PIXIM®
EVERY PIXEL TELLS A STORY

White Paper:

Compression Advantages of Pixim's Digital Pixel System® Technology

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Most of the advantages of Pixim's innovative Digital Pixel System® image capture and processing technology are easy to see: video images with high resolution, natural color and superb accuracy, and free of image-compromising visual noise, regardless of a scene's lighting conditions.

The Digital Pixel System advantages do not stop with the visually obvious, however. Behind the scenes, Pixim's all-digital technology yields more highly compressed images that can dramatically reduce the costs of moving and storing security video in both analog and IP networked installations.

This paper outlines how Pixim's Digital Pixel System technology is able to deliver compression advantages for users of video security systems.

The role of efficient compression algorithms

Compression algorithms determine compressed bit rate – i.e., the bandwidth required to transmit video images – and the hard disk space consumed within a digital video recorder (DVR) or network video recorder (NVR) – i.e., storage space. The efficiency of a compression algorithm such as MPEG-4 or H.264, whether the compression takes place in a DVR or inside an Internet protocol (IP) camera, is affected by four primary factors:

- **Bit-rate strategies and limits.** DVRs have controls that allow users to select between variable bit-rate (VBR) and constant bit-rate (CBR) compression strategies. In addition, they can allow users to set upper limits on the compressed bit rate, in return for reduced video quality. If a DVR or IP camera uses CBR compression, there is no way to offer a compression advantage. As a result, this paper will focus entirely on factors affecting VBR compression, which is being implemented in many state-of-the-art video cameras and recorders.
- **Amount of motion present in the scene.** Scenes with high degrees of motion lead to higher bit rates and larger compressed file sizes. Video compression algorithms monitor the amount of motion present in a scene; in areas with no motion, the algorithms encode the data more efficiently.
- **Amount of noise present in the video.** To a video compression algorithm, temporal noise looks like motion. A lot of temporal noise looks like a lot of motion – and it leads to higher bit rates and larger compressed file sizes.
- **Amount of high-frequency content in the scene.** From a video compression standpoint, high-frequency content means sharp edges in the scene. These edges could be the sharp lines separating brightly lit and deeply shadowed areas, the edge of a building, or even stripes and other patterns against the solid background of a shirt. These sharp transitions increase the compressed bit rate as well as the size of the file on the DVR or NVR.

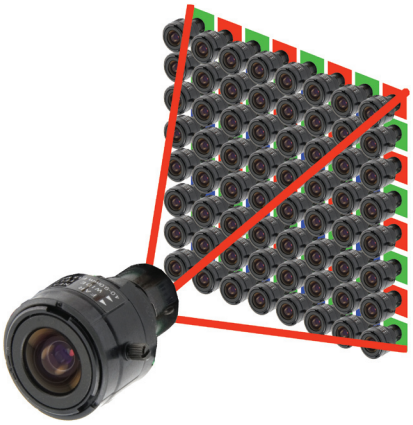
The first two factors are beyond the control of a camera's video capture and image processing technology. With the last two factors, however, Pixim's Digital Pixel System technology has a significant impact.

A brief overview of Digital Pixel System technology

The Digital Pixel System technology features a unique architecture and tightly coupled imaging software, which enable superior image quality even under highly variable lighting conditions and in wide dynamic range scenes that have both dark and bright areas. The Digital Pixel System provides dramatically better wide dynamic range images than existing analog technologies, including those produced by the charge-coupled devices (CCDs) or CMOS active pixel sensors (APSs) used in other video camera implementations.

Pixim's current product line based on Digital Pixel System technology consists of a highly integrated two-chip set comprising a digital image sensor chip and a digital image processor chip.

Digital Pixel System technology works by converting the quantity of light striking each picture element (pixel) to a digital value at the earliest possible point: at the pixel itself. An analog-to-digital converter (ADC) is designed into each pixel and is operated simultaneously with all other ADCs in every pixel of the sensor. This pixel-level ADC architecture permits the use of many highly parallel low-speed circuits, operating close to where the photodiode signals are generated – which is key to optimizing the signal-to-noise ratio (SNR) for each pixel.



With the Digital Pixel System, every pixel is essentially a separate, independent camera.

