APPLICATION NOTE

Design Considerations for ChromaLit 360

Remote Phosphor Light Sources

Introduction: The following document describes the technology and application of three dimensional remote phosphor ChromaLit sources. These sources provide a uniform Lambertian radiation pattern when combined with efficient blue (450-460nm dominant) LEDs at specific color temperatures suited to the application. These color temperatures include warm white through cool white and color rendering indices of 70-98.

Contents

ChromaLit Remote Phosphor Review 2

Thermal Management 4

T_{max} Location 4

Measuring Remote Phosphor Temperatures 5

Thermal Test Example #1 – Engineering prototype (Over Driven) 8

Heat Sink Design for Thermal Management 11

Distribution Patterns 12

ChromaLit Attachment Method 14

Designing the Mixing Chamber 16

Driver Considerations 17

ChromaLit Remote Phosphor Review

ChromaLit 360 are molded products that contain the appropriate phosphor(s) necessary to provide the proper color temperature and color rendering when excited by royal blue LEDs with nominal dominant wavelength of 455nm. The distribution of light for these remote phosphor sources are defined by the shape and Lambertian surface radiation characteristics. An external diffuse globe will modify the far field distribution pattern and must be considered for applications with special distribution requirements such as that for A19 blubs defined by ENERGY STAR.

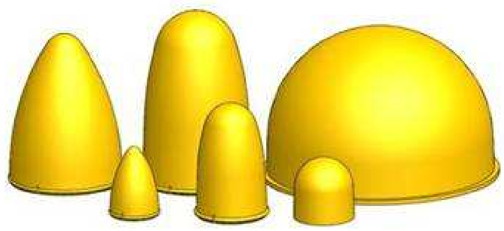


Figure 1 Ellipse, Candle and Dome ChromaLit sources (See ChromaLit 360 datasheet for detailed dimensions).

An example of a light source using the remote phosphor is shown in the graphic display below. The blue radiant output from the LED array illuminates the inside surface of the remote phosphor. About half of the incident blue power that is down converted is returned at all angles towards the inside, while the remaining power exits the remote phosphor. The LEDs are surrounded by a reflective material which helps recycle the converted light as well as the blue flux which is unconverted by the phosphor. A portion of the LED blue power is also transmitted through the remote phosphor, which when combined with the converted light, provides the final spectral power distribution. The color temperature, whether warm white such as 2700K or cool white such as 5000K, is defined by the properties of the remote phosphor, as are the color rendering properties.

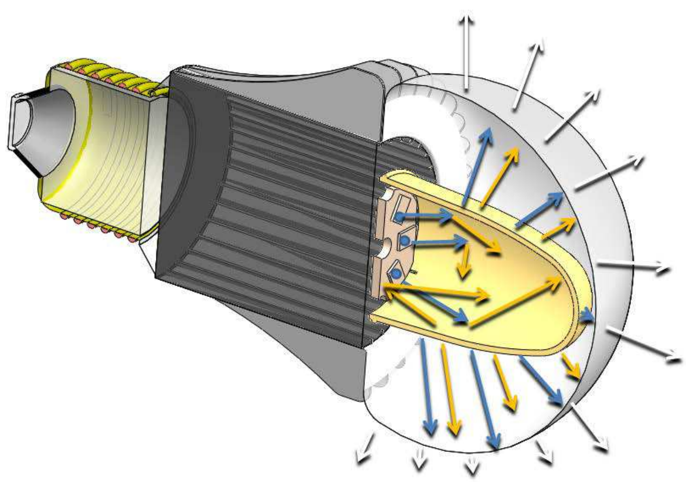


Figure 2 Remote phosphor used in an A19 bulb (driver not shown)

INTEMATIX

The higher color temperature sources (4000K, 5000K) have a higher level of transmitted blue flux, and the warmer colors (2700K, 3000K) have significantly less. The warmer colors with high color rendering also have significantly broader red spectral power as shown in the example spectral plots below.

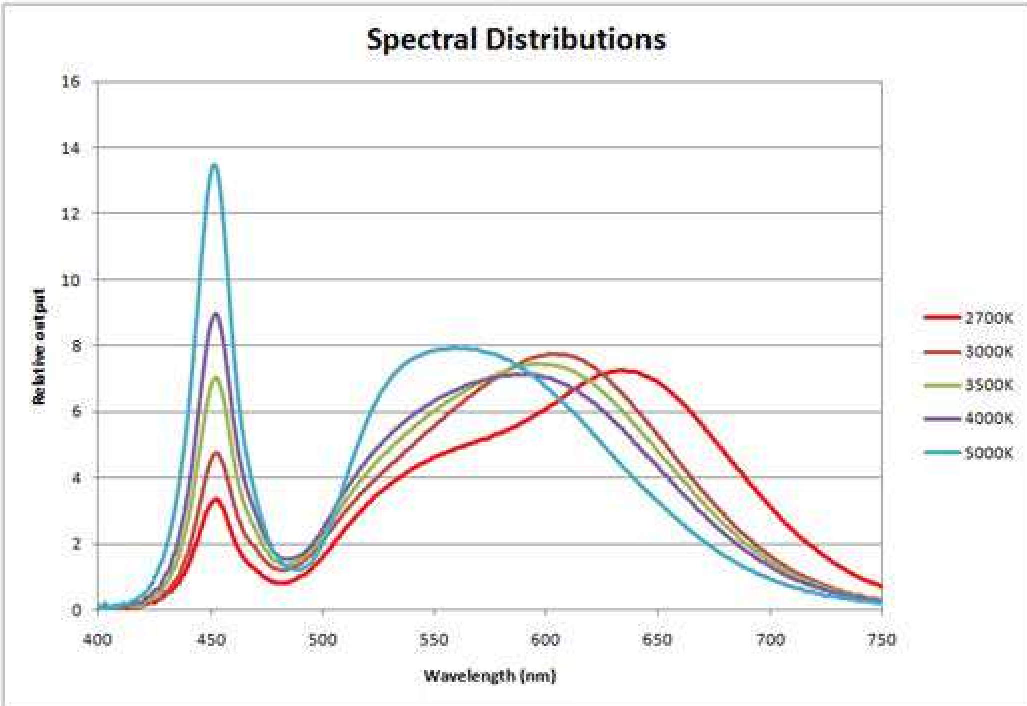


Figure 3 Typical spectral power distributions for remote phosphor sources.

