Avoiding the Mega Pixel Marketing Trap for Integrated Notebook Webcams

By (Shone Tran, Product Marketing Engineer, Cypress Semiconductor Corp.)

Executive Summary

With the recent proliferation of integrated notebook webcams, designers today face the challenge of balancing the actual consumer need vs. marketing seesaw. Webcams risk heading down a path similar as DSCs: the drive for more pixels (higher resolution) when there really isn't a compelling need for one. In reality, going down this route can severely degrade the end-user experience because packing more pixels into smaller sensors translates into smaller pixels, which dramatically decreases low-light performance. Currently, chat programs like AIM, Yahoo, Windows Live Messenger, and ICQ do not support high resolution web conferencing or video chatting because of very limited broadband infrastructure, so webcam designers should not rush to design in the highest resolution webcams where there is no real application need.

This article will suggest that notebook PC OEMs take a step back and ask themselves whether they are designing with the right considerations in mind to optimize the end-user experience. It will discuss key issues related to integrating webcams into consumer notebooks, including how to maximize the performance attributes which really affect image quality: size, low light performance, resolution, and frame rate, while keeping in mind the limited broadband infrastructure and the typical applications/environment in which consumers operate their webcams.

Walk Down Memory Lane with Digital Still Cameras

The average consumer was first introduced to the idea of mega pixels when digital still cameras (DSCs) took off in the late 90's into the early millennium. A consumer who owned a DSC during this period was the center of attention in his group of friends. At the time, the subject of conversation was on what DSCs could do and how convenient they were compared to traditional 35mm film cameras. Fast forward to 2004, the casual user had already become comfortable with using DSCs and was starting to compare one camera's mega pixels to the next when shopping for a new camera. At the beginning of this trend, migrating quickly from VGA to 1.3MP to 2MP and then 3MP did benefit the end users because they would realistically print pictures in 4x6 or 5x7. As camera vendors started packing in more pixels than realistically needed (4MP and more), consumers began to mistakenly associate the number of pixels with the actual picture quality of the camera. Perhaps this happened because it was a quantitative metric that consumers can grasp and compare, or it was simply the result of great marketing by the DSC vendors, functioning as a tool for differentiating their products. Few consumers understand that more mega pixels are only necessary if pictures need to be blown up for editing or developing large prints. From the surface, this may not appear to be a big problem as consumers get to pay less for more mega pixels over time, except now they are brainwashed to take the same approach when evaluating integrated webcams in their notebooks. Notebook PC vendors are glad to feed the fire and give consumers what they were trained to look for. Ultimately, this can be detrimental to the consumer experience because of the degradation of image quality in higher mega pixel webcams. As discussed below, integrated notebook webcam designers need to consider many other important factors beyond mega pixels to most improve the end user experience.

Understanding the Typical User Environment for Integrated Notebook Webcams

There are two typical characteristics about the environment in which consumers use integrated notebook webcams: 1) Over the internet on IM chat clients and 2) In unfavorable lighting conditions like the home or office. Designers must consider these characteristics when designing integrated notebook webcams.

The Internet and The World of Instant Messaging

Let's first look at the Internet and IM environment. Notebook PC vendors are rushing to integrate webcams as online instant messaging (IM) achieves critical mass. AOL Instant Messenger (AIM), Yahoo! Instant Messenger (YIM), Windows Live Messenger and ICQ are the most popular IM clients that support video based chatting. All chat clients use the Internet as the

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medium to connect users from a few doors down the neighborhood to relatives and business counterparts across the globe. While the Internet is powerful enough to connect users across the globe, it presents one major restriction to the performance of a webcam: limited bandwidth. A corollary to limited bandwidth is the fact that different users have varying connection speeds. IM clients take this into account by compressing already low-resolution video down to manageable sizes to transport through the Internet for the average connection speed.

At the time when video conferencing over webcams on IM clients was first introduced back in 2003, the average consumer broadband connection speed was on the order of 384kbps down / 128kbps up. To compare this in context with webcams, consider Apple's popular iChat software which supports AIM, ICQ, Jabber, and .MAC protocols, which uses cutting edge H.264 compression to deliver MPEG-2 quality video over the web at half the data rate. Even with using such high compression technology, Apple's iChat requires a minimum 100kbps up/down bandwidth to squeeze VGA resolution video through the Internet at 30FPS. At a glance, the 384kbps down / 128kbps up average broadband speed appears to suffice, but factoring in simultaneous usage of email, web browsing, and the physical distance between users across the globe, suddenly 384kbps down / 128kbps up seems barely sufficient. Over the past few years, the average broadband speed has inched up to averaging between 384-768kbps down and 128-384kbps up, which is less than two times the bandwidth increase.

