

IP Video Rendering Basics

CohuHD™ offers a broad line of High Definition network based cameras, positioning systems and VMS solutions designed for the performance requirements associated with critical infrastructure applications. CohuHD Helios products utilize the latest HD imaging technology, including H.264 and MJPEG codec standards to produce the highest quality of video in the market.

When poor quality video is being viewed on a PC monitor, the first accused of being the source is the IP camera. Frequently, the source of this poor video quality can be attributed to the computer system being used to display the video.

A core benefit of CohuHD cameras is the ability to use non-proprietary, off-the-shelf PC's and network attached storage equipment. The result of this benefit allows consumers or designers to use existing computers or purchase the latest computer on sale for displaying their IP video needs. This is the beauty of being able to use non-proprietary hardware!

However, in order to effectively take advantage of this benefit, you need to understand what performance level you can expect from a given computer system, or be capable of specifying a computer system that will meet your High Definition video display requirements.

This white paper presents an overview of the key elements and the video processing steps a computer uses to render video onto a display. In addition, you will gain an understanding and appreciation for the amount of data that is being processed within the PC in order to display streamin video. Using the results of this his knowledge, you will be able to specify and select an appropriate PC that can efficiently display a desired amount of video camera streams using a scientific approach.

Video Processing Fundamentals on a PC

Video decoding and rendering are the most challenging aspects of any live video display system. It is a very computationally intensive process and requires high performance equipment. With all the choices of video rendering and decoding hardware and software available, some basic questions should be answered before selecting the video processing system. How many cameras do I need to view simultaneously?

What are the camera resolution(s)? What is the data rate the cameras will be streaming at? What is the encoding format? What is my budget? Each scenario has a different set of video requirements. Answering these basic questions before selecting the system will help to prevent potential problems, including issues with decoding and rendering.

This paper will discuss a number of hardware and software variables to consider in order to successfully render and decode video through the system and have high quality images on the display.

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Video Processing on a PC

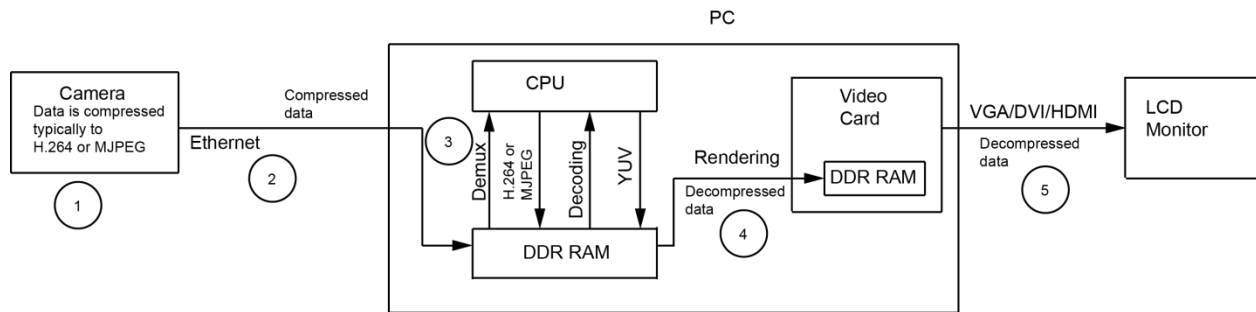


Figure 1

Figure 1 is a block diagram showing video data transmission from the camera to the monitor.

Step one: Digital video streams, especially high definition (HD) resolution, require a large amount of data to be transmitted from the camera system to the video processing system. In order to reduce the amount of data to be transmitted through the network the video is encoded into transmission format. In IP camera systems, encoding (compression) happens in the camera or an external video encoder. Typically H.264 or MPEG codecs are used.

Step two: Compressed video is transmitted through the network. (In this paper the network process is not addressed.) The video processing system receives data in a compressed format.

Step three: Video data travels between the CPU and the DDR RAM. The CPU is responsible for complex computations, including video decompression, rendering, and decoding video into YUV color space. The DDR RAM is used as a fast storage facility.