Any impact on the spectral characteristics of external optics such as a diffuse outer envelope should be characterized early in the design phase to verify that the desired chromaticity and color rendering properties are maintained. Even if proven to have no impact on the spectral output, an outer envelope will tend to have about 5-10% light loss for limited diffusion levels and 10-15% light loss for heavier diffusion levels.
In the table below, source colors are designated CL-xyy, where x is the first digit of CRI and yy are the first digits of color temperature.

Color Designation	CCT (K)	SDCM	Min CRI	Typ. Conversion Efficacy (lm/W_{rad}) at 25^{o}C
CL-827	2700	3	80	165
CL-927	2700	3	90	140
CL-830	3000	3	80	185
CL-930	3000	3	90	150
CL-835	3500	3	80	190
CL-840	4000	3	80	195
CL-750	5000	4	70	220

Table 1 ChromaLit 360 CRI and CCT designations with conversions efficacies

The conversion efficacy for each ChromaLit design is specified in lumens (lm) per blue watt (Wrad) input. This is not to be confused with system efficacy in terms of lumens per electrical input watt. The conversion efficacy provides a starting point in the prediction of how many lumens can be obtained for a given color temperature and CRI knowing the amount of blue LED power presented to the remote phosphor. If the remote phosphor is operated at temperatures beyond the rated maximum, the conversion efficacy will drop slightly. It is therefore important to drive the remote phosphor at or below its rated maximum temperature.

The remote phosphor is designed for LED blue power with dominant wavelength at 455nm. Typical acceptable range of spectral blue power is 450-460nm. However, the color point will vary slightly with the average dominant wavelength. For overall system efficacy to be maximized, the LED's efficiency in converting DC electrical power to blue spectral power should be the highest possible. Current state of the art LED blue output power verses DC input power is about 50-56% and is a function of die temperature (drive current). LEDs well below 45% should not be considered for high system luminous efficacy applications or where thermal management is more difficult (when lower LED power is desired).

Thermal Management

Maximum rated inside surface temperature for the remote phosphor sources is 90^{o}C. Due to the details of the assembly, it is best to test the temperature at the top, side, and bottom of the part to verify the maximum. For the candle shapes, the temperature is best measured 0.5 to 1mm below the top center. To achieve the specified conversion efficacy in Table 1, it is important that the maximum temperature anywhere in the part not exceed 90^{o}C. Although the temperature of the remote phosphor will increase with blue flux power, the temperature is far more important than the maximum blue flux incident on the remote phosphor with regard to efficacy.

Description	Maximum Values
Maximum operating temperature (T_{max})	90^{o}C
Minimum operating temperature	-40^{o}C
Max storage temperature	90^{o}C
Minimum storage temperature	-40^{o}C

Table 2 Maximum temperatures of ChromaLit 360 sources

T_{max} Location

For any new design, the maximum inner surface temperature of the ChromaLit must be determined and found to be less than 90^{o}C under fully stabilized, maximum ambient and power up condition. Since the inner surface is isolated from external free air convection and is continuously exposed to the blue power from the LED when lit, the maximum temperature will be on the inner surface. In some cases, it may be located at an inner surface location near the LED(s) and PCB and depending on orientation, most likely on the topside.

T_{max} values should be measured on ChromaLit sources on the inside surfaces at locations illustrated in Figure 4 as a minimum. If a non-contact thermal imaging camera is available, the hot spot can be located on the outside surface and then the inner hot spot can be measured or derived.

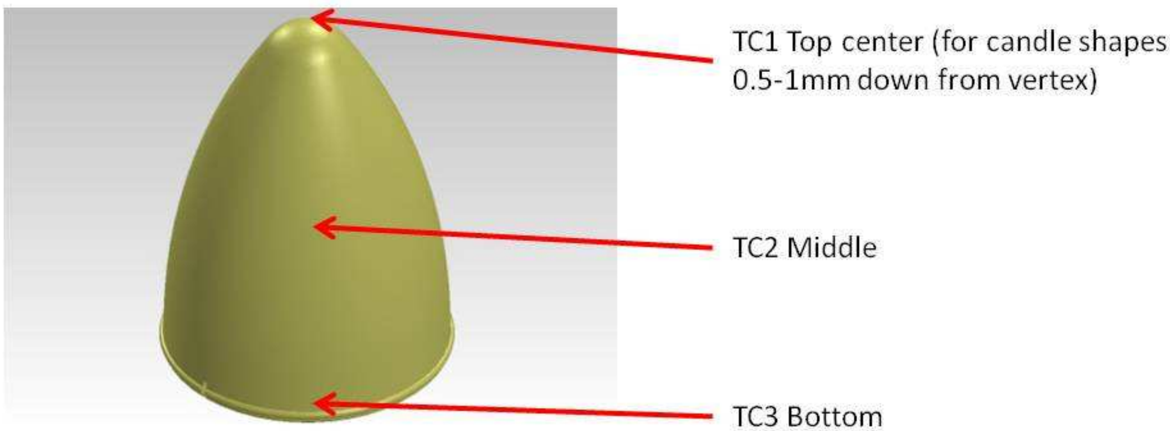
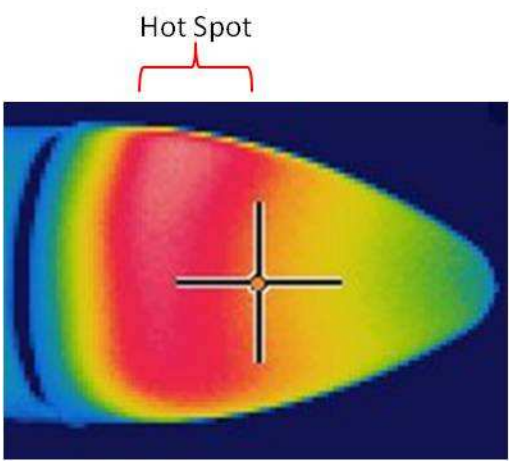


Figure 4 ChromaLit 360 temperature locations necessary to determine hot spot maximum

Inside surface temperature must be determined.

The maximum temperature for horizontally operating remote phosphor sources will typically be located on the top of the part due to natural convection. Furthermore, the hot spot may also be near the opening due to the proximity of the remote phosphor to the LED and LED PCB. For horizontal orientation and mounting to a high output LED PCB, the hot spot will most likely be as indicative below.