On the other hand, integrated notebook webcams were introduced at VGA resolution by well known notebook PC vendors like Sony and Asus in 2004. By 2005, other notebook PC vendors began to introduce webcams, but skipping VGA altogether and immediately entering the market with 1.3MP cameras. The additional bandwidth requirement increased ~4 times going from VGA to 1.3MP. Comparing this to the increase of broadband speed adoption, which is ~2 times, integrated notebook webcams seem to be outpacing the broadband infrastructure in terms of bandwidth requirement. The advance of integrated notebook webcams up the mega pixel curve is simply not feasible.

While VGA and 1.3MP are still the dominant resolution in 2006, notebook PC vendors are already designing in 2.0 mega pixel cameras. Will consumers adopt the 2x or 3x bandwidth required within the next year or two? It seems unlikely, as broadband adoption overall is leveling off at 53% (Source: Pew Internet Project Survey, May 2005) in 2006 and internet service providers charge a tremendous premium for high upload speeds. Analysts predict that even if adoption rate increases, the speeds will stagnate or even decrease on average as more fierce competition drive the low cost packages down.

The Home and Office Setting for Webcams

Now, let's evaluate the typical environment where a user operates his webcam: in a home or office. The typical camera flash emits 2000 watts of light to properly expose a picture. A typical home or office environment uses lighting from 100 to 150 watt light bulbs, perhaps with multiple bulbs. This order of magnitude difference illustrates that users are operating webcams in unfavorable lighting conditions. Image sensor vendors do all sorts of tricks like decreasing frame rate to maximize integration time and using pixel binning to accumulate additional light from neighboring pixels in order to improve low light performance. This generally works when taking still image captures, but when capturing video, these methods severely hurt frame rate and affect clarity of the picture.

Targeting the Webcam Specifications that Matter

Mechanical Constraints: This is probably where the designer really starts from and needs to choose a webcam architecture that will meet the size constraints put on by the laptop bezel, while satisfying performance requirements. For example, given a very small bezel, perhaps low light performance will be compromised and the designer will need to choose an architecture that maximizes pixel area and pixel size. The different architectures are described below.

Architectures

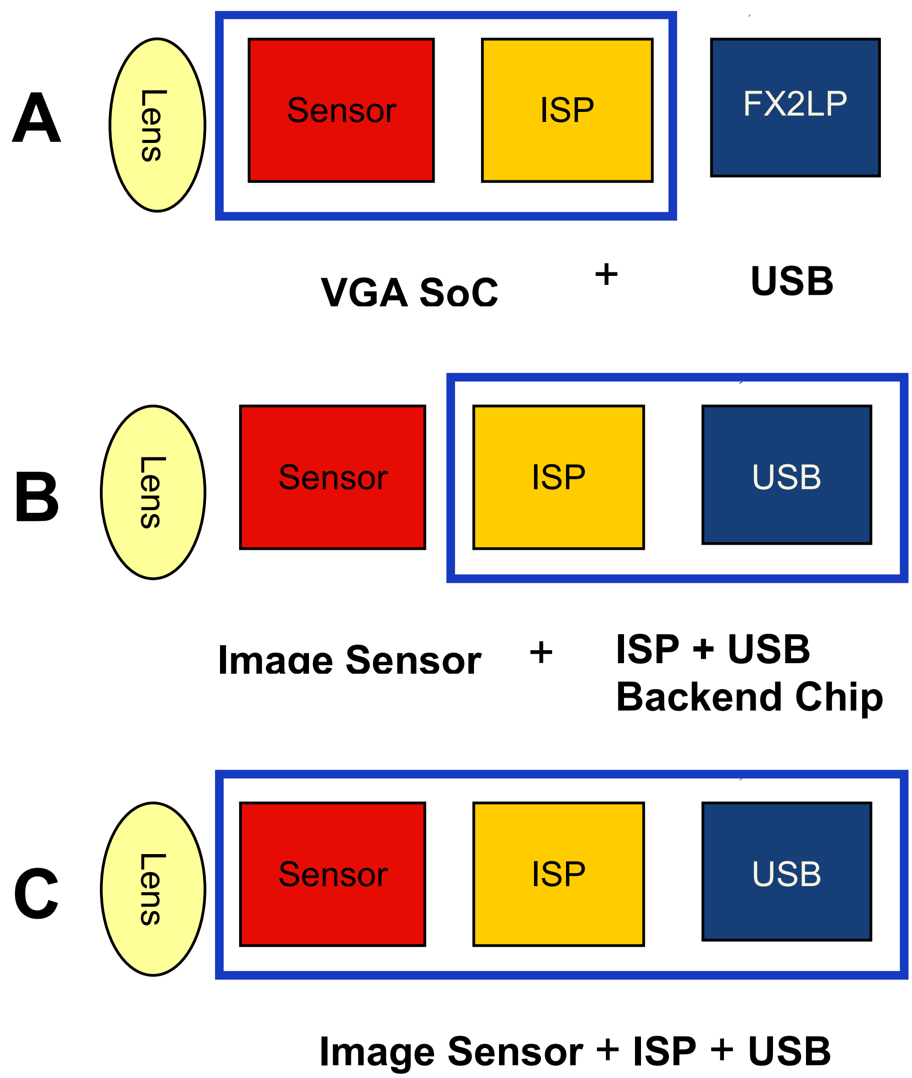
Choosing the proper architecture can make or break a webcam design, as each has its pros and cons. Consider the following architectures:

A) **SoC + USB** is a 2-chip solution that uses an image sensor integrated with image processing (SoC) and a Hi-Speed USB peripheral controller like Cypress's EZ-USB FX2LP. A particular advantage of this architecture is that the image sensor vendor knows their sensor best and can optimize the ISP to best complement the sensor characteristics. A drawback of going with an SoC is the fact that sensors tend to be designed thin and use less metal layers to build the ISP logic. Therefore, it may take more silicon area to realize the same ISP logic in an SoC, thereby reducing pixel area and further limiting the mechanical constraints of a laptop bezel.

B) **Image Sensor + Backend Chip (ISP + JPEG + USB)** is also a 2-chip solution, but the difference is that the image sensor stands alone while the ISP (Image Signal Processing) portion is integrated (sometimes with JPEG compression) with the USB controller. An advantage of this architecture is that you can choose a bigger sensor with larger pixels, while the designer can choose a different ISP for a given sensor and gain more flexibility. At the same time, this can be cumbersome for designers not verse in evaluating imaging pipelines. On the same token, a possible disadvantage is that a given pipeline may not be optimized for the different image sensors a designer might choose to use.

C) **Image Sensor + ISP + USB** is a 1-chip integrated solution which has currently gained little traction because it is limited to full-speed USB which ultimately limits the resolution. These 1-chip solutions are potentially limited to full-speed USB because high-speed USB uses extremely fast signaling, which generates significant heat. Since the USB is essentially built onto the same die as the pixel array, heat is a big issue in these solutions. For those designers looking to differentiate, using this architecture limits you to only 1 or 2 vendors at the time of this article.

Figure 1.



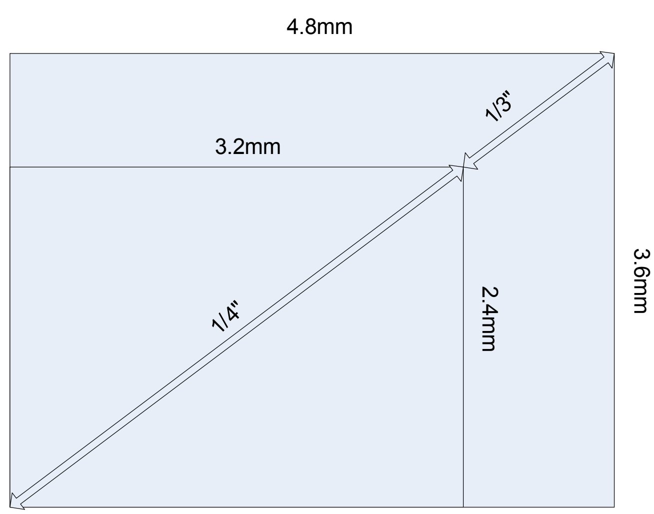
Resolution

As already discussed, there is an obvious tradeoff between mega pixels and frame rate and low light performance. A major consideration is whether there really is a need for video conferencing in high resolution. Traditionally, higher resolution would enable blowing up an image to do editing or to print larger stills. These two usages are effectively moot points when the webcam is used for video capture. Consider the average laptop or LCD display, which run on 1024x768. Such a display would not be able to show an entire 1.3MP picture. Also consider the usage model of web conferencing, where users are usually multitasking. That means users would not want a full screen video anyway, because they need to access email or view a document that they're discussing. Avoiding the mega pixel marketing trap is the only way to deliver the best image quality and smoothest video over the current Internet infrastructure. Designers need to ask themselves if offering more pixels will really improve the end user experience, or actually drag down the factors that really matter.