The Digital Pixel System technology uses the individual ADCs to perform non-destructive multi-sampling at each pixel. The Pixim technology uses this capability to sample the growing light intensity at each pixel many times during every image capture period. This allows exposure levels of every pixel to be determined by the rate of change of charge collected, rather than only by its absolute magnitude. It also allows each pixel to subtract out its own unique noise characteristics for each video frame using real-time digital correlated double sampling (CDS).

Every pixel also is provided with an adjustable offset cancellation gain amplifier to assure uniform response throughout the sensor array. These innovations greatly reduce noticeable temporal noise problems commonly associated with the column- or sensor-level ADCs used on APS and CCD sensors.

How Digital Pixel System technology affects compression

Pixim's Digital Pixel System technology conditions the video output from the camera to optimize what the DVR or IP camera's video compression algorithm receives as input from a scene. The Digital Pixel System technology works with the compression algorithm's input in a variety of ways:

- **Noise reduction and elimination.** Pixim's Digital Pixel System technology is based on intelligent exposure, color and noise processing algorithms that maximize the SNR under all lighting conditions.

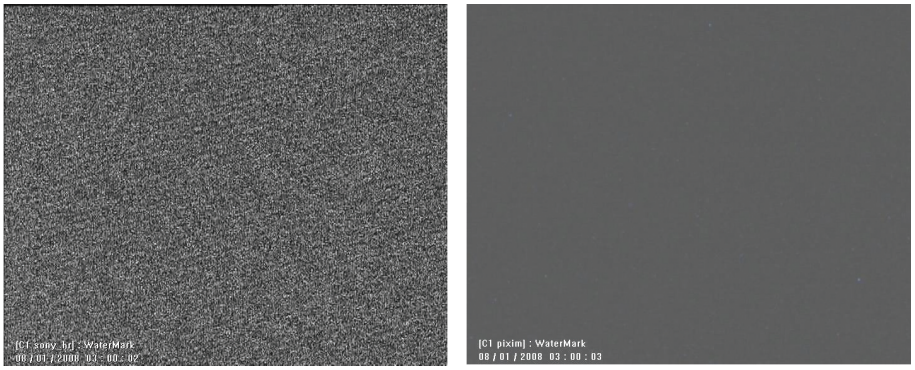
  A negative feedback unity gain amplifier in each pixel eliminates any offset voltage, resulting in much greater uniformity throughout the Digital Pixel System sensor array. To minimize reset noise, each pixel value is read non-destructively at the beginning of the exposure, and this value is later subtracted from the final measured value for the pixel. This non-destructive method of correlated double sampling is unique to Digital Pixel System technology; most other sensors must read the CDS value, reset the sensor and then capture a new value. However, the random background noise change from the initially captured CDS value introduces distortion that is detectable to the human eye. Pixim's approach avoids this visual noise.

  With Digital Pixel System technology, every pixel is converted to digital format immediately when it is captured – and it remains in digital format from end to end until it leaves the camera. As a result, once the pixel is initially captured, there is no way to introduce noise into the file at any point during image processing. (This process is analogous to how audio compact discs work to provide the crystal-clear audio playback that contrasts so vividly with noisy vinyl and cassette tape analog recordings.)

  Because the pixels are converted to digital format immediately upon capture, any noise that exists in the image is introduced only at the point of capture. Such noise tends to be fixed-pattern noise – which remains stationary within an image – instead of randomly distributed noise, which appears as motion to a compression algorithm. This is a key distinction.

Pixels are captured by the Digital Pixel System technology digitally into on-chip memory. This approach contrasts with that of CCD cameras, which read out pixels via analog interline transfers. Interline transfers introduce row or column noise that can appear as motion or high-frequency content to a compression algorithm. In Pixim's approach, this interline transfer noise is not introduced.

In images captured by Digital Pixel System technology, black is black. When a pixel is truly black, Pixim's technology provides a true digital black level that does not modulate with random noise. In contrast, other approaches tend to provide noisy levels of black and dark shades of gray that are interpreted by video compression algorithms as high amounts of motion. (To test this capability, connect a Pixim-powered camera to a monitor, install a lens cap and look at the video produced. Now try the same thing with a CCD or other CMOS camera, and compare the results.) True black dramatically reduces compressed file sizes in dark scenes.



CCD Image | Digital Pixel System Image

Pixim's Digital Pixel System technology provides a true digital black level that is not modulated with random noise. (Both images were lightened by the same amount to enhance contrast for printing.)