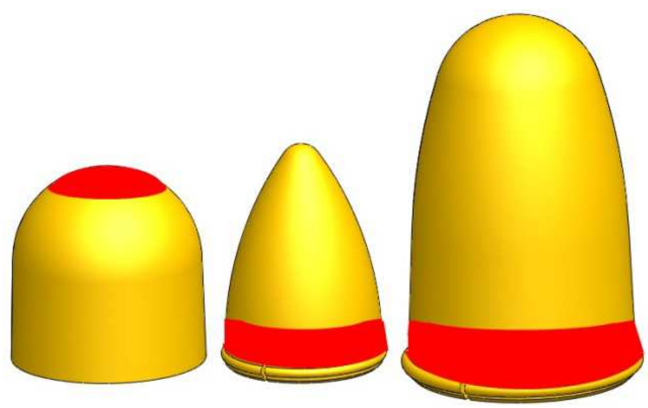


Figure 5a Remote phosphor hot spot

Figure 5b Typical warmer regions for Ellipse, Candle & Dome

The mixing chamber in a blue LED system with remote phosphor requires a broad spectrum, high reflectivity material between the blue LED(s) and the remote phosphor source. With this configuration, the color and spatial mixing of the light is optimized. The output beam is then exceptionally uniform with regard to color and brightness across the exit aperture of the remote phosphor.

Measuring Remote Phosphor Temperatures

To measure the surface temperature of the remote phosphor, it is recommended that a 36-AWG insulated K-type thermocouple (TC) be used. This has a small weld head to minimize radiation absorption and allows multiple locations to be monitored with minimal impact on light output, if that is being monitored as well. Inserting the entire thermocouple inside the remote phosphor is not recommended due to greater inaccuracies in temperature readings due to blue power absorption. This can result in temperature readings between 10-25°C higher than expected.

Method 1: Through hole drilling

A small hole can be drilled through the remote phosphor using a Dremel 108 engraving cutter or equivalent and the thermocouple can be fed through the hole from the outside. The weld bead can then be attached on the inside surface away from the entrance hole as shown in the picture below.

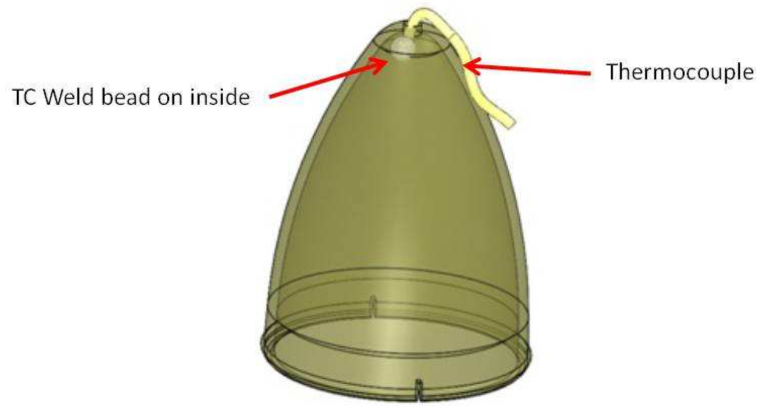


Figure 6 Thermocouple attachment

Dispense a small amount of 2-part LockTite Poxy Pak on a clean surface as shown on the bottom left. Be sure the two part epoxy is well mixed prior to application.

> Note: For permanent mounting of the remote phosphor, Intematix recommends 3M 2-part DP-460 high performance epoxy adhesive. It is not currently recommended to use LockTite Poxy Pak for anything other than shorter term engineering temperature characterization. Alternatively, DP-460 can be used for temperature test, however, the relative maximum operating temperature are 149C and 120C for the Poxy Pak and DP-460 respectively.

Figure 7 Dispense 2-part epoxy on clean surface

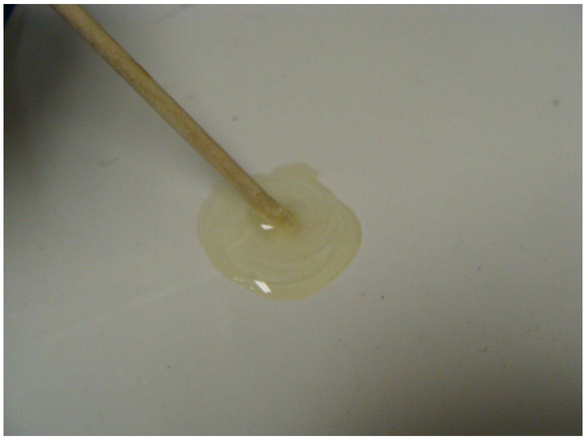


Figure 8 Be sure the epoxy is well mixed

After the thermocouple is inserted into the remote phosphor hole, it can be taped down on the outside surface. Bending the thermocouple on the inside can be done in such a way as to ensure positive force of the weld bead against the remote phosphor surface prior to applying the cement.

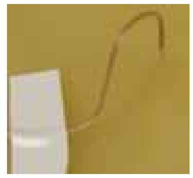


Figure 9 Thermocouple held in place using electrical tape prior to applying epoxy

Next, drop a small amount (about 1mm diameter) pre-mixed 2-part epoxy onto the thermocouple weld bead on the inside surface. Try to minimize the total amount of epoxy around the weld bead to minimize the thermal mass. After the weld bead is glued into place, a small amount of epoxy can also be applied to the thermocouple wire where it enters the remote phosphor on the outside surface to ensure a tight bond.

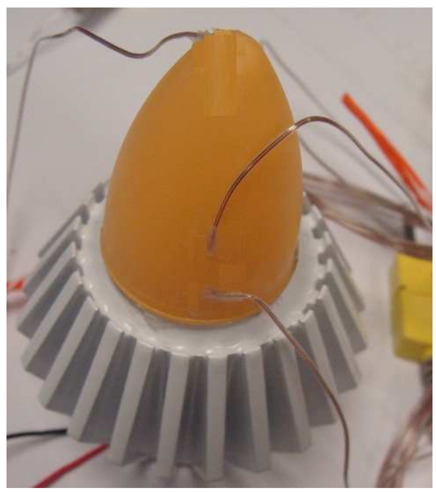


Figure 10 Remote phosphor ready for thermal test. Three locations on inside surface to be monitored.

Allow 90 minutes dry time while maintaining surface contact between the TC and remote phosphor. Use care when moving the assembly even after epoxy is dry since the thermocouple can be pulled away. Taping the thermocouple to provide strain relief during curing is recommended.

