Darkoo	DK45xx-REF				
Luminus Devices	CXM-7	Darkoo	DK7512-R&L-022				
Luminus Devices	CXM-14	Darkoo	DK92xx-REF				
Luminus Devices	CXM-14-AC00/ CHM-9-XH00/CXM-11-XH00	Darkoo	DK92xx-R&L				
Luminus Devices	CXM-27	Darkoo	DK95xx-REF-C				
Luminus Devices	CXM-27	Darkoo	DK95xx-REF-SP2024C				
Luminus Devices	CXM-9-AC	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM-9-AC	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM-9-AC	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM-6-XH	Ledil	CN13130_Mirella-50-S-DL-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM-6-XH	Ledil	CN13131_Mirella-50-M-DL-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM-6-XH	Ledil	CN13132_Mirella-50-XW-PF	49.9	23.9	Bender & Wirth	434 Typ L1
Luminus Devices	CXM/CHM-18/CHM-14-XH00	Ledil	F13659_Angelina-S-B	82	36.04	BJB	47.319.2281.50

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COB	Optics Solutions					Connector Solutions	
COB p/n	Manufacturer	Reflector p/n	Beam Angle FWHM (deg)	Diameter (mm)	Height (mm)	Manufacturer	Connector/Holder p/n
CXM/CHM-22	Ledil	CN12706_LENINA-S	27	74	48.35	Ideal BJB TE TE	50-2204CT 47.319.2030 6-2154874-3 2-21554857-2
CXM/CHM-22	Ledil	CN12707_LENINA-M	39	74	48.35		
CXM/CHM-22	Ledil	CN12708_LENINA-W	58	74	48.35		
CXM/CHM-22	Ledil	CN12965_LENINA-XW	73	74	48.35		
CXM/CHM-22	Ledil	CN12709_LENINA-S-DL	28	74	48.35		
CXM/CHM-22	Ledil	CN12710_LENINA-M-DL	40	74	48.35		
CXM/CHM-22	Ledil	CN12711_LENINA-W-DL	58	74	48.35		
CXM/CHM-22	Ledil	CN12979_LENINA-XW-DL	73	74	48.35		
CXM/CHM-22	Ledil	CN13649_LENA-SS	23	111	85.6		
CXM/CHM-22	Ledil	CN12716_LENA-M	27	111	85.6		
CXM/CHM-22	Ledil	CN12717_LENA-W	50	111	85.6		
CXM/CHM-22	Ledil	CN12721_LENA-S-DL	21	111	85.6		
CXM/CHM-22	Ledil	CN13650_LENA-SS-DL	25	111	85.6		
CXM/CHM-22	Ledil	CN12722_LENA-M-DL	29	111	85.6		
CXM/CHM-22	Ledil	CN12723_LENA-W-DL	50	111	85.6		
CXM/CHM-22	Ledil	F13662_ANGELA-S-B	16	119.5	79.31		
CXM/CHM-22	Ledil	F13663_ANGELA-M-B	22	119.5	79.31		
CXM/CHM-22	Ledil	F13664_ANGELA-W-B	40	119.5	79.31		
CXM/CHM-22	Ledil	F13841_ANGELA-XW-B	72	119.5	79.31		
CXM/CHM-22	Ledil	F13659_ANGELINA-S-B	32	82	36.04		
CXM/CHM-22	Ledil	F13660_ANGELINA-M-B	48	82	36.04		
CXM/CHM-22	Ledil	F13661_ANGELINA-W-B	63	82	36.04		
CXM/CHM-22	Ledil	F13839_ANGELINA-XW-B	91	82	36.04		
CXM/CHM-22	Ledil	FN14074_STELLA-HB	73	90	19.5		

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TIR Lenses			
Manufacturer	Part Number	Type	Compatible COB
Carclo	10755	30mm Narrow Spot TIR-Plain	CXM-6, CXM-7
	10756	30mm Narrow Spot TIR-Frosted	CXM-6, CXM-7
	10757	30mmMedium Spot TIR	CXM-6, CXM-7
	10758	30mm Narrow Wide TIR	CXM-6, CXM-7
	10759	30mm Elliptical Beam TIR	CXM-6, CXM-7
Ledlink	LL01CR-ABG24L02	Medium Beam TIR lens	CXM-6, CXM-7, CXM-9
	LL01CR-ABG38L02	Wide Beam TIR lens	CXM-6, CXM-7, CXM-9
	LL01ED-ABX24L06	Medium Beam TIR lens	CXM-11, CXM-14,CXM-18
	LL01CR-ABG12L02	Narrow Beam TIR lens	CXM-11, CXM-14,CXM-18
	LL01CR-BAY38L06	Wide Beam TIR lens	CXM-11, CXM-14,CXM-18
Fraen	FNL-N1-75-R	Narrow Beam Nested TIR lens	CHM-6, CHM-9
	FNL-N1-75-R	Medium Beam Nested TIR lens	CHM-14

4.2 Power Solutions

Driver ICs	
Manufacturer	Part Number
iWatt	iW3602-03
Marvell	88EM8183
Texas Instruments	LM3463
Allegro Microsystems	LC5220
Diodes Incorporated	AP8801
Analog Devices	ADP8140
Atmel	MSL3082

