Designing Next-Generation Pico Projectors

New Technologies Offer Breakthrough Opportunities for Delivering Lower Cost and Power Consumption with Improved Performance and Resolution

Intersil Corporation

Over the past few years, pico projector technology has offered the promise of delivering large display output from very small product form factors. However, so far the products on the market have mostly been either small standalone projectors or less-than-elegant add-on projectors that act as appendages to other devices. This article reviews the primary design objectives and tradeoffs, as well as providing a look at new technologies that are opening the door to wider adoption of pico projectors as small, efficient, embedded capabilities within a widening range of devices.

Optimizing Cost, Size and Power

From an applications standpoint, the key challenges limiting wider adoption of this nascent technology are the same things that designers often face: Cost, Size and Power.

Currently the cost factor is probably the biggest element that has hampered aggressive market adoption and embedding of pico projector technology. Market feedback indicates that the pico projector system needs to have a BOM cost of less than $50.00 to spur adoption and ideally a forward cost of less than $35.00 per unit to really accelerate widespread usage and drive new high-volume embedded applications, such as mobile handsets and tablets.

Small size is also a critical element for pico projector systems, especially where the projector function is to be embedded within an already tightly constrained form factor such as a mobile phone. Generally the embedded optical engine electronics should take up no more than 5.5 cubic centimeters and offer a low profile of less than 10-15mm high. (See Figure 1) As described later, for both size and power reasons, it is also important to avoid requiring fans, heat sinks or other external cooling methods if possible.

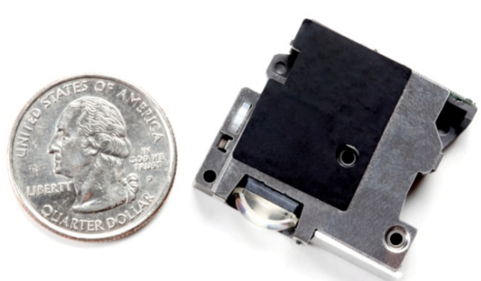

Figure 1 – Micron compact E330 Optical Module (7.5mm x 31mm x 30mm)

Power efficiency is another key challenge because of the need to maximize battery life. When looking at pico projector technology as an embedded function, it is important to keep in mind the concept of "net battery impact" on the overall design. Most handheld devices have a TFT display panel. Depending on the device type, the TFT panel can range from 3.5 inches for smart phones or a camera to 10 inches for tablets to as big as 17 inches for notebooks. Power consumption for today's displays can range from 0.25W to as high as 20W or more. An embedded Pico projector can offer a significant net power saving by creating an image that is larger than the internal display but consumes less power to produce. For example, a 10 inch tablet that consumes 6W of power, if the internal display is placed into sleep and switching over to an embedded 2W Pico projector, the battery life would be more then 2.5X at a display size of 2X of the build-in display. The enlarged display size and the extended battery life would provide an improvement to the user experience.

The overall power budget that product designers ideally would like to see is less than 2W, which can be achievable with new technologies, depending on the required performance levels, size, fan requirements, etc. Some of these key design alternatives and tradeoffs are described in the next section.

A Pico Projector Design Approach

One of the leading imaging technologies for implementing Pico projectors is Liquid Crystal on Silicon (LCoS). With LCoS, liquid crystals are sandwiched between a glass and the surface of a silicon chip. The silicon surface is coated with an aluminized layer and polished for optimum reflectivity. Finally, the polished surface is protected with a passivation layer. A differential voltage is applied between the glass and the silicon surface causing the liquid crystal to align to a pre-define crystal direction. The twisting affect enable lights to be reflected by the reflective layer. By modulating the liquid crystal, light level can be controlled to generate the full range of light intensity.

LCoS technology has very small pixel sizes; the smallest pixel size known today is around 3.5um. This allows LCoS to deliver higher resolution with a small diagonal size; an ideal technology for embedding high resolution Pico projector into handheld devices.

LEDs are in expensive, making a LCoS / LED based optical engine a low cost implementation. With embedding Pico projector, a typical design specification includes small physical size of less than 6cc, an electrical to optical power conversion factor between 5 to 10 lumens per watt, display image to throw ratio of 1:1 (example: 20 inch diagonal image with a 20 inch projection display from lens to display surface), and a typical system power consumption of less than or equal to 2watts.

Key metrics to keep in mind are lumens-per-watt and lumens-per-cc, which are diametrically opposing design factors. As optical engine become smaller they inherently present more thermal management challenges. Electrical power not converted into light by the LEDs is directly converted into heat. Since elevated heat levels can drive down the efficiency of optical systems, with smaller devices it can be more difficult to get reasonable optical throughput and high power efficiency. The figure of merit that most product designers are targeting is about 10 lumens-per-watt within a physical size of 5cc, which represents a pretty good optical design today.