Method 2: Partial hole drilling

A partial hole approximately 0.7-0.8mm deep can be made from the outside of the ChromaLit at the three test locations shown in Figure 13. The thermocouple is then inserted into the hole and a small amount of adhesive is used to bond the thermocouple to the ChromaLit. Since this is nearly at the inner wall, the temperature reading is a very close match to the case of bonding the probe to the inner surface.

Method 3: Thermal imaging camera

An alternative method of measuring surface temperature is through the use of a non-contact infrared thermometer. However, to ensure that the thermometer is not sensitive to the light radiation of the source, an IR thermometer with detector sensitivity in the 7.5-13 micron region is recommended. All that is required is the emissivity of the material. Calibration to a mounted thermocouple can also be performed to ensure the proper emissivity value is used. Since this technique indicates an outer surface temperature only, it will be necessary to correlate the outside temperature to the inside surface. Note also that if a temperature is required using an external glass or plastic outer envelope, this technique cannot be used since it will determine the outer envelope temperature only.

With the thermocouple techniques described above in Method 1 and Method 2, thermal stabilization is required. This will typically take at least an hour.

A common method of determining that blue power absorption is not giving false readings is to monitor the steady state temperature immediately after turning off the power to the LEDs. If a large drop in temperature is noted immediately after powering down, this indicates an absorption issue or electronic noise to the thermocouple instrumentation that must be corrected.

Thermal Test Example #1 – Engineering Prototype (Over Driven)

A destructive test is performed using the warm white part shown below. The ten LED board shown on the left is used to over-power the remote phosphor and monitor top (T1), side (T2), and bottom (T3) temperatures.

Figure 11 10 LED PCB

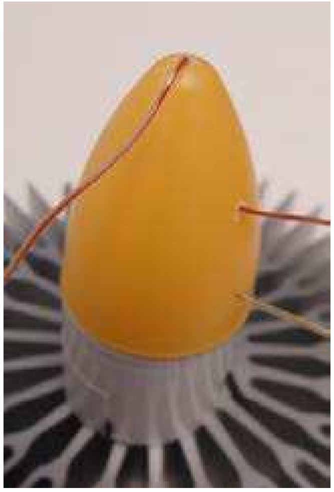


Figure 12 Test assembly

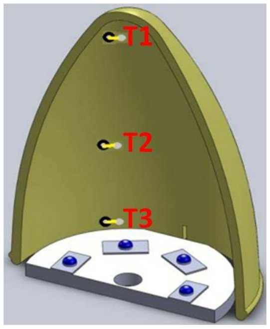


Figure 13 Temperature Test Location T1 (top), T2 (side), T3 (bottom)

INTEMATIX

The table below summarizes the data obtained. Note that the lumens are over the recommended 600 lumens for this part throughout the test. The chart below the table show that the conversion efficacy of the source is nearly constant until about 100°C where a decrease in conversion efficacy (lumens per blue watt input) results.

Current (I)	Voltage (V)	Power (W)	T1 (°C)	T2 (°C)	T3 (°C)	Temperature Comment	W_{rad} Blue Power (W)	Lumens	lm/W_{rad}	Lm/DC P	Lumens Comment
0.3	27.2	8.16	67	71	69		3.756	680.3	181.1235	83.3701	Just over spec
0.4	27.3	10.92	79	88	84		4.837	859.7	177.7341	78.72711	Over spec
0.5	27.3	13.65	92	102	97	All Exceed 90°C	5.82	1011	173.7113	74.06593	Over spec
0.6	27.4	16.44	109	113	101	All Exceed 90°C	7.211	1127	156.289	68.55231	Over spec
0.7	27.5	19.25	121	124	109	All Exceed 90°C	7.99	1175	147.0588	61.03896	Over spec

Table 3 Over powered engineering prototype data

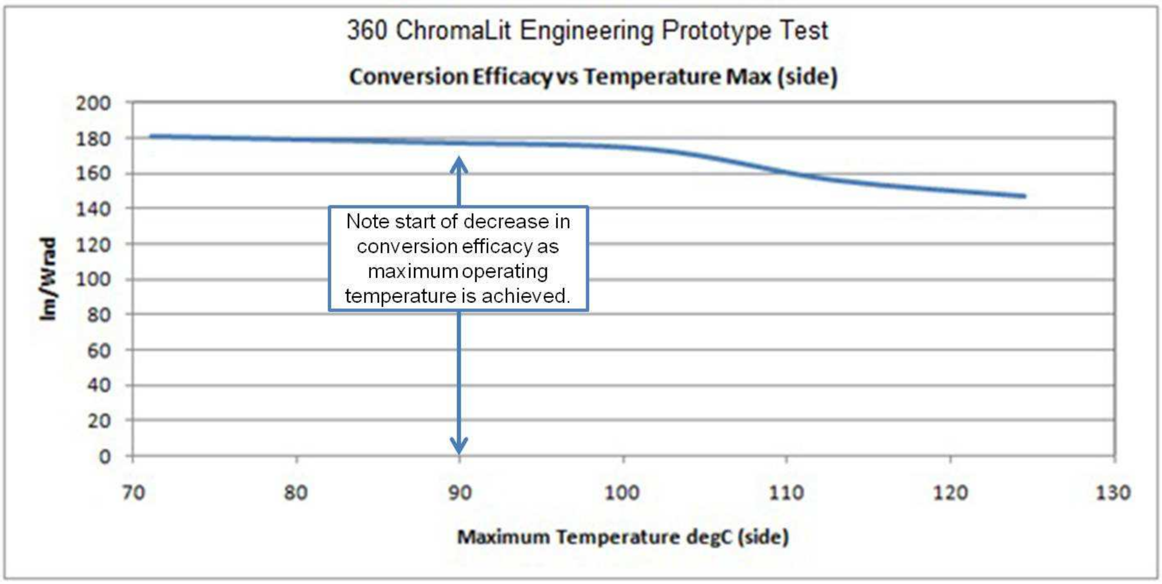


Figure 14 Conversion efficacies for over temperature condition

The graph below shows the input blue watts to the remote phosphor (dotted line, left axis), and the converted lumens (solid line, right axis).

