CleanCapture™ NDX-1260
Analog Image Processor

A No-Compromise Approach to Image Quality and Performance

CleanCapture™

NuCORE TECHNOLOGY

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The CleanCapture™ NDX-1260 Analog Image Processor
A No Compromise Approach to Image Quality and Performance

Until now, discussions surrounding digital imaging technology have concentrated simply on the number of mega-pixels. NuCORE Technology is now refocusing these discussions on the issue of image quality and level of detail that can be captured, with the introduction of its new CleanCapture™ Technology. NuCORE's CleanCapture Analog Image Processor dramatically minimizes color noise and digital artifacts in image capturing and processing to allow digital cameras to capture a truer representation of the actual subject being photographed.

State-of-the-art Analog Image Processor for Digital Still and Motion Video Applications

With the industry's highest throughput of 50 mega samples (pixels) per second (MSPS), the NDX-1260 provides analog signal conditioning and data pre-processing for CCD sensors to ensure that the follow-on Digital Image Processor can process very high quality pixel data without digital artifacts.

The IC integrates a low-noise, high-speed dual differential Correlated Double Sampler (CDS), a precision pixel-by-pixel Programmable Gain Amplifier (PGA), a precision 16-bit high-speed dual-pipeline Analog-to-Digital Converter (ADC), and advanced Black Level Auto-Calibration circuitry.

Unlike other 12-bit AFEs, the NDX-1260 processes the imager signal with greater than 14-bit resolution throughout. The 16-bit ADC output data is truncated to 12-bits just prior to the DBE Interface output.

Types of Noise and the Sources

There are many different types of noise sources that can cause degradation in the final image quality. Many camera companies spend a lot effort in their digital processing to minimize the visual distraction caused by noise. This approach is almost always a trade-off between the effect and image resolution or sharpness.

NuCORE's approach is to eliminate the source of the noise, so that neither the camera nor the user needs to spend time and effort to try to minimize the visual distraction caused by these noise sources, after the picture has been taken.

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Noise Type	Cause-Effect	NuCORE's Solution
Cross Color Noise	Caused by mixing of adjacent color pixels signals	Patented Balanced CDS that operates at 50 MSPS with full flushing of the CDS between each sample
False Color Noise	Generated when using a digital White Balance, which provides insufficient resolution in shadow areas	Analog White Balance in the AFE
Color Phase Noise	Shows up as color blotches in dark gray areas, where there was no color; can also show up as a shift in the original color	16-bit ADC and Analog White Balance so as to provide high resolution in dark areas of the picture
Digital Artifacts	Multiple causes; in an AFE it can be caused by having insufficient A/D resolution which causes step to be seen in smooth tonal areas	16-bit ADC to provide smooth tonal response and provide an effective 42 to 48 bits of Color Depth
Random Noise	Caused by shot noise in the CCD or insufficient SNR in the AFE	Use a low noise CDS, PGA, ADC and black level calibration so as not to add any noise
Fixed Pattern Noise	Caused by a measurement mismatch in the sampling of alternate pixels	Patented Balanced CDS that operates at 50 MSPS
Line noise	Shows up as horizontal streaks in dark areas of the image and is caused by the black level calibration using adjustment steps that are too large, and therefore visible	Use a ultra precision 16-bit digital black level calibration circuit

Below are sample comparison images which give a better visual understanding of these different types of noises. All comparison pictures were taken under the same exact conditions using a light box with a glass mounted transparency of one of the HDTV test images, called "food", from the industry standard ITE Standard Test Chart:

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Below are blow ups of the egg and bottle which show examples of noise and digital artifacts:

NDX-1260 Differentiator →	*The gray shaded areas should have smooth tonal change from light to dark, as is shown in the NuCORE image on the right. The image on the left has "false colors" where there were none. In addition there is roughness in the image, due to insufficient resolution (Bit-depth) in the shadow areas. Noise is also apparent.*