The Digital Pixel System technology is also the only imaging solution that allows capture of wide dynamic range scenes while eliminating the flicker and color roll artifacts that are common in situations where fluorescent lighting or other lighting systems that use ballasts (e.g.; mercury vapor) are used. Fluorescent flicker and color roll are interpreted by video compression algorithms as motion and have significant effects on compressed bitrates and file sizes.

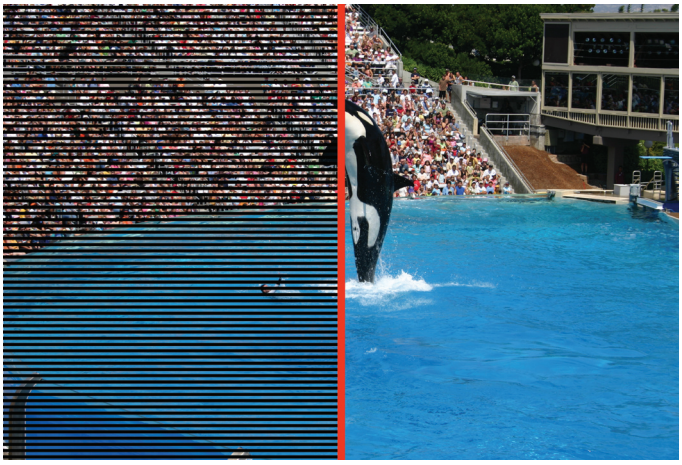
› **Global shutter vs. rolling shutter.** Video capture technologies employ either a global electronic shutter or an electronic rolling shutter, and the two approaches vary dramatically. Note that in this terminology, there is no physical shutter covering and uncovering the sensor. The "shutter" refers to the timing of exposure of the sensor during the process of video capture.

A rolling shutter, which CMOS APS cameras use, captures different portions of a scene at different times – i.e., "rolling" through a frame. With a rolling shutter, the sensor directs different portions of the frame to become light-sensitive at different instances, one area at a time, until the full frame is exposed (e.g., from top to bottom). During this process of sequential capture, the rolling shutter can introduce artifacts such as skew (a kind of "leaning" effect) and wobble (video with a "rubbery"or "jiggly" look). These artifacts make it seem as if an image has more motion than is actually present in the scene being captured.

Both images were captured from a moving vehicle. The image on the left was captured using a global shutter, and the image on the right with a rolling shutter. The same would happen if the image of a moving object was captured from a stationary camera. The"leaning" artifact is known as "skew".

Digital Pixel System technology uses a global electronic shutter that captures the entire scene all at once. This global shutter capability takes advantage of Pixim's on-chip memory to capture all the pixels simultaneously, which prevents the jerky appearance of skew and wobble artifacts. Fewer artifacts means improved image compression.

› **Progressive capture vs. interlaced capture.** Analogous to global and rolling shutter, progressive capture and interlaced capture differ in how they capture images: all at once vs. in pieces.



Interlaced Progressive

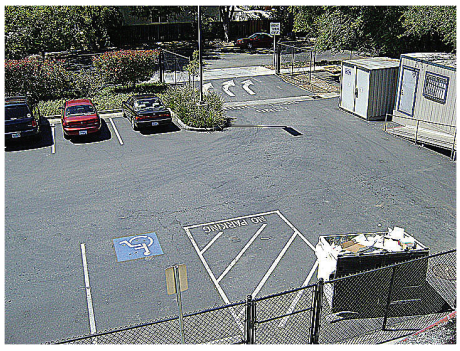
With interlaced capture, half the image is captured, in lines separated by non-captured areas. Then, the other lines are filled in during a second pass. If any motion occurs during those two passes, it creates field-to-field motion "combing" artifacts such as jagged edges and smearing. These artifacts tend to increase the amount of data generated by the compression algorithm.

"Combing" artifacts in interlaced video caused by motion of an object between the capture of the two fields.

The progressive capture approach, which is what the Digital Pixel System technology uses, captures every line of the image simultaneously. It is more like taking a single snapshot of the whole scene, so no combing artifacts or other noise can be introduced. The result is a clearer, cleaner image with a lower bit rate and smaller file size.

› **High-frequency content reduction.** As mentioned previously, high-frequency content refers to the sharp edges of a scene. Pixim's Digital Pixel System technology uses color kernels (which are what the image processor uses to convert what the sensor captures into "real" color, pixel by pixel) and digital signal processing algorithms that have been designed to produce sharp, color-accurate images – while not over-sharpening the images, as some other image processors do. Over-sharpening introduces high-frequency content into the scene that does not compress efficiently.