Step four: Decompressed YUV data is rendered from the PC's DDR RAM to the video card's DDR RAM.

Step five: Decompressed video files from the video card are transmitted to the display.

Key Elements Required for Processing Video on a PC

As Figure 1 shows, the **computer hardware components** that affect rendering and decoding processes the most are:

- CPU processor
- DDR RAM
- Video card

CPU (Central Processing Unit): The CPU interprets and executes instructions and data contained in software programs. Performance of a PC system is partially determined by the processor. As seen in Figure 1, the CPU computes data, including demultiplexing and decoding the video files into YUV color space.

Note: Multiplexing is the process of combining multiple data streams for transition over a shared data stream or a single data channel. Demultiplexing performs the reverse process of splitting a combined stream into the original data streams.

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DDR RAM: RAM plays a very important part in rendering and decompressing. The data that the computer receives from a camera system has typically been compressed to MJPEG or H.264 formats. The DDR RAM is responsible for storage of the data while the CPU transforms the data from a network stream to the YUV video files. The process of demultiplexing and decoding is very data-intensive and requires a lot of resources. Thus, having a faster DDR RAM speed is an important factor in the video display process.

Video Card (also known as graphics accelerator card or display adapter): The video card is an expansion card that allows the computer to send graphics information to a video display device. It is designed to produce the screen images and is responsible for heavy-duty operations, such as rendering and video processing. As seen in Figure 1, the decompressed data from the DDR RAM must be transferred to the video card. The process of transferring decoded (decompressed) video data from the PC's DDR RAM to the video card is called **rendering**. The video card then transforms the YUV video data into a format that is compatible with standard monitors such as VGA, DVI or HDMI.

Other hardware variables that affect rendering are:

- Motherboard
- Network card

Motherboard: The motherboard is hardware to which the CPU, RAM, and video card are connected and through which they communicate. The CPU, RAM and video card must be compatible with the motherboard.

Network interface card (NIC): This acts as the interface between a network cable and a computer. The purpose of the network interface card is to send and receive data on the network. When you choose a NIC it is necessary to know whether it is compatible with your motherboard and how much bandwidth it has. It has become common to have a NIC rated at 1000 Mbps. In a system with multiple cameras and a single NIC, it must be able to handle the total bandwidth of all cameras.

Bandwidth: This is the amount of data that can be transmitted in a fixed amount of time. For network streaming the bandwidth is typically expressed in bps (bits per second). For operating systems the bandwidth is typically expressed in Bps (Bytes per second).

Bandwidth Measurements:

bps – bits per second	Bps - Bytes per second	8 bps = 1 Bps
kbps – kilobits per second	kBps – kiloBytes per second	
Mbps – Megabits per second	MBps – MegaBytes per second	

Bandwidth values can be calculated using the binary system or decimal system.

Binary system:	Decimal system:
1kBps = 1024Bps	1kBps = 1000Bps
1MBps = 1024kBps	1MBps = 1000kBps
1GBps = 1024MBps	1GBps = 1000MBps

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Software variables that affect rendering include:

Codec: A codec is a computer program or a hardware item (such as an IC) capable of encoding and decoding a digital data stream. More precisely, a video compression codec executes an algorithm that carries out compression or decompression of the video images. It reduces the video stream size or recovers the original data. Several codecs can be implemented in the same device. Codecs are defined by standards such as MPEG-1, MPEG-4, MJPEG, H.263, H.264, and Motion JPEG 2000. Different codec standards were created to meet different criteria.

Compression Codecs

Two of the most commonly used formats for the compression and transmission of high definition video are H.264 and MJPEG. CohuHD’s Helios cameras support both of these standards.