Low-Cost LCoS LED-Based System

The LED design approach illustrated in Figure 2 is optimized to provide the smallest electronics footprint for a Pico projector, with low power requirements as well as the lowest available BOM cost. The electronics footprint is 1.7”x 2.0” for accessory applications and can be designed to less than 1.5”x1.0” typical footprint for embedded applications.

The optical engine requires only 1W of electrical power for 6 lumens output, and offers a total system power budget of less than 1W. The design is operated from a battery with a 1700mA capacity or by an external AC wall adaptor.

The electronics system is capable of driving 1.5A current for a brighter projected image; up to 10lumens can be achieved. No active cooling method is required. BOM cost can run from less than $50 depending on application type and on production volumes.

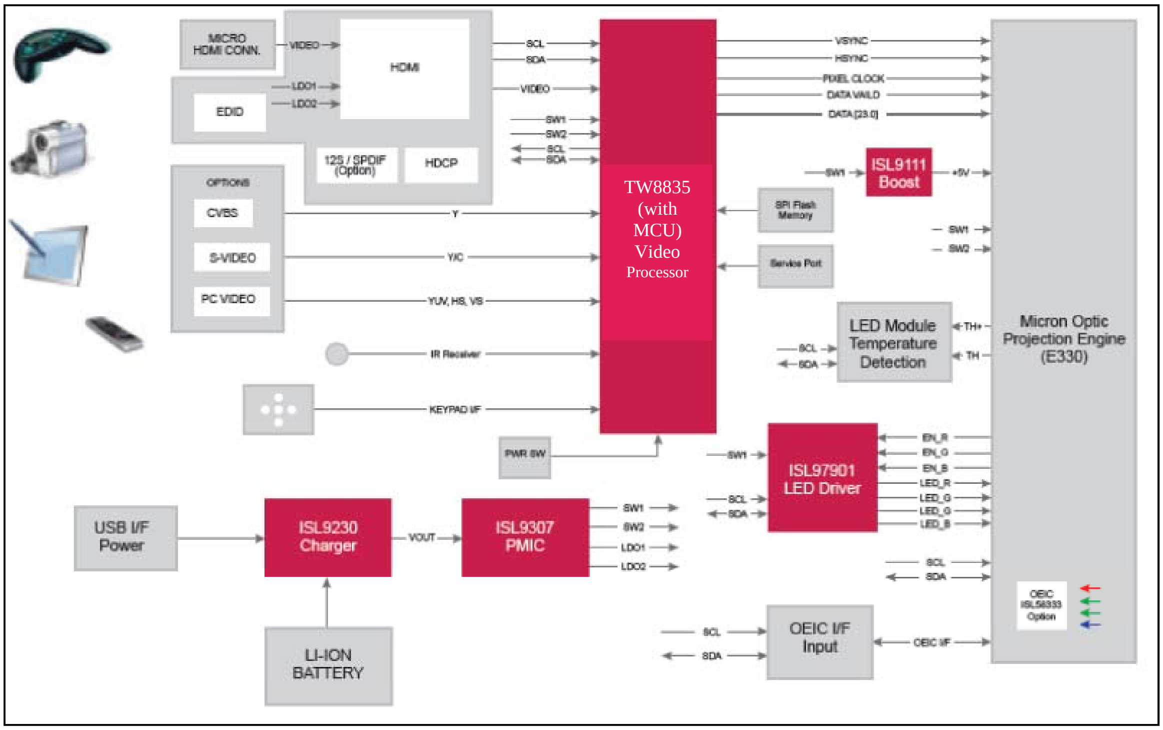

Figure 2 – Low-Cost LCoS Pico Projector Reference Design

Compatible with up to 1080p input video formats, this low-cost LED design includes an onboard scaler which down scales to optical engine’s 960 x 540 (qHD) resolution panel. The integrated HDMI interface provides wide compatibility with a range of HDMI ready video sources. For an even lower cost accessory design, S-Video, CVBS or RGB can be implemented as the video input interface standard. For embedded application, the input interface can be using the 24-bit RGB digital input directly tied to the embedded media processor.

The optical engine design has a 5.5cc volume with the key vertical height dimension kept to a low 7mm. The minimum height makes the optical engine ideal for embedding into tablet, camcorder, camera and smart phone applications. The projected qHD resolution image makes it ideal for camcorder, camera, and smart devices to display larger image size for family/public viewing.

By achieving a balance of low BOM cost and high image quality, this type of approach addresses today's immediate needs for designers of many digital cameras, video players, head mounted displays, toys, mobile phones and ultra-compact low-cost standalone projectors.