Optical Format

This attribute simply specifies the diagonal length of an image sensor. While a given resolution image sensor can have a range of pixel sizes, given the same optical format size (typically 1/3" or 1/4"), more mega pixels inevitably translates into smaller pixels. Optical format is an important consideration, as notebook PC vendors are trying to fit webcams into the small bezel of a notebook LCD. Ideally, a designer will choose the largest optical format that will fit within physical limits, while using the largest pixel size at a reasonable resolution.

Figure 2. This diagram illustrates the typical dimensions of a 1/4" and 1/3" optical format sensor



Frame Rate

The human eye generally sees fluid motion at 24 frames per second (FPS). To give an idea of what 24 FPS looks like, consider movies which are usually shot and displayed at 24 frames per second. Typical VGA CMOS sensors found in webcams can capture video at 30 FPS in full light, but increasing integration time, for example, can easily reduce the frame rate below 20 FPS, where the human eye will perceive choppiness. Minimizing the need for integration time to improve low light will keep the camera from having to run lower frame rates to compensate for poor low light performance.

Low Light Performance

This is a characteristic of webcams that is difficult to measure. Designing for maximum low light performance requires pinpointing the factors which most directly affect it. Pixel size is directly related to low light performance because in general, the bigger the pixel, the more light it can collect, which improves exposure. Given a constant optical format, typical pixel sizes for VGA sensors are in the 5.6um range, while 1.3MP sensors are in the 2.8um range and 2.0MP sensors are in the 2.2um range.

USB

Throughput: Webcams are ubiquitously connected to PCs via USB connections and is the method of choice even in integrated notebook webcams. To ensure smooth video, the USB 2.0 specification allows for dedicated bandwidth via isochronous transfers. The maximum theoretical throughput using isochronous transfers is 24Mbytes/second. While Hi-Speed USB 2.0 is a standard, not all USB controllers are created equal and not all of them will produce robust, uninterrupted 24Mbytes/second isochronous transfers. Choosing a programmable and reliable, high-speed USB peripheral controller ensures maximum frame rate and easy upgrading to accommodate the ever-improving offering of image sensors. Most importantly, USB becomes a bottleneck above VGA resolution. Theoretically, USB delivers uncompressed video at 30FPS @ VGA and 15FPS @ 1.3MP. Squeezing more mega pixels and higher data rate through USB requires adding hardware compression, which will inevitably drive up the BOM cost of the integrated webcam. Adding an additional layer of compression which will be uncompressed and then recompressed by the IM client will further degrade image quality.

Heat

An often subtle and overlooked consideration is the problem of heat and its effect on image quality in a webcam. Heat often causes unwanted noise in the image. This shows up as graininess and blurry edges. Chip selection will be an important consideration to battle the effects of heat on image quality. The USB controller generates tremendous amounts of heat due to high-speed signaling and in serious cases where the USB controller is sitting next to the image sensor, the image actually shows bleeding and extreme degradation in quality on the side adjacent to the USB controller. Given the confined space within notebook LCD bezel, designers need to design the board to separate the USB controller as far as possible from the image sensor, while choosing a USB controller with the lowest current consumption, which translates to lowest heat.

Dynamic Range

Simply put, this is how well the image sensor can handle extremely low light and extremely bright light. When evaluating image sensors, this is an important characteristic designers should benchmark, because it is very likely a lamp in the background can ruin the video capture. The below image illustrates how an image sensor with poor dynamic range washes out on brighter parts of the picture (left) while an image sensor with good dynamic range maintains composure.

Figure 3

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Conclusion

Falling into the mega pixel marketing trap results in severe degradation of low light performance and frame rate, which are limited by the typical user environment. Designers of notebook PCs can swing the ship back in the right direction by also focusing on mechanical constraints, architecture, resolution, optical format, frame rate, low light performance, USB throughput, heat, and dynamic range when designing integrated notebook webcams. By focusing on these attributes which matter most, designers will ultimately improve image quality and the end user experience.

References

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone: 408-943-2600
Fax: 408-943-4730
http://www.cypress.com