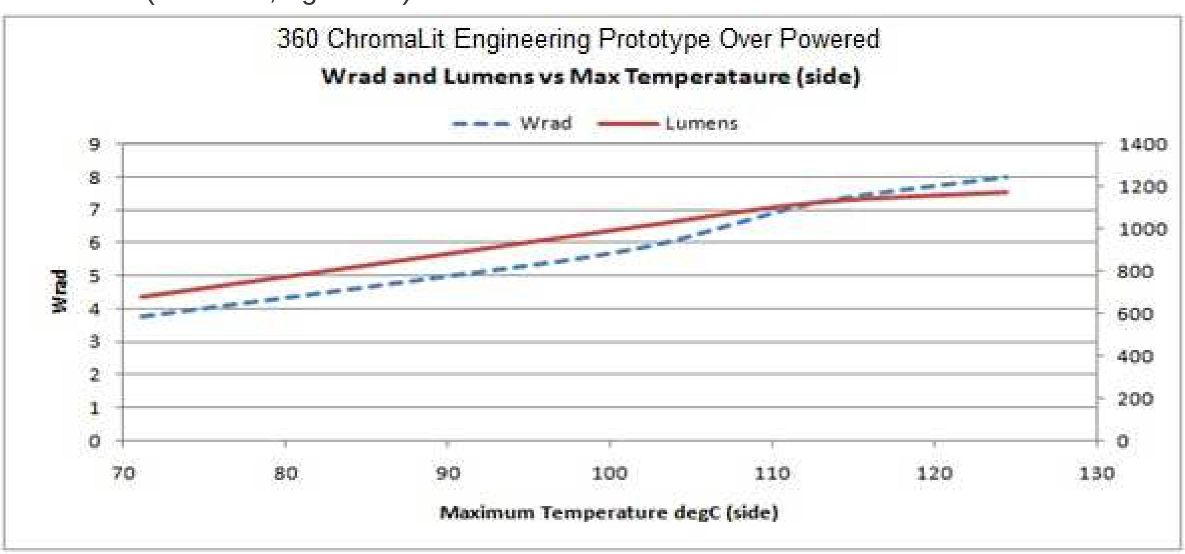


Figure 15 Over powered engineering prototype, lumens and W_{rad}

INTEMATIX

Thermal Test Example #2 – Engineering Prototype

Temperature measurements were performed on engineering samples of 2700K source at the test locations shown in the photo below. The candle source is powered by ten high flux Rebel ES PR-02 1100 LEDs mounted on a World Class Illumination square MCPCB, which is mounted on a small radial heat sink.

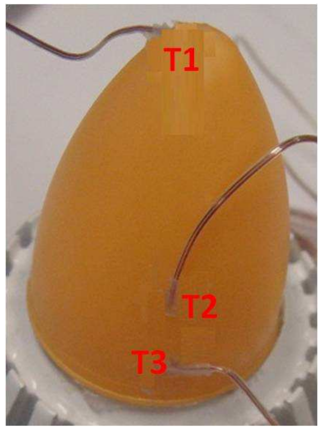


Figure 16 Test temperature locations

(Part tested is larger than standard production candle part, the inner surface area is about 20% larger).

Temperatures measured without glass dome are shown below. A 60-minute stabilization period is allowed for each measurement. The part tested here has an inner surface area about 20% larger than the standard production CAN40.

Vdc (volts)	Ldc (amps)	Pdc (watts)	Lumens	T1 (°C)	T2 (°C)	T3 (°C)
27.2	0.20	5.44	450	37.8	36.7	49.4
27.4	0.30	8.22	655	51.1	52.8	70
27.7	040	11.08	829	66.7	64.4	84.4
27.7	0.50	13.95	983	75	72.2	96.7*
27.8	0.60	16.68	1108	83.3	79.4	107.8*
27.7	0.70	19.38	1203	90	85.6	113.9*

Table 4 Engineering prototype data (without outer envelope)

* Temperature beyond recommended maximum

Additional data is obtained with a glass diffuser envelope in place. No modification to the thermocouple attachment was made between the previous set of data without the outer envelope.

Figure 17 Prototype with diffuse envelope in place

Vdc (volts)	Ldc (amps)	Pdc (watts)	Lumens	T1 (^oC)	T2 (^oC)	T3 (^oC)
27.1	0.20	5.42	408	55.0	51.1	55.0
27.1	0.30	8.13	591	71.1	65.0	71.7
27.6	0.40	11.04	752	85.6	78.9	83.3
27.6	0.50	13.8	889	97.8*	91.7*	102.2*
27.9	0.60	16.7	1005	108.3*	102.2*	114.4*
27.9	0.70	19.3	1093	116.1*	110*	125*

Table 5 Candle data with diffuse envelope

* Temperature beyond recommended maximum

The diffuse envelope in this case raised the temperature as much as 20^{o}C. Smaller volume globes with higher levels of diffusion could raise this difference even further. Therefore, thermal testing should always include the diffuse outer envelope and maximum ambient temperatures to ensure the light source has sufficient thermal design margin.

The following items should be evaluated for their impact on the remote phosphor temperatures:

1. Mounting method (inside press fit to PCB may increase heat load).
2. External envelope, whether diffuse or clear.
3. Any secondary optics.
4. Heat sink and thermal interfaces and thermal interface materials.
5. Ambient temperature and fixture.
6. Power delivery.

Heat Sink Design for Thermal Management

As with any LED system design, the LED case temperature will determine, to a great extent, the life of the product. Worst case scenarios for limited free convection should be considered as well as maximum blue power and converted lumens from the remote phosphor. The remote phosphor source has a low thermal conductivity (about 0.2W/mK), so the main heat transfer paths for the remote phosphor are by convection and radiation.

The following are some items to keep in mind with regard to proper thermal management.

1. Maximum LED case temperature allowed.
2. Light ray obscuration due to heat sink size near the remote phosphor.
3. Thermal resistance between the LED case and ambient.
4. Thermal conductivity of the heat sink material.
5. Heat sink fin geometry thickness at base, thickness at tip, fin density, and fin height/length.
   a. Thick fin conducts better.
   b. Fin spacing too small can limit convection.
   c. Angled fins can reduce radiation trapping.
   d. Anodized surfaces are better for radiation.
6. Fin orientation verses gravity vector (prefer convective flow along length of fin where possible).
7. Maximum power which must be handled (LED array as well as driver electronics).
8. Interfaces and thermal interface materials. Thermal interface materials (TIMs) are better than air but generally relatively poor in thermal conductivity to metals; use thin layers of TIM. Also minimize the number of thermal interfaces which add to thermal resistance.
9. Attachment methods: PCB to heat sink and driver to heat sink.

