PHILIPS

# White Paper

## The Advantages of LUXEON® Flash Power LEDs versus Xenon Technology for Digital Photography

**Introduction**

Compared to the rapid progress seen in areas such as computing or communications, lighting technologies for flash photography have advanced relatively slowly. Only two major technologies – pyrotechnics and gas discharge – have serviced this application space since its inception. Rapid change, however, is in progress, as power LEDs leveraging solid-state semiconductor technology are now proven to deliver the light output required in a wide range of photography applications. At the same time, power LED systems are significantly smaller and slimmer than xenon systems allowing for smaller handset designs, they are delivered in packages appropriate for surface mount automated assembly, they require less power, and will lead to lower overall system costs.  And unlike xenon solutions, power LEDs offer variable operating modes creating opportunities for differentiation and additional valuable functionality.

LUXEON® Flash Power LED

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**Flash Photography: Past, Present and Future**

The introduction of reliable gas discharge technology, from Doctor Harold Edgerton's work in the 1920s, led to low-cost and straightforward flash photography suitable for consumer use. This technology has evolved, resulting in today's intense and repeatable xenon flash tubes for professional flash modules as well as smaller form factor units integrated within compact consumer cameras. The typical lifetime is now several thousand flashes. However, xenon flash tubes remain cumbersome in the modern era of semiconductor technology, and assembling a complete driver and flash unit typically requires manual assembly. The technology places high demands on the power source, reducing available power and requiring a re-charge of the system after each discharge.

The next step for camera vendors, and designers of flash equipment, is to automate assembly, add new operating modes to enhance convenience and offer differentiating features, and to achieve further size reductions. The major driver of this demand is the increasingly intense market interest in miniature cameras and sophisticated, high quality camera capabilities integrated into portable equipment such as cellphone handsets and PDAs, chiefly to take advantage of new communication services such as picture and video messaging.

Achieving market success in consumer markets necessitates that functionality minimally impact design flexibility while delivering the expected performance. Although xenon system size is shrinking, at its smallest it still requires substantial space and power. And the development roadmap that foresees the size and power of xenon reducing also implies restricting the performance that a xenon flash can actually deliver in a practical cellphone implementation.

The advent of white power LEDs, in small surface mount packages created the possibility to advance flash photography in the directions required by the various markets for camera equipment. The brightest power LEDs on the market today offer comparable illumination to the xenon flash of an entry-level digital still camera (DSC). With the added advantages of easier design, flexible operating modes, small physical size, and compatibility with automated assembly methods, these devices offer a valuable step forward in embedded camera applications such as cellphones and PDAs.

As has been realized with other technologies, such as processor chips and telecommunications, both adoption and innovation occur at a rapid pace. White power LED technology stands at the beginning of its development roadmap, a roadmap that promises to bring tangible benefits to both consumer and enthusiast camera equipment, in terms of reduced cost, smaller form factor, new features and capabilities and faster time to market, as well as longer battery recharge intervals.

**Light Output for Flash Photography**

*Brightness*

A usable flash technology must be capable of adequate illumination within a range considered reasonable for the target application. For example, a flash unit embedded within a camera-phone may be expected to have a range of about two meters. With this established, it is possible to determine the required brightness of a suitable flash source.

Conventionally, the Guide Number is used as a measure for brightness for flashes. For an ISO 100 sensor sensitivity, the flash range is defined as the Guide Number divided by the F_number of the lens. Although this measure is still commonly used, it does not properly reflect the amount of light generated by a LED flash, due to the fact that a LED flash generates light during the whole period that the shutter is open.

By expressing the efficacy of a flash unit in Lux.sec @ distance, meaningful comparisons can be established between these different flash technologies. A high energy xenon discharge achieves a high peak output, in Lumens (Lux), for a short duration. This is a powerful characteristic in applications such as stop-action photography of high-speed events, or other professional techniques, where the flash is deliberately used to control the exposure time. In consumer photography, the exposure time is determined by the camera shutter speed, which may be preset or adjusted automatically to optimize exposure of the sensor element. In this context a maximum shutter opening of around 1/30 second (33ms) is usually recommended, to capture sharp images when the camera is handheld. Hence a Luxeon Flash unit, which produces a steady light output throughout the period the shutter is open, is more than capable of producing a crisp, well-lit flash image.