Driver Boards								
Manufacturer	Part Number	Type	Input Voltage	Input Frequency	Output Voltage	Output Current	Output Power	Compatible COB
Shenzen Ottima Electronics Co.	OTM-60W-A04	constant current LED driver board	90-300 VAC	60-70HZ	25-45V	1.5-1.8A	51-100W	CXM-27
Shenzen Ottima Electronics Co.	OTM-12W-AR111-40320	12W DC 20-40V mr16 constant current led driver	12 VAC	60-70 HZ	20-40V	0.380 A	1-50W	CXM-7,CXM-9,CXM-14
Wintek	WRC-032-A900W	Single output constant current open frame switching power supply	90-264VAC	47-63 HZ	28-36V	0.9 A	1-50W	CXM-14, CXM-18

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Ballasts										
Manufacturer	Part Number	Type	Input Voltage	Input Frequency	Power Factor	Outputs	Output Voltage	Output Current	Output Power	Compatible COB
Lumotech	L050211i2	Dimmable LED driver	180-240 VAC	50-60 Hz	>0.9	1	6-42V	0.150-1.2A	20W	CXM-6,CXM-7,CXM-9,CXM-14
Lumotech	L05020-40250	Dimmable LED driver	110-240VAC	50-60 Hz	>0.9	1	0-43V	0.20-0.25A	12W	CXM-6,CXM-7,CXM-9
Lumotech	L05049	Dimmable LED driver	110-240VAC	50-60 Hz	>0.9	1	0-60V	0.245-1.050A	40W	CXM-6,CXM-7,CXM-9,CXM-14,CXM18
Magtech	LF1048-36	Switch Mode LED Power Supply	100-277 AC	47-63Hz	>0.92	1	36V	0.150-1.7A	48W	CXM-6,CXM-7,CXM-9,CXM-14,CXM18
Magtech	LP1040-36	Switch Mode LED Power Supply	100-277 AC	47-63Hz	>0.9	1	36V	0.11-1.1A	40W	CXM-6,CXM-7,CXM-9,CXM-14,CXM18
Meanwell	CEN-100-36	constant current LED power supply	90-295VAC	47-63Hz	>0.9	1	36V	0-2.65A	100W	CXM-6,CXM-7,CXM-9,CXM-14,CXM18
Meanwell	PLM-25-700	Isolated LED power supply	90-295VAC	47-63Hz	>0.97	1	18-36V	0.7A	25.2W	CXM-18
ERP	ELP/ELR009		110-240VAC	50-60 Hz		1	18V-36V		9-12W	CXM-6,CXM-7, CHM-7,CXM-6-XH

4.3 Thermal Solutions

Thermal Interface Materials				
Manufacturer	Part Number	Type	Description	Performance
3M	8805	Arcylic	Thermally conductive adhesive transfer tape	Excellent
3M	5590h	Arcylic	Thermally conductive acrylic interface pad	Good
GrafTech	eGraph HiTherm	Graphite	flexible graphite	Good
GrafTech	eGraph HiTherm	Adhesive	flexible graphite with adhesive	Good
Berquist	Liqui-form 2000	grease	Shear-thinning, conformable	Excellent
Arctic Silver	Arctic Silver 5	Grease	High Density Polysynthetic Silver Thermal Compound	Excellent
Panasonic	PGS	Graphite +Acrylic	Thermal Graphite Sheets	Excellent
Omega	OmegaTHERM	Grease	High Temp Thermally Conductive Paste	Excellent
Rathburn	8805	Graphite+Adhesive	Thermally Conductive Transfer Pad	Good
Rathburn		Graphite + PET	Thermally Conductive Transfer Pad	Good

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Heat Sinks

Manufacturer	Part Number	Type	Material
Mechatronix	ModuleLED 9950	rayed/surface mount	anodized aluminum
Mechatronix	ModuleLED 9980	rayed/SM	anodized aluminum
ThermoCool	TCP7574	linear	extruded aluminum
ThermoCool	TCP7577	linear	extruded aluminum
Ivin	IS-E-5-4 GU10	finned/housing	anodized aluminum
Ivin	IB-E-15-3 E27	finned/housing	anodized aluminum
Fuerd	GFMR-16	LED heatsink	die cast aluminum
Fuerd	GFMR-15	LED heatsink	die cast aluminum
Cooliance	CPL4050-406	Passive LED Cooler	anodized aluminum
Cooliance	CPL4070-406	Passive LED Cooler	anodized aluminum
Cooliance	CPL5050-406	Passive LED Cooler	anodized aluminum
Cooliance	CPL5070-406	Passive LED Cooler	anodized aluminum
Cooliance	CPL7050-406	Passive LED Cooler	anodized aluminum
MingfaTech	EtraLED-Lux-4850	48x50/80mm	anodized aluminum
MingfaTech	EtraLED-Lux-4880	48x50/80mm	anodized aluminum
MingfaTech	EtraLED-Lux-8550	85x50/80mm	anodized aluminum
MingfaTech	EtraLED-Lux-11080	110x80mm	anodized aluminum
Shenzen Fluence	GK100		
Shenzen Fluence	GK150/150X		

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