Thermal resistance R_T is the change in temperature between thermal interfaces divided by the watts transferred.

Example: The maximum thermal resistance (R_{TMAX}) from the LED case to ambient = (max case temp-ambient temp)/power dissipated. If maximum case temperature is 85°C and ambient is 35°C and the power dissipated is 7 watts, the thermal resistance is (85-35)°C/7 watts = 7.14°C/W.

The total thermal resistance above will be a parallel or series combination of thermal resistances between several thermal interfaces and materials. The PCB to heat sink will be one example. If the thermal resistance of the PCB to heat sink is R_{TIM}, then the $R_{TMAX} = R_{TIM} + R_{hs}$, where R_{hs} is the thermal resistance of the heat sink to ambient.

The main question is how much surface area is required to convectively cool the product. To derive the minimum cooling surface required start with the thermal resistance equation for the heat sink as follows:

$R_{hs} = (T_{hs} - T_a)/Q$

T_{hs} = temperature of heat sink
T_a = temperature of ambient
Q = power dissipated

Rewriting in terms of $Q = (T_{hs} - T_a)/R_{hs}$
But we also know $Q = h_c A_s (T_{hs} - T_a)$

h_c = heat transfer coefficient of heat sink
A_s = effective cooling surface of heat sink

Therefore $R_{hs} = 1/h_c A_s$, which can be written $A_s = 1/h_c R_{hs}$

Assuming a heat transfer coefficient of $5 W/m^2K$ and from before R_{TMAX} (thermal resistance from heat sink to ambient) = $R_{TIM} + R_{hs}$, then $R_{hs} = R_{TMAX} - R_{TIM}$. R_{TMAX} was calculated as 7.14°C/W and if the thermal interface resistance is 0.2°C/W, then R_{hs} = (7.14-0.2)°C/W = 6.94°C/W. So the minimum cooling area is then $A_s = 1/h_c R_{hs}$ = 1/(5 Wm^2K x 6.94°C/W X °K/°C) = $0.0288 m^2$. Note that this area is relatively small since the total thermal resistance from the heat sink to ambient is relatively large. To reduce the thermal resistance, the area would be significantly greater.

The calculated watts per surface area (7 watts / $0.0288 m^2$) translates to about 0.06 watts/in^2. A typical value for surface area of heat sink per watt of power is 10in^2/watt, which is under the 16.7in^2/watt for this example.

Approximate ranges of total thermal resistance for heat sinks based on application and LED power levels are shown below.

Application	Approximate LED Power Range	Approximate range of thermal resistance for heat sink required
Spot Lights	1-15 watts	2.7 to 9.5°C/watts
Down Lights	10-60 watts	0.7 to 4.18°C/watts
Street/High Bay	60-240 watts	0.355 to 0.670°C/watts

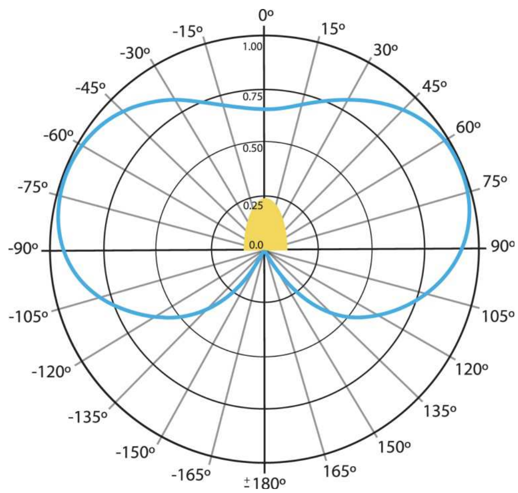
Table 6 Typical heat sink thermal resistance ranges

Distribution Patterns

Examples of intensity plots for the ChromaLit CAN40 and ELP60 are shown in the figures below. These are bare remote phosphor intensity plots and are found in the datasheet for each source design.

INTEMATIX

CAN40 Typical Distribution



ELP60 Typical Distribution

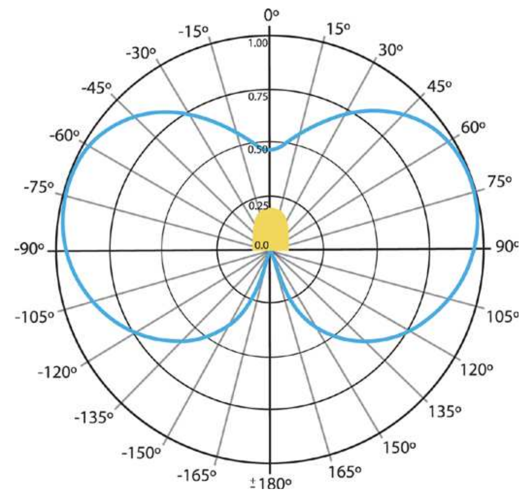
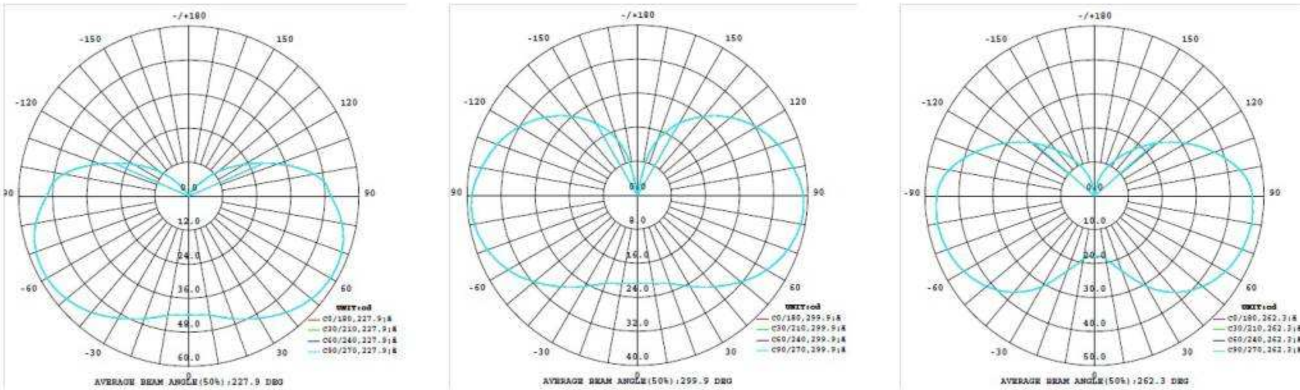


Figure 18 Distributions

The intensity distribution will also be influenced by the diffuse globe surrounding the remote phosphor. The picture below shows an engineering reference bulb that was tested using the elliptical remote phosphor with and without diffuse globes of various size and shape.