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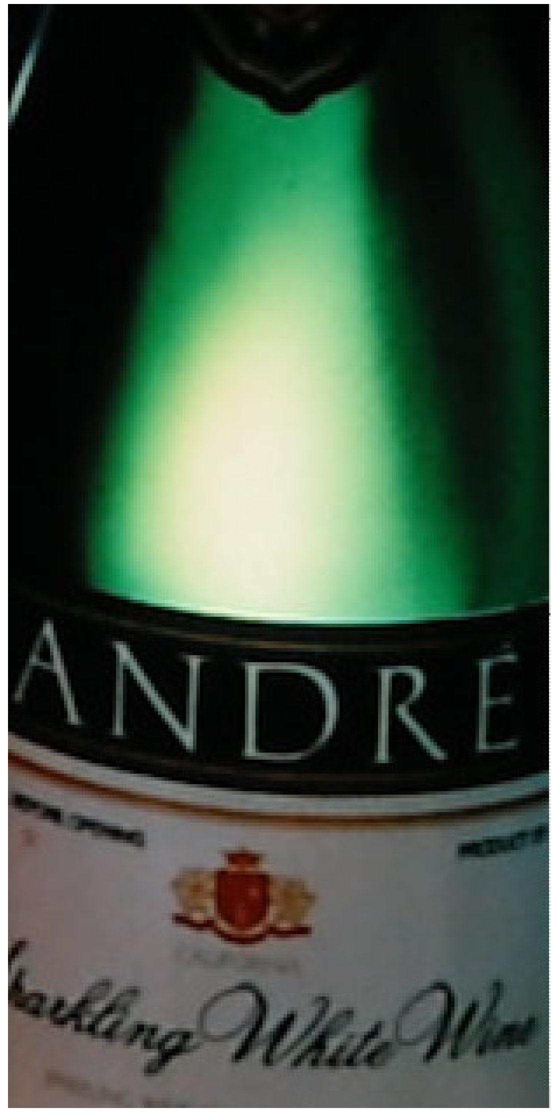

NDX-1260 Differentiator →	*The image on the left has "digital artifacts" in the form of "posterization". As the image transitions from light to dark, there are discrete changes in brightness instead of a smooth transition as is shown in the NuCORE image on the right. This is caused by insufficient resolution (bit-depth). Noise is also apparent.*

Below is a block diagram of the CleanCapture™ NDX-1260, showing all the major analog blocks of the image pipeline. NuCORE has gone the extra mile to provide a no compromise world class Analog Image Processor which will take digital still cameras and digital motion video cameras to the next level of image quality and performance.

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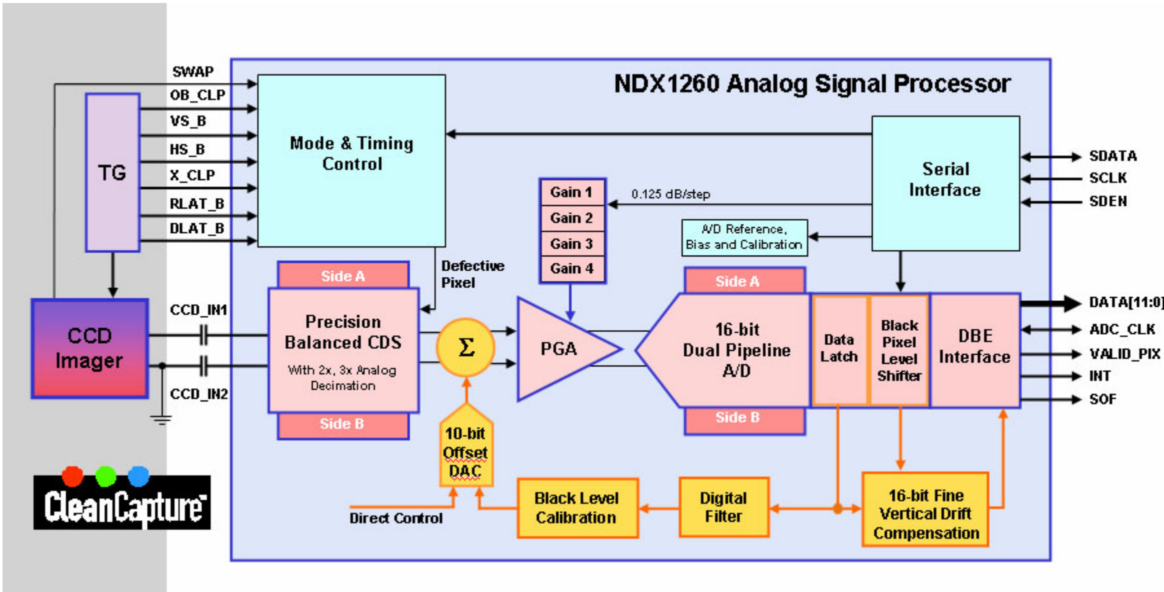