The Next Push Forward to High Efficiency Pico Projection System

With the continuing push for higher brightness, higher current LED must be employed. As heat rises, LED efficiency decreases; making it necessary to increase the LED current to maintain brightness. For example, as brightness is pushed from 10 lumens to 30 lumens, LED efficiency potentially could fall from 10 lumens per watt to 3 lumens per watt. This is one tradeoff that offers an advantage to laser-based systems because the optical power efficiency degrades much less precipitously at higher brightness levels. As a general rule, at around 10 lumens, LEDs and lasers are relatively equal but at 20 to 40 lumens laser-based systems can be as much as 2 to 3 times more efficient than LED-based systems. Efficient thermo management within the optical engine and the system chassis becomes an ever more important challenge.

From a power efficiency standpoint, the key different between LED and laser based systems is laser has a much flatter curve for input power vs. optical output power. Basically, lasers require a certain level of current to reach the lasing threshold (such as 10ma for a typical blue direct laser) before there is any optical output. But, after the threshold point has been reached, lasers provide a relatively flat linear slope that is directly proportional to the additional power input.

In contrast, with an LED there is no threshold point. Even at the lowest levels, power input results in light output. However, driving LED to higher output power requires increasing amount of input power. This curve is not linear. To get small amount of increase in brightness, more input power is required, resulting in more heat, which can further degrade the efficiency.

Laser power efficiency curves are significantly less impacted by heat levels than are LED curves, with LEDs degrading much more precipitously as a result of temperature increases. This means that, with performance requirements such as brightness continuing to escalate, laser-based systems will offer better price/performance advantages going forward.

The other key difference between LEDs and lasers is the degree to which the light needs to be focused in order to achieve the required display quality. Both approaches require some beam shaping but, because lasers product coherent light, for all practical purposes in a LCoS based Pico projectors design, lasers are able to provide high optical power to be reflected by the LCoS and adds the advantage of infinite focus over LED design where limited depth of focus requiring an additional manual focusing mechanism.

Despite the differences described above, today's market requirements are driving demand for laser based systems. A high-efficiency, cost-effective laser-based system could be the better option for embedded Pico projector alternative then LED based system.

Laser Light Source Advancement

Recent advances in laser technologies have opened new opportunities for designing highly-efficient laser Pico projectors with a combination of excellent visual output and low cost. The direct laser diodes make it possible to implement a LCoS / Laser based optical engine in a small form factor, i.e. 3.8cc. The optical engine design employs two different illumination units; both units use direct RGB lasers with either 3 or 4 lasers. The difference is the 4 laser version uses two green lasers to achieve higher optical output performance.

As illustrated in Figure 3, the ideal green wavelength is 532nm to provide the "best visual green". Since semiconductor doping processes for creating different green lasers cannot exactly achieve this ideal 532nm wavelength, the combination of two green lasers (510nm and 525nm) offers a significantly closer to true green color gamut than with either single green laser.

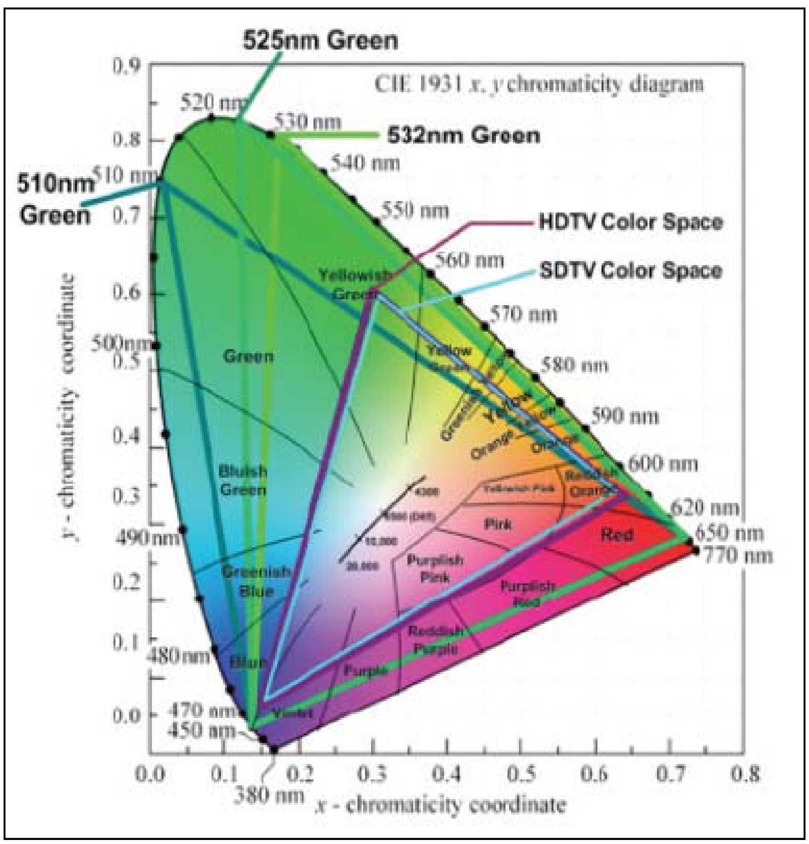

Figure 3 – Chromaticity advantages of 4-laser Systems with two green lasers

As deployment volumes increase along with the demand for higher brightness systems, the cost curves for direct laser systems will go down much faster. For those product manufacturers looking at 2-4 year time horizons, the cost/performance advantages of laser-based systems can be much more compelling then the LED based system.