On the other hand, a very bright xenon flash can result in an overexposed picture when capturing a scene at short range. Camera and flash-gun manufacturers have successfully countered this by implementing automatic light control that cuts off the light discharge to optimize the lighting of the scene (that is, when the Lux.second product reaches an adequate level). Implementing automatic light control in a cameraphone requires additional circuitry, adding to design time, size, bill of materials, and assembly complexity.

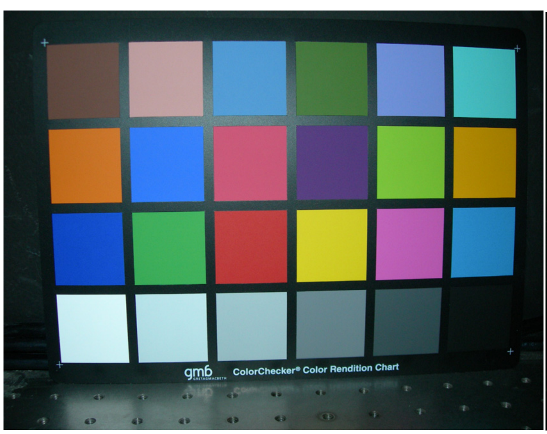
A further important consideration is that the brightness of a conventional flash solution is highly dependent on its overall size. When size is no restriction, large capacitors can be used in xenon solutions. Hence they can show extreme Guide Numbers or Lux.sec values. However, in portable applications such as camera-phones, PDAs and miniature DSCs small size is a key figure of merit. To achieve suitable overall dimensions for these types of end product, the size of the capacitor that can be fitted for a xenon flash is limited to around 10-15microFarad (µF). Under these conditions, xenon flash intensity is reduced to around 4 Lux.sec @ 1m for xenon flash. The

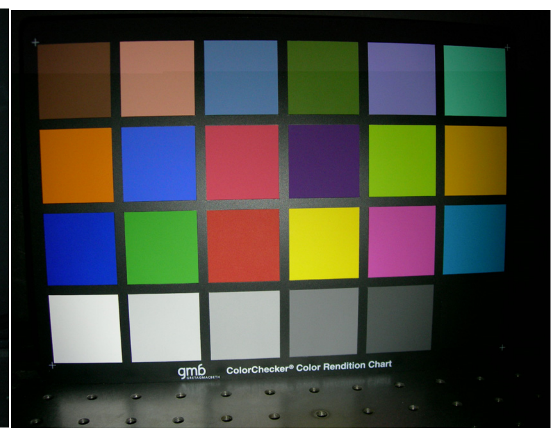
Luxeon LED flash technology can match this performance fairly easily, but within a far smaller volume.

Further development of Luxeon white LED technology is likely to deliver ongoing enhancements in terms of light output.

*Color Temperature and CRI*

The color temperature emitted by the flash unit is an important indicator of the composition of the light produced. Today's most advanced power LED technologies, such as Philips Lumileds' Luxeon Flash LEDs, produce white light displaying a color temperature of around 7000 K. This is slightly cooler than a xenon flash, which his typically about 5500 K, implying slightly greater blue content compared to warmer colors such as red or yellow. However, the key to realistic flash photography lies in good adjustment between the color reproduction of the camera sensor (CCD or CMOS) and the characteristics of the emitted light. Hence, if the light spectrum of the flash is known, and is stable, then high quality results can be achieved by tuning the settings of the camera itself.




Xenon LUXEON® Flash

Most digital still cameras implement software features to adjust color temperature sensitivity, or white balance, to match ambient, incandescent or flash lighting. Hence the techniques to optimize the white balance for a camera-phone, to match the light produced by an LED flash unit, are well established.

Often, people refer to the color rendering index (CRI) to describe how well the light source is able to reproduce colors. A CRI value of 100 reflects ‘perfect’ color reproduction. However, here the human eye is used as a reference and not the camera sensor. This makes comparisons difficult. Although the CRI of Luxeon white LEDs is already high, at more than 80, it is possible to achieve excellent color reproduction by adjusting the camera setting correctly.

*Light Distribution*

For high quality flash images, the illumination of the scene should be as even as possible. A raw light source, whether xenon or LED, will tend to concentrate its illumination around the central axis. The proven solution is to fit a diffusing lens to the flash unit. Analysis of the illumination produced by Philips Lumileds Luxeon Flash LEDs, when fitted with a suitable secondary lens, shows that a broad and even light distribution can be achieved, which closely matches that of a comparable xenon flash assembly.

