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Fresh, sealed, and safe
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WITH HELP FROM HIGH-PRESSURE-RATIO PUMPS, PG 22

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No blur allowed

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New industrial vision cameras can keep up with the fastest line speeds thanks to advances in CCD imaging.

The KAI-0330D CCD chip from Eastman Kodak Co. can read out 120 full frames/sec. This gives it a place on high-speed production and packaging lines. Among the industrial cameras that use it is the Pulnix TM-6710.

No engineer would use a toy camera to handle serious industrial imaging. In the same vein, it generally doesn't make sense to use the imaging chips found in low-end consumer goods for cameras doing duty on the factory floor.

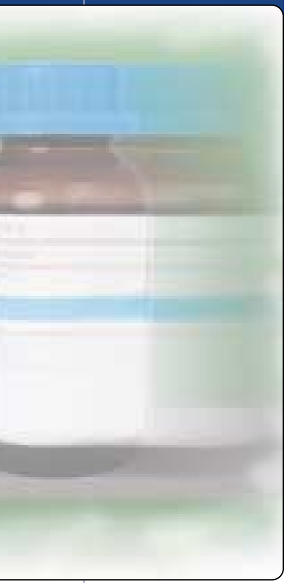
Many of an industrial camera's most important specs are a function of the imaging chip it uses. That is why it pays to know a few things about imaging chips when planning an industrial vision system. Familiarity with basic chip technology can go a long way in showing what will be required of vision components for specific applications.

CRUCIAL QUALITIES

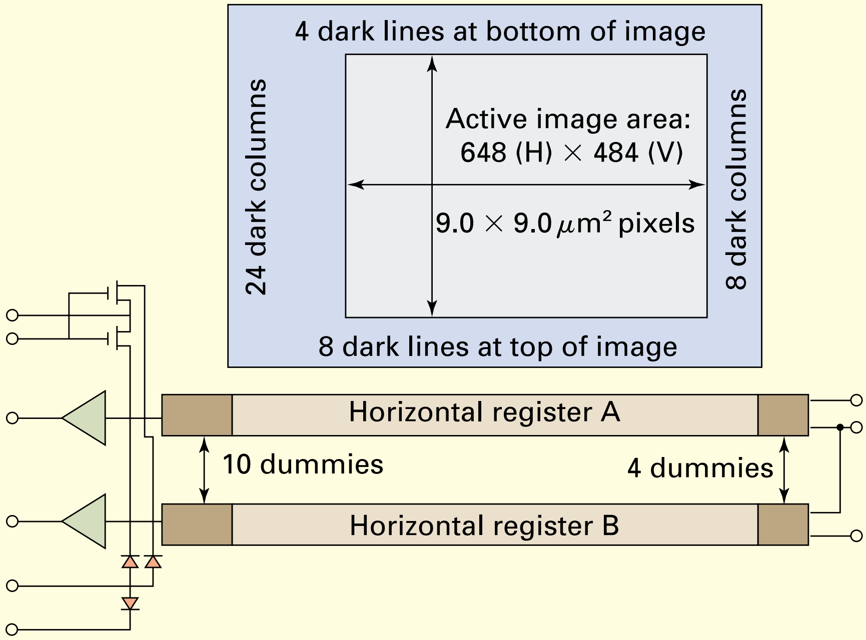
Look inside a $99 digital camera for consumers and you will probably find a CMOS imaging chip. These ICs are considered good enough for fixed-focus cameras in this price range and for low-res needs such as camera-equipped cell phones. One reason is they use little power and can incorporate much of their signal conditioning and imaging circuitry on the same chip. They can also work directly from 3-V power supplies.

But CMOS imagers have far less resolution and performance in dim light than alternative technologies. About 5 Lux is the lowest light level they can image. The reason is they have about ten orders of magnitude more dark current due to thermal noise (on the order of 0.2 nA/cm^2) than charge-coupled-device (CCD) chips used in midrange consumer and industrial devices. Such drawbacks keep CMOS imagers out of many serious uses.

The better-quality digital cameras familiar to consumers generally contain CCD imaging chips rather than CMOS devices. They hold on the order of 3 mil-



Simplified block diagram



The Kodak KAI-0330D CCD image sensor uses two horizontal shift registers, each with its own output, to hit 120 frames/sec. A fast-dump feature permits quick dumping of unwanted rows to hit even higher frame rates for reading out a subsection of the full image. This feature lets the chip deliver two full-length rows at 400 frames/sec.

lion pixels. (CCD chips get their name from their use of special MOS transistors and photodiodes at each pixel. These structures create an electrical charge proportional to the amount of impinging light.)