Properly Sharpened Image



Over-Sharpened Image

Notice the additional, unnecessary detail in the pavement and chain link fence in the over-sharpened image.

Over-sharpening is a common side effect of other image capture approaches, caused when their algorithms attempt to compensate for the cameras' physical and architectural limitations when capturing scenes with wide dynamic range (i.e., scenes with areas of both bright and dark areas). Because Pixim's Digital Pixel System technology is a true wide dynamic range image capture technology, it does not fall prey to over-sharpening and so its images compress more efficiently.

- **Frequency domain issues.** Frequency domain issues arise when images are converted between digital and analog formats. Pixim's Digital Pixel System technology preserves each pixel in digital format from end to end: from the instant it is captured at the photosite until it is converted back to analog format by the video encoder, which converts the digital pixels into analog video for transmission to the DVR. (In an IP camera based on the Digital Pixel System technology, the pixels stay in digital format and never go through this late-stage digital-to-analog conversion.)

  With Pixim's technology, that digital-to-analog conversion happens in the same frequency domain as the compression hardware used in the DVR. As a result, sampling errors and artifacts are minimized or eliminated.

  Pixim's technology uses a full 10-bit, broadcast-quality video encoder to maintain color accuracy in the output video and eliminate what are known as quantization errors. This choice of a full 10-bit video encoder eliminates artifacts in the output video that would otherwise cause increases in compressed bit rates and DVR file sizes.

To summarize, Pixim's Digital Pixel System technology begins with low-noise digital pixels and then uses advanced processing to enhance image quality and reduce image noise to minimal levels. This technology succeeds in providing cleaner video that compresses better.

Independent validation

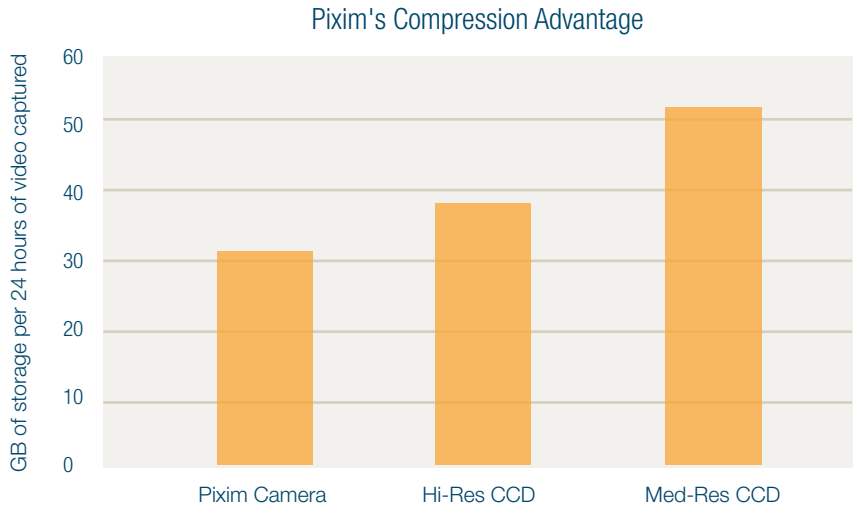
Recently, Pixim worked with an independent test lab[1] to determine the significance of the compression advantage and DVR space savings offered by Digital Pixel System technology in typical security applications. The results were quite impressive.

The independent lab tested three cameras side by side: a high-resolution Pixim-powered camera, a high-resolution CCD camera (540 HTVL) and a medium-resolution CCD camera (320 HTVL), all with identical lenses installed. All the cameras captured the same scene that was recorded by the same DVR over a 24-hour recording cycle. The test lab's reported observations included the following:

- The file size on the high-resolution CCD camera was 19% larger than the file size for the Pixim-powered camera.
- The file size for the medium-resolution CCD camera was 62% larger than the file size for the Pixim-powered camera because of artifacts and noise introduced during the process of scaling the video to 4CIF resolution.

[1] dBeech Associates, Ltd., www.dBeech-Associates.com

- The Pixim-powered camera captured visibly superior color, resolution and dynamic range during daytime operation.
- The nighttime performance of the high-resolution CCD camera and the Pixim-powered camera was similar, but the Pixim-powered camera captured dark areas of the scene at noiseless black levels.