NDX-1260 Differentiator →	*NDX technology provides pixel-by-pixel Analog White Balance that operates at 50 mega samples per second and does not introduce digital artifacts due to its precision Balanced CDS and Balanced Dual-pipelined ADC.*

<u>Precision Balanced Correlated Differential Sampling (CDS)</u>

Today's CCD imagers are constantly sampling faster due to larger image sensor arrays of 5, 8 and 12 mega-pixel size. These CCDs require sampling pixels in the 30 to 50 MHz range. In order to precisely measure the analog signal at such a high sampling rate, NuCORE uses a **patented dual Balanced CDS sampling** scheme not found in other Analog Front Ends.

The CDS receives negative going video signals from a CCD image sensor, and subtracts the black level voltage from the CCD signal in order to remove common-mode signal noise and power supply noise.

This scheme uses two sets of precision sampling capacitors in order to permit more time for the samples to settle down to their actual value. One common amplifier is shared between the two sampling stages to insure that there is no mismatch in gain between the samples in order to avoid **"Fixed Pattern Noise"**, caused by a measurement mismatch in the sampling of alternate pixels. In addition, the samples are fully reset (discharged with the X_CLP pulse) between each measurement in order to insure that there is no **"Cross Color Noise"** due to mixing of adjacent color pixels signals.

Since the NDX-1260 was designed to meet all of its specifications at 50 MSPS, it provides even lower noise and higher performance at 30 MHz when compared to other Analog Front Ends (AFE).

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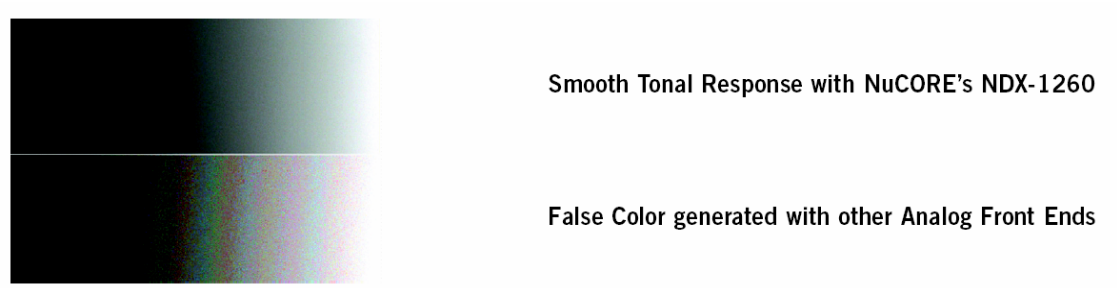
4-Channel Programmable Gain Amplifier (PGA) Permits Pixel-by-Pixel Color Correction for Maximizing Signal-to-Noise (SNR)

The Programmable Gain Amplifier has a 32dB range in 0.125dB steps. It is the second step in analog signal processing of the CCD signal.

The PGA has four independent gain channels to handle both RGB and CYMG color array patterns. Having four independent channels permits each pixel color to be precisely measured, since each channel has its own set of sampling and switched-capacitors circuits. The PGA gain can be changed on a per-pixel basis at 50 MPSP to provide Analog White Balance (AWB).