A point to note about consumer cameras is that they are relatively slow. The CCD (and CMOS) chips they employ are capable of recording about 12 images/sec at most. Some can hit 30 images/sec, the rate used with ordinary video, by recording images at a lower resolution.

Limited speed is one reason why CCDs for consumer goods are seldom found in industrial cameras. Many production and packaging lines today run at rates that demand far more than 30 images/sec. CCDs need special architectures to get much above these speeds. One such architectural scheme is called interline. It is so named because each pixel consists of two parts, a photosensitive region and an associated shift register. This setup lets the chip capture an image while pixel information for a previously acquired image is read serially from the shift register.

Architectures like interline make it possible to use electronic rather than mechanical shuttering to capture images. This is an advantage for industrial cameras because mechanical shutters in near constant use are prone to break.

Electronic shuttering, in contrast, employs no moving parts. The CCD chip is electronically shuttered by circuitry that drains the charge out of the photosensitive pixels. The technique can also be used to balance the color response of red, green, and blue channels by selectively limiting the exposure time of the appropriate pixels.

Another CCD feature with image-capture speed in mind is progressive-scan mode. This means the CCD can acquire an entire image at once. Generally speaking, cameras equipped with progressive-scan CCDs employing electronic shutters are the easiest way to obtain high-speed and high-resolution. One such CCD is the KAI-0330D sensor from Eastman Kodak Co. It can read out 120 full frames/sec, or one every 8.3 msec. It has VGA-sized resolution, 648×484 pixels, and can read out a 100 or 200-row subregion to boost image throughput. One of the cameras that uses it is the Pulnix TM-6710.

Progressive-scan contrasts with interlaced format as used by ordinary analog TV displays. Analog TVs refresh only every other raster line. Similarly, CCDs operating in interlaced mode read out first the even rows and then the odd rows of pixels. The two fields of information are then combined to create one frame.

However, there is a problem with interlaced CCDs when working with fast production lines. Each field gets captured at a slightly different time. The time difference may be enough to cause image distortion when the camera is imaging scenes that move at the upper limit of its acquisition speed.

One way out of this dilemma is to just capture one field of information rather than two. The trade-off is resolution. The resulting image will have exactly half the density of one captured in a full frame. This may not be practical if the application requires the full camera resolution to image product details properly.

Some CCD chips can work at something less than maximum resolution as a way of giving a quick setup. The idea is to only sample a subset of the pixel rows. The classic example of this feature is in microscopy. Researchers might operate a camera in subsampling mode to quickly center a specimen in the field of view, then shoot it with the camera at full resolution.

COMING SOON

The trend in cameras for industrial imaging is toward faster frame rates. CCD chips scheduled to become available this fall will hit 240 full frames/sec. Also in the works are CCDs with physically smaller pixels, at least for consumer cameras. Smaller pixels let CCD chips of a given imaging area provide more resolution. The trade-off, however, is in image dynamic range. The amount of charge a pixel can generate is directly proportional to its size. The larger the charge capacity, the bigger the dark-to-light range of the resulting image.

For example, the Kodak KAI-0330D chip has pixels measuring 9 microns square. As a comparison, the CCDs and CMOS imagers that consumer cameras employ have about 6-micron pixels or less. There will soon be devices available for consumer cameras with pixels in the 2-micron range.

Some applications need resolutions exceeding those of VGA. Sensors handling such needs include the KAI-293 which has a 1,900 × 1,000-pixel format. It is used in the Pulnix TM-2016 camera which is often applied in checking for defects on integrated circuits and on circuit boards that have been loaded with components.

Applications in production and packaging lines tend not to need sensors able to handle a wide range of light levels. Users may note, however, that there are CCDs designed with high dynamic range in mind. The KAI-0372 found in the Pulnix TM-9701, for example, handles a 60-dB light range for the variety of lighting conditions found outdoors. Among its uses are intelligent traffic systems where cameras shoot car license plates as they pass through tollbooths or go into parking lots. These systems make automated billing possible and, perhaps unfortunately, also play a part in automated traffic speed traps. ■