H.264 standard vs MJPEG standard:

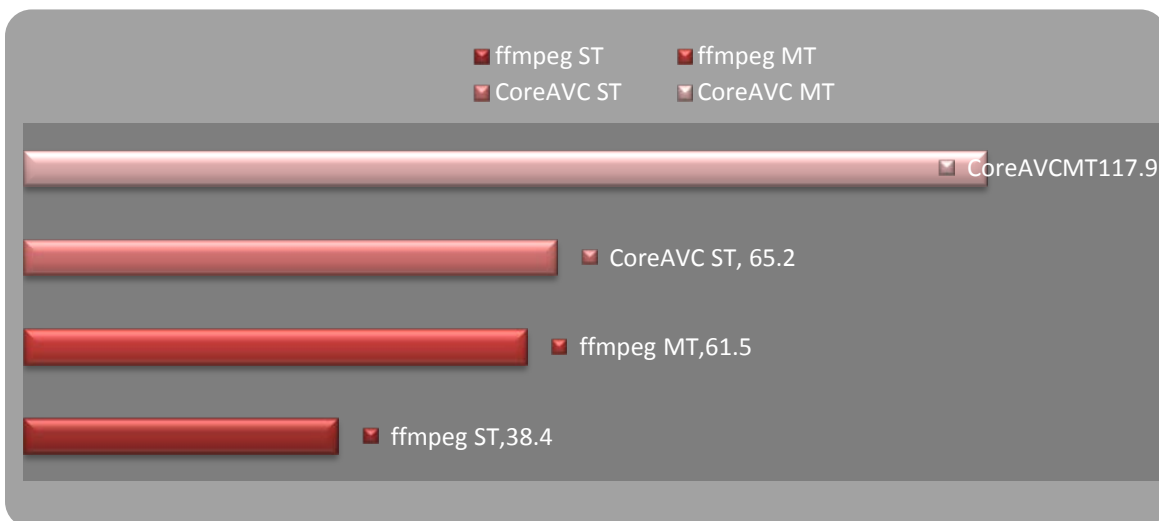
The H.264 standard has a higher compression ratio and reduced storage requirements, while preserving the image quality. It is designed for real-time video and supports up to 120 fps (frames per second). On the other hand, decompression in the PC requires more resources, resulting in fewer video streams than MJPEG.

The MJPEG standard is an unlicensed standard available on all PCs. It can support a large number of cameras. Image quality is high and consistent. It consumes less computer resources than H.264. On the other hand, it has large bandwidth and storage requirements, which can be a great disadvantage.

Decompression Codecs

- **FFmpeg** library vs **CoreAVC** codec for decoding H.264:
- FFmpeg is an open source library and contains many codecs.
- CoreAVC is a closed source, proprietary codec for decoding H.264 video. It is one of the best at supporting the NVIDIA® Cuda parallel processing pipeline and Intel’s multicore architecture.

Chart 1. Decompression speeds (fps) of H.264 video, 720p stream



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As shown in Chart 1 the decompression speed of CoreAVC ST (single-threaded) and CoreAVC MT (multi-threaded) were compared with ffmpeg MT and ST. The test was conducted on a PC with Intel Core™ 2 Quad processor. In the test, CoreAVC significantly outperformed ffmpeg in both multi- threaded and single-threaded applications.

For more information on the test please refer to <http://keyj.emphy.de/h264-benchmark-part2/>

YUV color space: Digital video is often encoded in YUV color space. (The accurate name for the color space used in digital broadcast is YCrCb. YUV is often used as a general term.) The term YUV refers to a family of color spaces, all of which encode brightness information (Y) separately from color information (U and V). Since the human eye is less sensitive to changes in hue than changes in brightness, an image can have less chroma information (U and V) than luma information (Y) without sacrificing the quality of the image. The YUV requires less data bandwidth than RGB signals. Most video codec formats, including MPEG and H.264, use YUV color space.

