The Amazing Shrinking Camera

By Roman Gutierrez, Tessera Friday, October 15, 2010

Have you ever dreamed of having a miniature spy camera small enough to fit inside of a pen? Chances are you already do – inside of your cell phone. While there may not be a large market for spy cameras these days, more than 1 billion cameras are deployed in cell phones each year. This huge market opportunity is driving innovation and image quality previously inconceivable for a camera smaller than a pencil eraser.

Camera size reduction is becoming as pervasive and relentless as Moore's Law, which, since 1971, has accurately predicted that transistor counts in a central processing unit (CPU) would double every two years. Because the image device in a camera is a digital electronic device, it can be expected that the number of pixels in a camera will double every two years as well. However, the number of pixels per unit volume in a cell phone camera is doubling every year; twice the rate expected by the Moore's Law extrapolation. This means that the volume available to the other components in a camera module is being reduced by a factor of two every two years.

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An illustration of this is an auto-focus camera that was 11.5x11.5x8.5mm at 2 megapixels (MPix) only three years ago has shrunk to 8.5x8.5x6mm for 5 MPix today. That is an increase from 1.8 MP/cm^3 to 11.5 MP/cm^3. Based on this trend, a 12 MPix auto-focus camera will fit in a 6.5x6.5x5mm package by 2013, cramming 57 MP of imaging resolution into one cubic centimeter.

The progress being made on complementary metal oxide semiconductor (CMOS) processes is partly responsible for this miniaturization because it is directly responsible for the increase in the resolution of image sensors. Only three years ago, a pixel occupied a square 2.2mm per side. Today, image devices with a pixel size of 1.4mm are being released into production, and it is expected that they will have pixels less than 1mm in size by the end of 2012. In addition, other emerging wafer-level manufacturing technologies, such as wafer-level packaging, wafer-level optics and micro-electro-mechanical systems (MEMS), are helping to shrink the other components that make up a camera.

Similar to the miniaturization of any electrical system, packaging and electrical interconnection are important issues that must be addressed when reducing the size of a camera. Wafer-level packaging and ball grid arrays (BGAs) are emerging as the packaging methods of choice for image devices. These advanced forms of electronic packaging eliminate the need for bulky printed circuit boards (PCBs) inside of a camera, allowing the image device to be directly bonded to the PCB inside of a cell phone.

An important consideration in this miniaturization trend is that the size of a camera is based on more than the number of pixels of resolution. Features included in the camera that improve the image quality also add to its overall size. For example, the auto-focus actuator and electronics inside of a camera that ensure the image is in focus require additional space. Adding a shutter that captures objects in motion takes up even more real estate.

There are several technologies to help address the challenge of more features in the same or smaller footprint. MEMS are integrated components manufactured on silicon wafers which include both mechanical moving and electronic parts. Using photolithography and etching enables dramatic miniaturization of actuators because the features that can be machined are dramatically smaller than 1mm -- or 1 one-hundredth the width of a human hair. These technologies allow a wider range of applications to be included in the image device within the existing limited space.

Finally, there is the lens. Arguably one of the most important components in a camera, the lens occupies a large portion of the volume in an imaging device. Reducing its size is a real challenge, especially considering that the resolution requirements increase proportionally as more pixels are incorporated into the device. Here again, wafer-level technologies offer interesting options. Wafer-level optics allow the fabrication of arrays of lenses at the wafer level. These lens wafers are then precisely assembled using wafer bonding, after which they are diced to form stacks of multiple lenses akin to the lens barrel in conventional cameras. By eliminating the need for a barrel around the lens stack, reducing assembly errors and using higher index materials, wafer-level optics enable the significant reduction of the volume occupied by the lens in a camera while improving optical performance.

So, although it is unlikely that you will need a spy camera any time soon, you can be sure that the future will bring smaller, better quality cameras to your cell phone, thanks to emerging wafer processing and integration technologies. After all, electronic circuits have followed the same path. From discrete component assembly to batch manufacturing of integrated circuits, the electronics industry has undoubtedly proven the value of using silicon wafer processing to miniaturize electronic devices. Thanks to these and other ongoing advances in wafer-level processes, we should be able to keep up with the demand for ever shrinking cameras.

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