Although test results will vary by application and scene content, this independent testing validates claims made by numerous Pixim-powered camera customers: that Pixim's Digital Pixel System technology provides a clear compression advantage that requires less hard drive space in the DVR to store an equivalent amount of video content.

In addition to the compression advantages, the independent test lab also confirmed the superiority of the true wide dynamic range capabilities of Pixim's Digital Pixel System technology, including excellent performance in extreme backlight situations; natural color reproduction; images of high enough quality to fulfill evidentiary standards; lack of vertical smear, pixel blooming, image washout, over-saturation, and other image-degrading artifacts; and high total resolution, taking into account both horizontal and vertical TV lines.

The results: reduced overall system cost + greater flexibility

More efficiently compressed video images have lower bit rates and smaller file sizes – which means they are easier to move between the camera and a DVR (or between servers over a network) and more economical to store on DVR, server or networked storage device.

This ease of transport and storage translates directly into lower overall system costs for the video security system. There are four primary ways in which Pixim's Digital Pixel System technology can reduce video security systems' total cost of ownership:

- **All-digital technology.** In Pixim's Digital Pixel System technology, each pixel acts like an individual, self-adjusting camera that can respond optimally to the unique lighting conditions present at that specific pixel location. From an image quality standpoint, Pixim-powered cameras can capture highlight and shadow detail in the same image, regardless of lighting conditions in the scene. From a compression standpoint, this all-digital approach means the camera, video compressor, and DVR or NVR do not have to process, transmit and store extraneous information. In addition, from a cost-of-ownership standpoint, users of video security systems do not incur the expenses associated with the extra processing, transmitting and storing of images.

- **Reduced image artifacts.** Image artifacts such as vertical smearing, blooming and camera blindness not only diminish image quality, but also increase an image's bit rate and file size. Pixim's all-digital technology automatically eliminates or vastly reduces this visual noise, and owners of video security systems spend less on manipulating, moving and storing Pixim's more streamlined, noise-free images.

- **Color consistency.** Analog cameras generalize pixel settings, whereas Pixel's Digital Pixel System technology achieves pinpoint color accuracy with each pixel. As a result, Pixim-powered cameras deliver accurate white balance and true, consistent color – instead of saturated highlights or muddy shadows. Images with saturated and muddy colors require more processing to be made useful for security purposes, and they result in larger file sizes. Once again, Pixim allows owners of video security systems to avoid these extra costs.

- **Progressive capture.** Pixim's progressive capture imager with global electronic shutter dramatically reduces storage requirements in both networked and stand-alone environments. Images captured with the Pixim progressive capture imager have very little high-frequency noise, which leads to more highly compressed files with lower bit rates. The result is lower network traffic and reduced storage requirements, along with their associated cost savings.

By being able to store the same amount of video content in less DVR or NVR storage space, video security system operators gain tremendous flexibility in how they can use that additional space to achieve optimum benefit from their security system. For instance, they can:

- Store additional hours of video per camera.
- Store higher-quality video for one or more cameras.
- Increase the video frame rate stored for one or more cameras.
- Use smaller, less-expensive hard drives and backup systems.

	CCD Camera	Digital Pixel System Technology Camera			
Application Requirements		Higher Frame Rate	More Recording Time	Higher Resolution	Longer Retention
Continuous Recording	4 fps	**8 fps**	4 fps	4 fps	4 fps
Alarm Recording	15 fps	**30 fps**	15 fps	15 fps	15 fps
Scheduling	12 hrs / day	12 hrs / day	**24 hrs / day**	12 hrs / day	12 hrs / day
Resolution	CIF (320 x 240)	CIF (320 x 240)	CIF (320 x 240)	**2CIF (640 x 240)**	CIF (320 x 240)
Storage	12 days	12 days	12 days	12 days	**24 days**

Pixim's Digital Pixel System technology's compression advantage allows the user to decide how to best utilize the savings.

However you look at it, Pixim's Digital Pixel System technology delivers compelling benefits for video security systems. Cameras powered by this innovative technology not only are able to capture the crisp, accurate and true-to-life images required for effective security applications, but they also offer tangible financial benefits for their operators.

Thanks to the compression advantages of Pixim's Digital Pixel System technology, video security systems operators get the images they can trust, while reaping the transmission and storage benefits that derive from lower bit rates and smaller file sizes.

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