For more information on the test please refer to <http://en.wikipedia.org/wiki/YUV>

Determining How Much Video Data Needs to be Processed on a PC

Table 1 compares the amount of data transmitted from one camera at three different H.264 encoded video resolutions (1080p, 720p, and standard resolution D1). For 1080p resolution the compressed video enters the computer with typical network streaming bitrates of 8 Mbits per second (1 MByte per second). After decompression, data moves from the DDR RAM to the video card at 6 MBytes per frame

and 30 frames per second resulting in 180 MBytes of video being transferred every second. If 10 cameras are sending data to one PC, 1.8 GBytes of data will need to be moved each second.

Table 1 also shows that within the computer six times more data must be transferred for 1080p resolution than for standard resolution D1. The price to be paid for having higher resolution is an increase in the amount of data that must be transferred.

Table 1. Amount of data being transmitted

Format	Network	Computer	
	Average transfer bitrate between network and NIC	Average transfer data size between DDR RAM and video card	
		Decompressed video data size per video frame	Data size at 30 frames per second
1080p	8 Mbps (1MBps)	6 MB	180 MB
720p	4 Mbps (0.5MBps)	3.6 MB	110 MB
D1	2 Mbps (0.25 MBps)	1MB	30 MB

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Calculating the Bandwidth Required to Render an Image on a PC

To calculate the transfer bitrate between DDR RAM and graphics card the following information is needed:

- Image resolution
- YUV format used
- Frame rate

Width x Height = Resolution (in pixels)

4:2:2 YUV format: 2 Bytes of data are required to render 1 pixel

Since the reference website listed below is using the decimal system for calculation, the following calculations are done in the decimal system as well: 1 Byte per second = 10^{-9} GigaByte per second.

1Byte = 8 bits

In the following example a video stream from each camera of 720p resolution at 30 frames per second and 4:2:2 YUV format is used.

720p: 720x1280 = 921,600 pixels per frame

4:2:2 YUV: Two Bytes of data are required to render one pixel: 2 Bytes per pixel

921,600 pixel per frame x 2 Bytes per pixel=1,843,200 Bytes per frame

30 frames per second: 1,843,200 Bytes per frame x 30 frames per second = 55,296,000 Bytes per second

55,296,000 Bps = 0.055296 GBps

Each camera will require 0.055 GBps of bandwidth for normal transmission. However, the images are first written to and read from the RAM. This will double the bandwidth required. 0.055296 GBps x 2 = 0.11184 GBps

Therefore, one camera will require a bandwidth of 0.11184 GigaBytes per second or 0.8947 Gigabits per second. Each additional camera will require the same.

Table 2. Transfer Rate between DDR RAM and GPU

Number of cameras	Gigabits per second	GigaBytes per second
1 Camera	0.8947 Gbps	0.1118 GBps
8 Cameras	7.157 Gbps	0.8946 GBps
16 Cameras	14.31 Gbps	1.788 GBps
19 Cameras	16.99 Gbps	2.12 GBps

The website http://en.wikipedia.org/wiki/List_of_device_bit_rates provides a list of device bitrates to help choose a RAM module that will satisfy the necessary DDR RAM rate. Table 3 is an extract from this website and represents RAM module types. The transfer rate of the module type chosen must exceed the transfer rate from Table 2, which shows transfer rates required for the numbers of cameras to be used.

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Table 3. Random Access Memory

Module type	Chip Type	Memory clock	Bus speed	Transfer rate	Transfer rate
FPM DRAM	45 ns	22 MHz	0.177 GTps	1.416 Gbps	177 MBps
PC-133 SDR SDRAM	7/7.5 ns	133 MHz	0.133 GTps	8.528 Gbps	1.066 GBps
RIMM-2100 RDRAM	PC-700	533 MHz	1.066 GTps	17.034 Gbps	2.133 GBps
PC-3700 DDR SDRAM	DDR-466	233 MHz	0.466 GTps	29.864 Gbps	3.733 GBps

How Many Videos Can be Processed on One Computer?

Table 4 shows how to interpret computer performance analysis to determine CPU and GPU utilization. The rate of utilization helps answer the question of how many cameras can be run on a particular computer.