This avoids having to do digital white balance (DWB) in the DBE/ASIC/DSP and most importantly eliminates **false color noise** that would be generated when using a Digital White Balance. By independently amplifying each color with a different preset gain, each color pixel (RGB or CYMG) is able to fully utilize the maximum two volt (2V) Dynamic Range of the ADC, which in turn maximizes SNR.

Since Digital scaling is therefore avoided, this technique eliminates the **"Color Phase noise"** that is typically generated by Digital scaling circuits.



NDX-1260 Differentiator →	*Other Analog Front Ends (AFEs) are not able to handle the high speed needed to accurately do Pixel-by-Pixel gain adjustments. So analog White Balance can not be utilized. When White Balance is done totally in the digital domain false color artifacts are generated as can be seen in the lower image above.*

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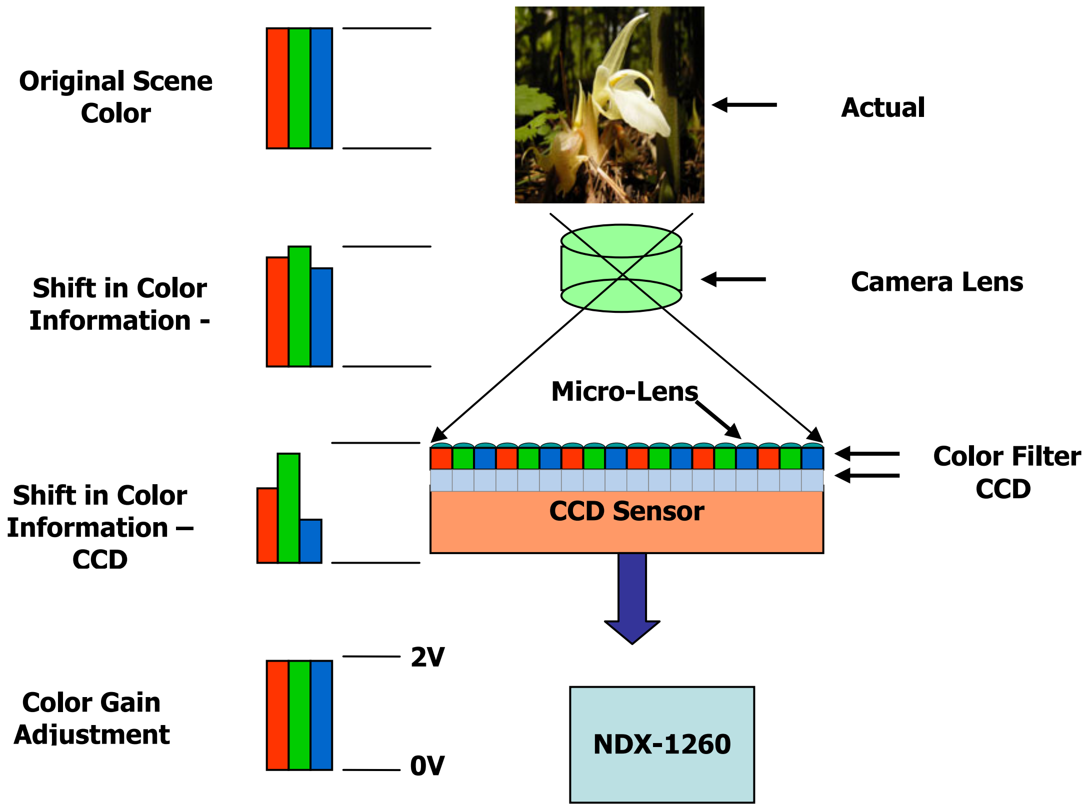


NDX-1260 Differentiator →	*With Pixel-by-Pixel Analog White Balance, each color pixel (RGB or CYMG) is individually amplified to 2V in order to utilize the full dynamic range of the ADC.*

<u>16-bit Analog to Digital Converter (ADC)</u>

The ADC is the third critical step in accurately digitizing the CCD signal without introducing digital artifacts, that could cause false color artifacts. The ADC input uses a 2V full-scale input to maximize dynamic range and therefore minimize noise.