Figure 19 Large globe (left), test bulb (center), small globe (right)

The resulting intensity plots are shown below. Note that the large globe has an extended distribution at the higher angles at the bottom of the bulb (upper portion on plot top right).



No diffuser
487.7 lumens, 70.95 LPW

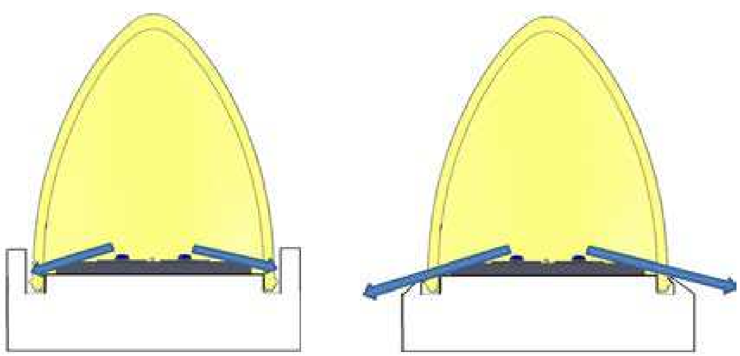
Large spherical diffuser
393.5 lumens, 57.77 LPW

Small Edison type diffuser
440.4 lumens, 64.44 LPW

Figure 20 Intensity plots: Note that image is inverted (top of bulb is at bottom of plot).

ChromaLit Attachment Method

The ChromaLit remote phosphor, in most cases, should be attached as a snap fit to a metal base heat sink that the PCB is mounted to. Since most remote phosphor sources have an external lip or flange, an external mount that captures this is recommended as shown in Figure 21. Some of the remote phosphor sources have two opposing slots at the bottom of the part to allow for compressing the part onto an internal or external diameter. To minimize light loss and prevent color temperature shift at the base, it is recommended to eliminate any external walls around the bottom outside of the remote phosphor. The attachment method below right is recommended. If the outside snap is necessary, the wall height should be just high enough to ensure a strong fit, but low enough to prevent light loss and color shift.

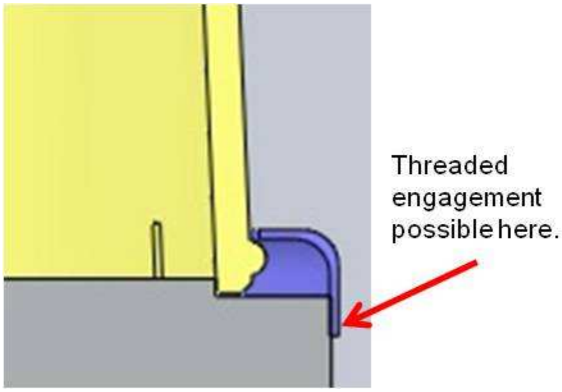


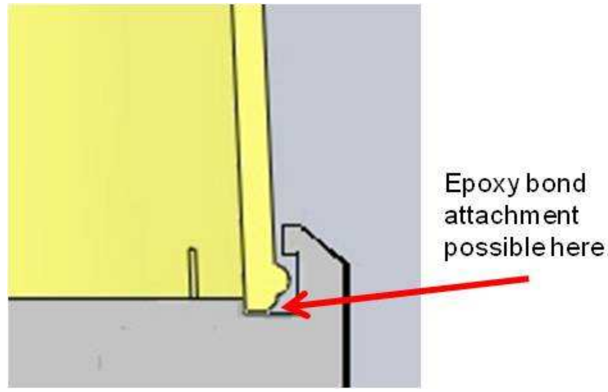
Light loss at base

Direct light out

Figure 21 Attachment method and light loss

INTEMATIX





Above left shows a base with an inside diameter fit to the ChromaLit with a secondary clip or ring that secures the feature on the OD of the ChromaLit. Upper right shows a similar one piece design. As shown above, it is recommended to design the remote phosphor with an internal fit whenever possible. Large holding structures on the outside of the part can result in significant light loss and/or color shift. Although the inside mount is preferred, an insertion depth of the LEDs should also not be too excessive to preserve uniformity of illumination and far field radiation patterns. Intematix recommends an LED insertion depth of 2mm or less to ensure proper light distribution performance. The insertion depth is measured for all remote phosphor parts from the bottom of the part to the LED emitting surface. A diagram of the insertion depth is shown below.

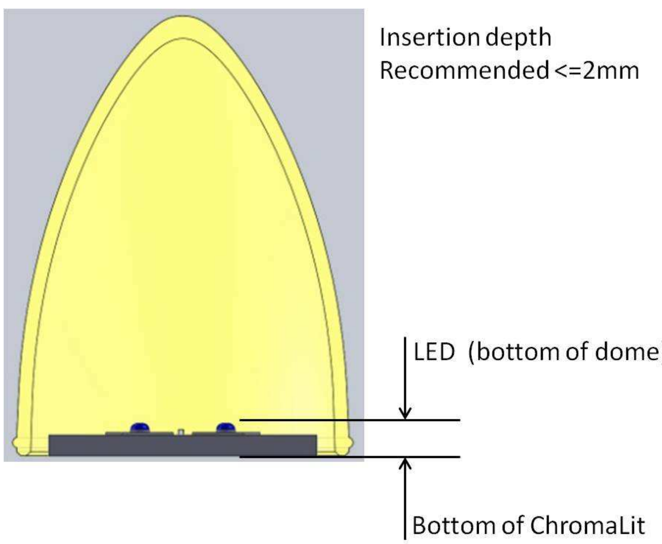


Figure 22 Insertion depth

For additional strength for these mounting methods, a small amount of epoxy can be used on the outside of the remote phosphor. For less stringent requirements epoxy alone may be suitable, however, any mounting scheme should be proven robust with appropriate shock and vibration testing following the expected extremes in operating and storage environmental conditions.

3M DP460 adhesive has been evaluated for ChromaLit-to-metal bond and tested to maximum remote phosphor temperatures without failure. Extreme care should be taken to eliminate any chance of getting epoxy on any of the LEDs and only epoxies with low outgas properties and maximum operating temperatures sufficient for all operating conditions is critical. Cree's XLampXP Soldering and Handling application note is a good reference for materials suitable for use with their LEDs. Again, maximum operating temperature for any material must be qualified and for more critical applications, the chosen material should be life tested to ensure long term suitability.