For such analyses two utilities can be used for monitoring computer performance:

GPU-Z 0.7.0. This free utility needs to be installed. For installation use <http://www.techpowerup.com/downloads/SysInfo/GPU-Z/>. The utility is designed to provide information about hardware, including GPU (video card).

Note: GPU-Z supports NVIDIA and ATI cards.

The Resource Monitor. The utility is bonded in Windows 7/Vista. In Windows 7: Start>All Programs>Accessories>System Tools>Resource Monitor.

Tests using multiple cameras were conducted at CohuHD to determine CPU and GPU utilization rates. The results are shown in Table 4 and Screenshots 1 and 2.

The following hardware specifications and video stream parameters were used in the tests:

Resolution: 720p

Compression Encoding: H.264 (main profile)

Bitrate: Network band width used between a camera and video processing computer system – 4 Mbps. See Table 1.

CPU: Intel i7-950@3.07GHz

DDR RAM: 6GB DDR3@1066MHz

Video Card: NVIDIA® GeForce® GTX 470 with 133.9 GBps memory bandwidth

Operating system: Windows 7 x64

VLC Media Player: ver. 2.0.0

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Table 4. CPU and GPU Utilization

	CPU Utilization	GPU (Video Card) Utilization
One Camera	Average 4%	Average 0.5%
Four Cameras	Average 14%	Average 7.3%
Eight Cameras	Average 28%	Average 16%
12 Cameras	Average 42%	Average 25%
16 Cameras	Average 75%	Average 33%
19 Cameras	Average 90 %	Average 37%

Consider the test results when 19 cameras were streaming videos to the monitor using the VLC media player. In this test up to 90% of CPU resources and 37% of GPU resources were used. To guarantee a stable connection and good viewing quality utilization percentage of hardware cannot be 100%. The utilization percentage depends on several factors, including the computer application that is used for video streaming, other open programs the computer is running, and OS background tasks and services. The effect of these factors is shown in Table 4 by the utilization of 90% of CPU when testing 19 cameras. In real life some computer resources must be preserved for peak performances.