Low-Cost, High-Performance Laser-based System

The reference design in Figure 4 shows an overview of a monolithic direct-laser system that is optimized for both power efficiency and very small form factor, which enables deeply embedded pico projector capabilities within a wide range of devices. With options for either 3-laser RGB or 4-laser RGGB configurations, this approach leverages the "always in focus" attributes of direct-lasers along with the ability to achieve rich color gamut requirements. Integrated laser speckle reduction technology assures high image quality across a variety of viewing surfaces.

This single-board LCoS laser system measures only 2.5 x 3.0 inches and the on-board ultra-compact 4cc size optical engine with 6mm thickness enables the design size to be even further reduced for embedded applications. With the direct-laser approach, the elimination of need for any manual focus wheels or levers also minimizes any extraneous elements that would add to the size and BOM cost with LED systems.

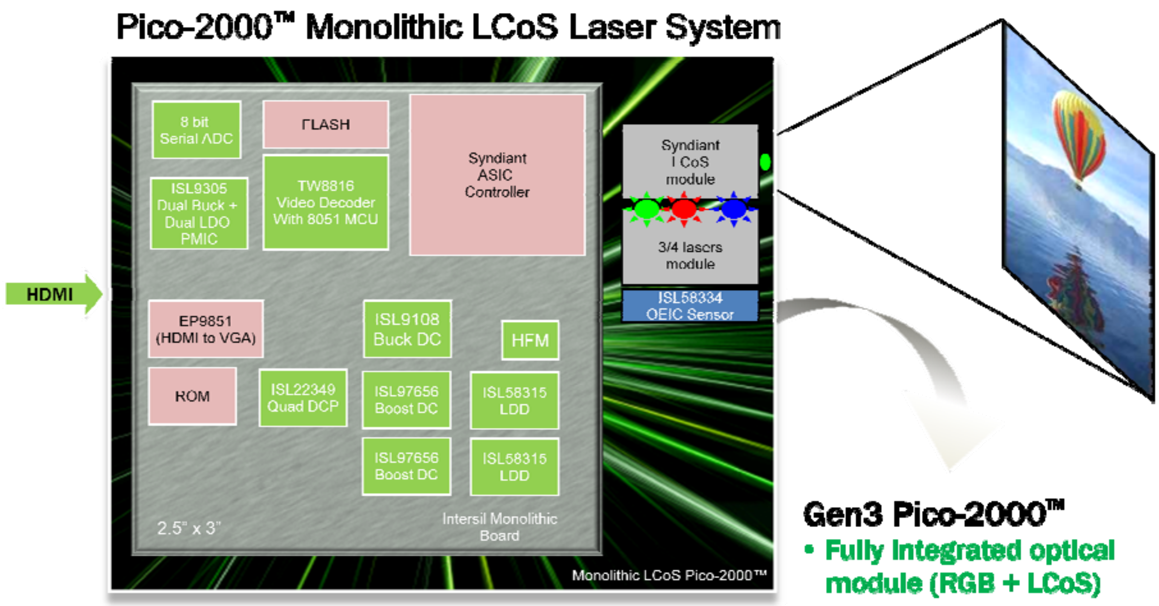

Figure 4 – High-Performance Laser-based Pico Projector Reference Design

The baseline electronics are also capable of supporting up to six lasers if needed in order to provide even higher brightness and the optical engine is optimized for low-power operation at less than 1W in embedded configurations. For product designers looking ahead to introduce high-performance deeply-embedded applications within a 2+ year timeframe, the advantages of such a direct-laser approach are very attractive.

Projecting Ahead to the Future

While new pico projector systems introduced over the next few years are likely to be a mix of low-cost LED and high-performance laser-based systems, it has become clear that in the mid to longer term, we believes lasers will become the dominate light source technology.

The bottom line is that enabling technologies for pico projectors are getting more mature all of the time. For LED approaches, the requirements of size and cost are being met already and the power capabilities are adequate for most of today's applications. Laser systems are already raising the bar on performance, power efficiency and small size, while the projected price/volume curves indicate that lasers will also soon take the lead in the cost arena as well.