**Ease of Design**

A miniature xenon flash tube is driven by a photoflash capacitor of up to around 15μF, which is charged to a high voltage (typically 300V-330V) by a dedicated charger circuit. An integrated charger IC is usually used, incorporating a flyback converter with on-chip driver transistors. xenon action depends not only on discharge of the capacitor, but also requires a very high voltage ionization pulse of around 3,000V. International standards such as the applicable UL and

CE documents require high-voltage circuitry to be physically separated by a specified distance. This may add further design approval overheads.

The drive requirements for power-LEDs, on the other hand, do not require high peak voltages. Hence the designer does not have to observe the safety guidelines that apply to a xenon driver. As a result, the LED driver is more compact, and uses fewer components of smaller physical size. In practical terms, a complete driver for an LED flash can occupy less than 10% of the volume of a comparable xenon driver.

When a premium performance level is required, the battery of the portable application (such as a cell phone) may be found to limit the available peak current. One way to overcome this is by using a low voltage capacitor. It is important to recognize that such a capacitor is optional for an LED flash, whereas a xenon flash cannot function without a photoflash capacitor. However modern low-voltage capacitor technology enables high storage (up to 1F) at voltages up to 5.5V in much smaller dimensions than the smallest 330V electrolytic capacitors, enabling a high discharge current capable of meeting peak current requirements for very high performance Luxeon LED flash. Emerging capacitor technologies such as SuperCap have an attractive flat form factor, making them extremely well suited for use in small sized portable applications. Overall, the combination of lower voltage operation and high CV capacitor technology allows highly miniaturized drivers that are well suited to embedded camera applications.

Bearing in mind the fact that the output of a Luxeon Flash LED, in Lux.sec, is comparable to that of a xenon flash suitable for a cameraphone, it is worth noting that the total energy consumption for xenon or LED flash units are quite closely matched. Hence, designers implementing an embedded camera in a battery powered device such as a cellphone handset can exploit the easier integration and greater operational flexibility of power LED with no appreciable reduction in battery recharge interval.

**Flexible Operating Modes**

The nature of xenon technology provides no real opportunity to control the characteristics of the flash after the unit is fired. One drawback is the tendency for the xenon flash to dominate other light sources in the picture, even if automatic light control is implemented, leading to unrealistic images.

The power LED, on the other hand, is driven electronically, affording control over the characteristics of the light output by manipulating the driver current and voltage waveforms.

*Duration*

Upon firing, a typical xenon flash has a duration of around 1ms. A very bright burst of white LED light, on the other hand, can be sustained for a duration of hundreds of milliseconds, depending on the design. During this time, numerous camera features can be invoked, such as dynamic white balance adjustment and illumination level adjustment. Other features such as sophisticated red-eye reduction and auto-focus assist can also be implemented. A xenon flash in a digital still camera, for example, may perform similar operations during a pre-flash sequence. However, in a camera phone, the charge storage requirements to do pre-flash are prohibitive

*Torch Mode*

Electronic control of the power LED enables even more flexible operating modes, such as torch or video mode. This ability to support prolonged operation at high light output allows night-time camera use in video mode as well as still camera mode. This feature cannot be supported using conventional xenon technology.

Although this is a new and unfamiliar – yet valuable - capability for a cameraphone, vendors of power LEDs have already established significant design expertise in this area. Applications assistance is readily available, as well as standard components optimized for torch mode operation, such as the Philips Lumileds PWM series Luxeon white power LEDs.

*Multi-LED Flash*

The range and spread of LED flash can also be optimized, for example by using a lens to focus the beam at a long range to enable zoom flash modes. Philips Lumileds has demonstrated a cost-effective triple-LED flash unit for camera phone applications, comprising two LEDs fitted with lenses for wide beam dispersal, plus a further, focused LED for zoom flash (patent pending). Moreover, this triple power LED array is implemented within a significantly smaller volume than a xenon flash unit, even while extending the flash capabilities and further enhancing efficiency in torch mode. In this way, power LED technology enables even more powerful, versatile camera modes in ultra-slim cellphone form factors, which xenon flash units cannot achieve.

**LED Economics**

For cellphone vendors, putting more and more functionality inside smaller and smaller devices has been the key to achieving higher selling prices and higher margins. Today, even with the aggregation of several functions into the emerging smartphone model, consumers of high-end products will not countenance a return to larger form factors to gain this extra functionality.