Choosing a PC that can render a specific amount of video

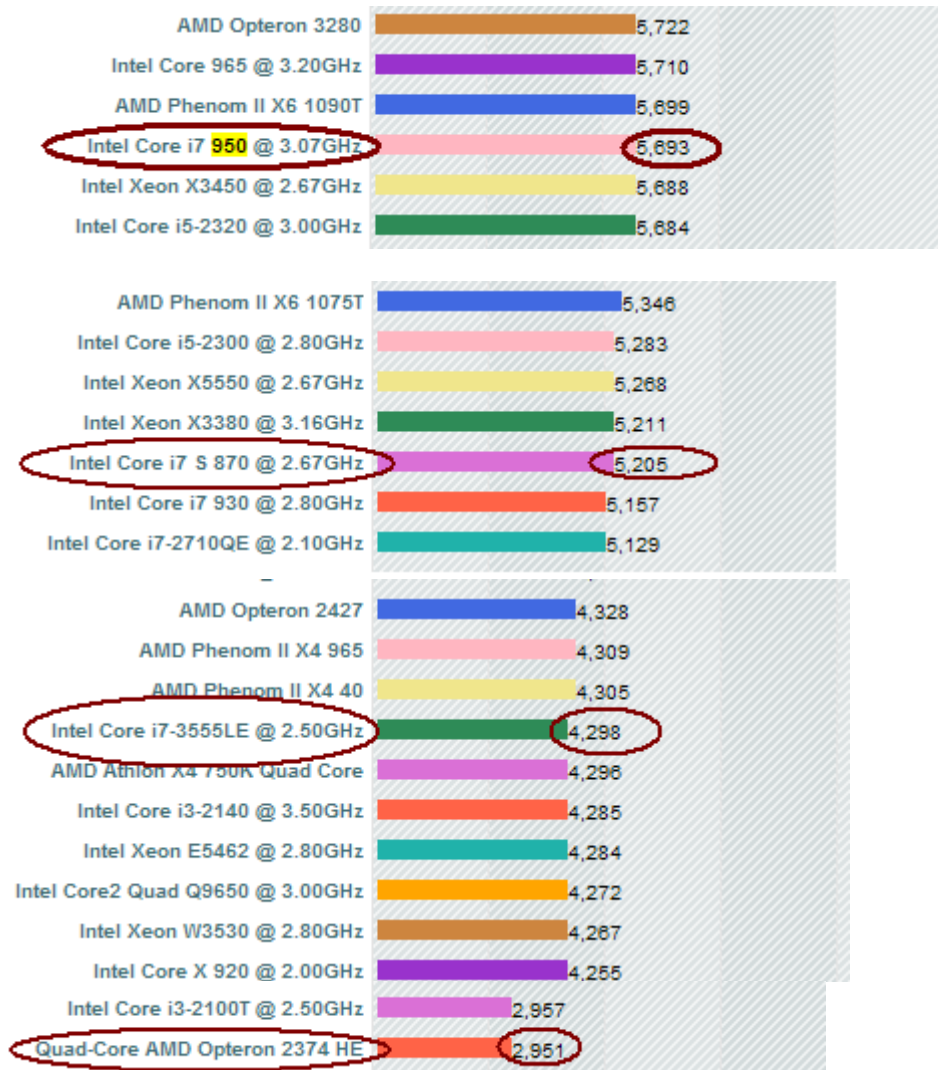
Choosing a CPU

The test described on page 6 proves that on an Intel [i7-950@3.07GHz](http://www.cpubenchmark.net/high_end_cpus.html) CPU a maximum of 19 videos with the specified parameters can be rendered. Website http://www.cpubenchmark.net/high_end_cpus.html (CPU Benchmarks>High End CPU Chart) shows performance scores for High End CPUs. See Screenshot 1. Knowing the scores will help identify a CPU capable of rendering video for the total number of cameras to be used. According to the Screenshot 1 Intel i7-950 was rated at a score of 5,693. This number was computed by using 100% of the CPU resources. Using the test results for CPU utilization shown in Table 4, a calculation can be made to find a card capable of rendering the desired number of video streams. See Screenshot 1 and Table 5.

Example: One camera running on a CPU with a performance score of 5,693 at a 4% (0.04) utilization rate (Table 4) will require a utilization performance score of at least 228.

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Screenshot 1. High End CPU Performance Score



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Table 5. Optimum Processor Recommendations

Number of cameras	Minimum CPU Performance Score Required	Suggested Optimum Choice of CPU (Score)*
1	$5,693 \times (.04) = 228$	Quad-Core AMD Opteron 2374HE (2,951)
4	$5,693 \times (0.14) = 797$	Quad-Core AMD Opteron 2374HE (2,951)
8	$5,693 \times (0.28) = 1,594$	Quad-Core AMD Opteron 2374HE (2,951)
12	$5,693 \times (0.42) = 2,391$	Quad-Core AMD Opteron 2374HE (2,951)
16	$5,693 \times (0.75) = 4,270$	Intel Core i7-3555LE @ 2.5GHz (4298)
19	$5,693 \times (0.9) = 5,124$	Intel Core i7 S 870 @ 2.67 GHz (5205)

* The lowest rated processor on Screenshot 1 was suggested as a best choice even though its capacity is far in excess of the required performance score. When a higher rated CPU is required for multiple cameras, it is recommended that a CPU listed several lines higher on a screenshot be chosen.