The ADC is a 16-bit dual pipeline ADC and uses a similar approach as found the CDS section. Most importantly, it uses a dual balanced architecture, in which alternate samples are sampled and stored in two sets of precisely matched switched-capacitor circuits while using a common amplifier chain.

So once again, the ADC has twice the time to accurately measure the value of each pixel. (Other 12-bit AFEs may use a pipeline ADC, but not a dual balanced ADC). And since a common amplifier chain is used, gain and offset matching of alternate pixel samples is assured. And of course when the ADC is operated at only 30 MSPS the precision increases even more. Since a 16-bit ADC is used, with the output truncated (cut-off) to 12-bits just prior to the output, the chip provides Improved Differential Non-linearity (DNL). Typically DNL is: 0.2 LSB versus 0.5 to 1.0 LSB for other 12-bit ADC.

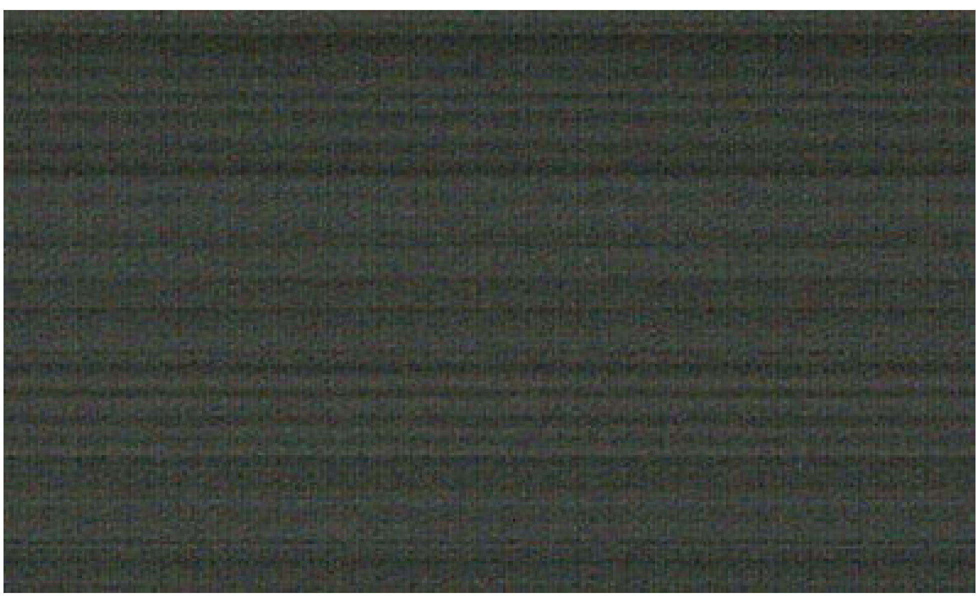
If only lower bits of data are needed for an ASIC or DSP, the chip has a programmable 8, 10, or 12-bit wide output data bus for 8, 10, and 12-bit image processing applications.

Analog-Digital Black Level Calibration

The advanced Black Level Auto-Calibration uses both an analog feedback loop and a precision digital feedback loop to compensate for CCD Black-level vertical voltage drifts. The Analog loop cancels out the black level with 0.125 steps by measuring the optical black pixels on the top of the CCD array. The optical black pixels at the end of each line may also be used to measure and cancel out the black signal from the CCD on a line-by-line basis.

There is also an ultra fine digital calibration loop after the ADC with 16-bit resolution (65,536 steps), to eliminate **line noise**, which is caused if the steps, which cancel out the CCD black level, are too large. Below is an image that shows line noise from other AFEs, which do not have a well working precision Black Level Calibration circuit.

There are essentially four black level calibration loops, one for each of the four color channels in the PGA block.