Please refer to the ChromaLit datasheet for detailed product mechanical outline drawings.

Designing the Mixing Chamber

The mixing chamber for the ChromaLit 360 is a reflective planar surface surrounding the LEDs. It is critical that the material be a highly reflective material with operating temperature rating acceptable for the application. See Intematix Application Note for Mixing Chambers.

The material should have minimal thickness. To minimize blue light loss at the LED aperture, 0.5mm is best. The material can be hard formed and screwed into place or adhesive backed. But the adhesive must be suitable for the high operating temperatures and compatible with the LED encapsulates. W.L. Gore Associates DRP material provides a thin 0.5mm thick, high temperature material that provides a nice conformal layer and is available in a high temperature adhesive backed version for easy installation. This is presently a high-end product only for applications that can absorb a high raw material cost. Genesis, White Optics, and Furukawa also have available lower cost materials with similar characteristics.

Examples of mixing chamber materials surrounding various LED arrays are shown below. A thin material will minimize the trapping of blue power around the LED aperture. Coverage of the complete LED device is preferable, but may be sacrificed for best collection of LED blue power at the aperture edge.

Figure 23 Mixing chamber material around LED arrays

Note that even a small screw as shown bottom left can impact performance. It is recommended to use a flat head screw whenever possible to reduce light obstruction. It is also recommended to cover the screw with highly reflective material. For the case below, an improvement of 5% in total luminous flux was obtained after covering the stainless steel screw with diffuse reflective material.

Figure 24 Flat head screw recommended

Figure 25 Reflective material on screw = 5% gain

Typical increase in efficacy is about 6% with highly reflective material compared to a bare PCB for a 20mm diameter board populated with 6 LEDs. Even larger gains are expected for non-white PCBs. A higher than expected color temperature may be due to a low reflectivity material that does not efficiently recycle the down converted rays hitting its surface.

The mechanical mounting of the LED PCB as well as wire gauge and routing should be considered in combination with the selection of reflective material type and thickness. Large wire gauge will result in considerable difficulty in achieving a flat reflective surface as will route wires across the PCB. The pictures below show the difference between selection of insulated 22-gauge wire and 28-gauge wire. The 28-gauge wire can provide a relatively flat solder locations and the wires can be routed more efficiently through a PCB slot or straight through the board. Although smallest wire gauge is desired, the proper wire gauge must be determined for the operating current required.

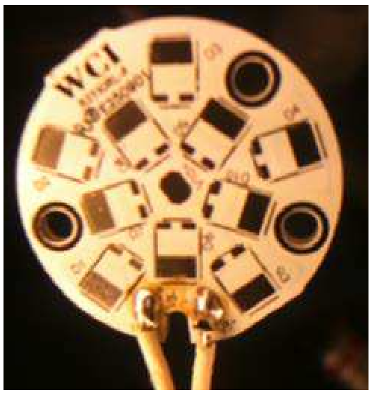


Figure 26 10 LED PCB, 22 gauge

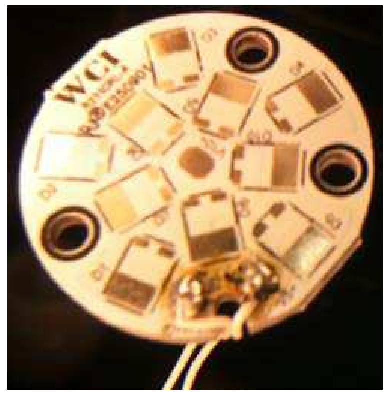


Figure 27 Same 10 LED PCB, 28 gauge

Driver Considerations

The first step for any design is to evaluate how much power must be delivered to achieve the required lumen output. This can be derived from the remote phosphor conversion efficacy x blue watts = lumens. This lumens value will need to be higher to compensate for AC to DC driver loss, diffuse cover glass loss, LED thermal losses, and any losses in light due to absorption around the LED (mixing chamber losses and heat sink obscuration). If dimming is necessary, additional AC to DC power losses must be accounted for.

LEDs work best with constant current. For series connected LEDs driving the same current though all devices will be more straight forward. The power supply must of course be able to deliver a voltage of at least the sum of the maximum forward voltage of each device in a strong. Since forward voltage may have relatively large tolerances for the chosen LED and the forward voltage depends on operating case temperatures, a driver capable of large voltage range with precise current delivery is necessary. Power factor correction is a common, necessary requirement as well as acceptance of universal line voltage (80VAC to 277VAC).

Typical Specifications:
Input Voltage Min, Typ, Max
Output Voltage Min, Typ, Max
Output Current/Power
Efficiency Full Load (verses input voltage)
Power Factor
Conducted EMI – meets CISPR 15B/EN550 15B
Harmonics EN610000-3-2-class D

Maximum Ambient Temperature (typical free convection/sea level)

Power Factor

The power factor of an AC electric power system is a dimensionless number between 0 and 1, defined as the ratio of the real power flowing to the load to the apparent power in the circuit. It is sometimes, but not always, the cosine of the angle between the voltage and current.

The definition of power factor (PF) is:

$$PR = \frac{\text{real power (capacity to perform real work in a particular time)}}{\text{apparent power (VA)}}$$

Due to energy stored in the load and returned to the source or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power will be greater than the real power.

In an electric power system, 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. Higher currents produce higher I^2R losses so larger component selection is necessary. Requirements for high power factor systems, with lower power loss are therefore desired.

Driver Topologies

Power Supply Topology	Benefits	Drawbacks	Comments
Linear regulator	Low part count, low EMI	Low power factor since current is drawn from the mains at the voltage peaks. Runs hotter.	
Step-down, Buck regulator	High efficiency	Electromagnetic interference produced due to the current being switched on and off sharply. Appropriate filtering is required to meet conducted and radiated emission specs.	When input voltage exceeds LED(s) total voltage
Step-up, Boost regulator	Simplest design for >350ma and variable voltage.	"	When minimum forward voltage always exceeds input voltage.
Buck-boost, SEPIC, Cuk, Flyback, Vn referenced buck-boost (floating buck boost)		"	Input voltage overlaps LED voltage range.

For more information on ChromaLit solutions please visit our website **www.intematix.com/chromalit**