The cellphone as DSC is no exception. A bulky flash implementation will result in a cellphone that is less popular and commands a lower selling price than competitive products that deliver equivalent flash performance within the form factors already established for premium handsets.

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Modern power LEDs allow cellphone designers the freedom to add versatile flash modes delivering equivalent photographic performance to that of a DSC flash, without suffering the size trade-off imposed by xenon flash technology. The lower total energy requirement of a power LED flash also eases the trade-offs between battery size, weight, and recharge interval.

Time to market is arguably the next most important factor determining the success or failure of a new cellphone design. Power LEDs and the associated drivers are easier and faster to design-in than a high voltage discharge technology such as a xenon flash unit. No reference or certification to high-voltage safety standards is required, and designers do not have to acquire high-voltage design expertise or procure a specialist, turnkey driver implementation.

The small size and fast time to market of a power LED flash solution combines with further benefits, including compatibility with automated assembly, innovative new flash modes and torch mode operation, and the ability to perform flash-assist functions using the same light source. With a xenon flash, additional light sources are usually required to perform essential DSC functions such as autofocus assist and red-eye reduction.

Hence, a power LED flash solution allows cellphone manufacturers to tick all the boxes for advanced performance and functionality, high manufacturing yield and throughput, early market entry, and high selling price. As a result, handsets that implement flash using power LEDs offer the prospect of higher commercial success, as a combined cellphone and DSC, than a competitor’s offering featuring a larger, more power-hungry xenon flash.

The combination of higher value in an end product that can be brought to market faster and assembled at lower cost provides the OEM with a strong economic case in favour of power LEDs over xenon.

**Optimized, Power LED Technology**

Not all white LEDs deliver the same quality of white light that is so essential to the image capture process. The technique most widely used to produce white light is to package a blue LED with a yellow-emitting phosphor material, using the phosphor emissions to compensate the blue output and thereby to emit white light. However, the most common manufacturing technique is to deposit the phosphor coating as a "slurry" over the LED. In sensitive applications such as flash photography, a uniform light output is required from any point on the device surface, in order to achieve high picture quality, Hence, conventional assembly techniques for white power LEDs can result in sub-optimal performance in camera applications.

One of Philips Lumileds most significant technology innovations is the patented conformal coating process employed on all the company's white Luxeon LEDs. Philips Lumileds' conformal coating results in much tighter control over the thickness and phosphor balance of the coating. Benefits include higher quality white light output, greater stability over time, and better manufacturing yield resulting in cost effective manufacture of very high-quality power LEDs for demanding applications such as flash photography.

Philips Lumileds also owns the packaging processes for its Luxeon product range, resulting in great control over quality, continuity of supply, price and lead-times.

**Conclusion: Escalating Performance, from Camera Phone to DSC**

The rapid convergence of digital photography, solid state storage and broadband communications, which have been advancing at speeds inspired by Moore's Law, is now demanding a great advance in supporting photographic technologies such as flash lighting. Conventional xenon technology, compared to power LEDs, offers no advantages in a cameraphone application and only slim advantages in terms of short term outright light output in DSC applications.

Power LED technology already holds clear advantages in terms of miniaturization, versatility, form factor, and time to market. These factors are critical in the consumer electronics space. Given the favorable light output of Luxeon Flash LED technologies, in terms of brightness, duration, light distribution, color temperature, and CRI, designers can now leverage the convenience and cost-savings of LED flash in cameraphones and PDAs offering entry-level DSC functionality.

Forthcoming generations of the highest power white LEDs will challenge xenon flash technology in more demanding applications such as premium DSCs, and enthusiast and entry level professional equipment.

Among the available white LEDs currently available to the market for flash applications, the Philips Lumileds Luxeon Flash range offers the smallest form factors and the brightest mass-produced parts currently available.

**Summary table:**

| | **Luxeon Flash power LED** | **Xenon** |
|---|---|---|
| Light output: Lux.s @1m | 4 Lux.s @ 1m | 4 Lux.s @ 1m |
| Color Temperature | 7000K | 5500K |
| Effective operating range | 3 meters | 3 meters |
| Overall size of implementation | Less than 10% of xenon | Larger components, and physical separation of high voltage circuitry required. |
| Operating voltage | 3.3V / 5.0V | 300V, with peak of c. 3,000V |
| Capacitor technology | None Required. | High voltage electrolytic capacitor required. |
| Assembly technology | Automated SMT | Hand assembly |
| Design/layout restrictions | None | Observe high voltage safety standards |