NDX-1260 Differentiator →	*Line noise is caused if the steps, which cancel out the CCD black level, are too large. The image above shows typical line noise from other AFEs, which do not have a well working precision Black Level Calibration circuit. The effect shows up as horizontal bands with different black levels.*

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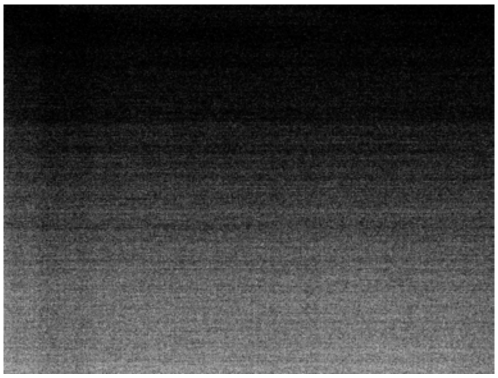
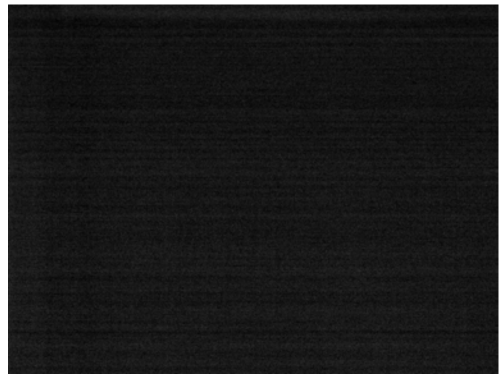
The function of the Black Level Calibration circuit is to remove the black level of each pixel, so when there is a black image it is uniformly black except for the random noise from the CCD. Black Level Vertical Drift is caused by the black level changing (drifting) as the CCD is scanned from the top to the bottom. The image on the left has no vertical drift compensation and the one on the right is produced by the NDX-1260 with vertical drift compensation.





NDX-1260 Differentiator →	*The NDX-1260 vertical drift compensation circuit eliminates vertical drifting, as seen in the above right image. Vertical drifting shows up as a black level difference from the top to the bottom as is demonstrated in the above left image.*

Serial Interface

The CDS, PGA, ADC, Black Level Calibration, and timing circuits are all controlled through a standard 3-wire serial interface to program color patterns, sensor size and optimized parameters for power dissipation versus pixel speed. The sensor pixel size registers eliminate the need to generate unique timing pulses for each CCD. The serial port also permits recalibration of the ADC at any time the camera system determines it is necessary.

Analog Resizing (Decimation)

Image resizing (2X or 3X Analog horizontal decimation) for preview mode is performed in the analog domain, as part of the CDS, to remove unnecessary pixel data and to reduce digital data processing load. This mode also provides reduced power consumption, since less time is needed to process an image.

This patented technique (a NuCORE exclusive) uses capacitors to average two or three samples in a row. Therefore, only one sample, instead of two or three, needs to be digitized. This technique reduces power consumption by operating the AFE and DBE at 1/2 or 1/3 the normal speed, during preview modes or Video mode with Mega-pixel or HDTV Imagers. The additional benefit is that the digital image throughput is increased by two times or three times, respectively.

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Defective (Bad) Pixel Swapping

When the NDX-1260 is informed that a defective or bad pixel is about to be sampled, it provides an analog average of the pixel before and after the defective pixel. This provides a simple real-time method of replacing defective pixels, without taking up the precious time in the Digital Image Processor to calculate the value of the pixel to be replaced.

NDX-1260 Differentiator →	*NuCORE permits replacing defective or bad pixels in the analog domain so as to eliminate doing the calculations in the digital domain, saving digital processing speed and power.*

Summary

The NDX-1260 precision analog image processor provides superior image quality with smaller file sizes, when using JPEG or MJPEG compression, due to a dramatic reduction in AFE-introduced digitizing artifacts.

When combined with a sensor and a digital image processor, such as the CleanCapture™ SiP-1270, a custom ASIC or DSP, the NDX-1260 is a complete, high-performance analog image processing solution that provides the highest image quality from an AFE, with dramatically reduced file sizes (key for still and motion digital image data storage and data transmission).

The IC's very low power consumption, superior image quality, and high sampling rate are achieved with NuCORE's proprietary NDX Technology™, which makes this solution well-suited for a wide range of still and motion video applications.