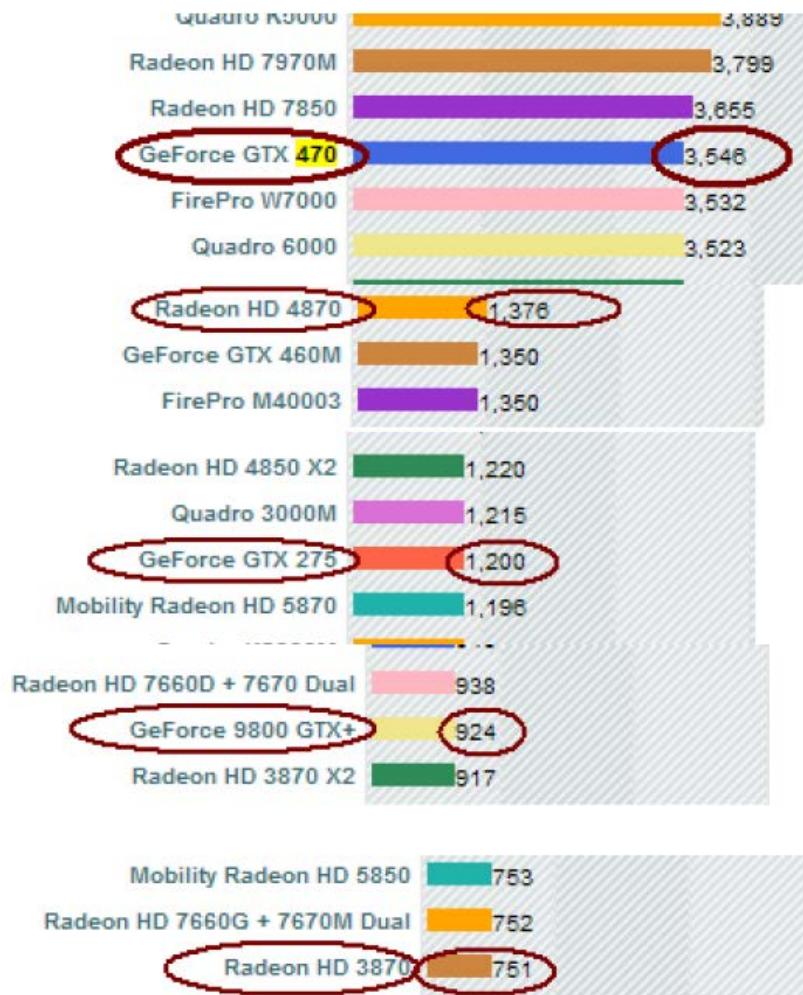
Choosing a Video Card

Website http://www.videocardbenchmark.net/high_end_gpus.html (Video card Benchmarks tab>High End Video Card Chart) provides a performance score of 3,546 for the video card NVIDIA GeForce GTX 470 used in the test. The number 3,546 was computed by using 100% of the GPU resources. Using the test results for GPU utilization shown in Table 4, a calculation can be made to find a card capable of rendering the desired number of video streams. See Screenshot 2 and Table 6.

Example: One camera running on a video card with a performance score 3,546 at 0.5% (0.005) utilization rate (Table 4) will require a utilization performance score of at least 18.

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Screenshot 2. Video Card Performance Score



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Table 6. Optimum Video Card Recommendations

Number of cameras	Minimum Video Card Performance Score Required	Suggested Optimum Choice of Video Card (Score)*
1	$3,546 \times (0.005) = 18$	Radeon HD 3870 (751)
4	$3,546 \times (0.073) = 259$	Radeon HD 3870 (751)
8	$3,546 \times (0.16) = 567$	Radeon HD 3870 (751)
12	$3,546 \times (0.25) = 887$	GeForce 9800 GTX+ (924)
16	$3,546 \times (.33) = 1170$	GeForce GTX 275 (1200)
19	$3,546 \times (0.37) = 1312$	Radeon HD 4870 (1376)

* The lowest rated video card on Screenshot 2 was suggested as a best choice even though its capacity is far in excess of the required performance score. When a higher rated video card is required for multiple cameras, it is recommended that a video card listed several lines higher on Screenshot 2 be chosen.

Video Processing Bottlenecks

The test described in Table 4 shows that CPU utilization was 90% when 19 video streams were being processed on the computer. The video card utilization was only 37%. This shows that in this test configuration the CPU becomes a bottleneck if the number of cameras is increased.

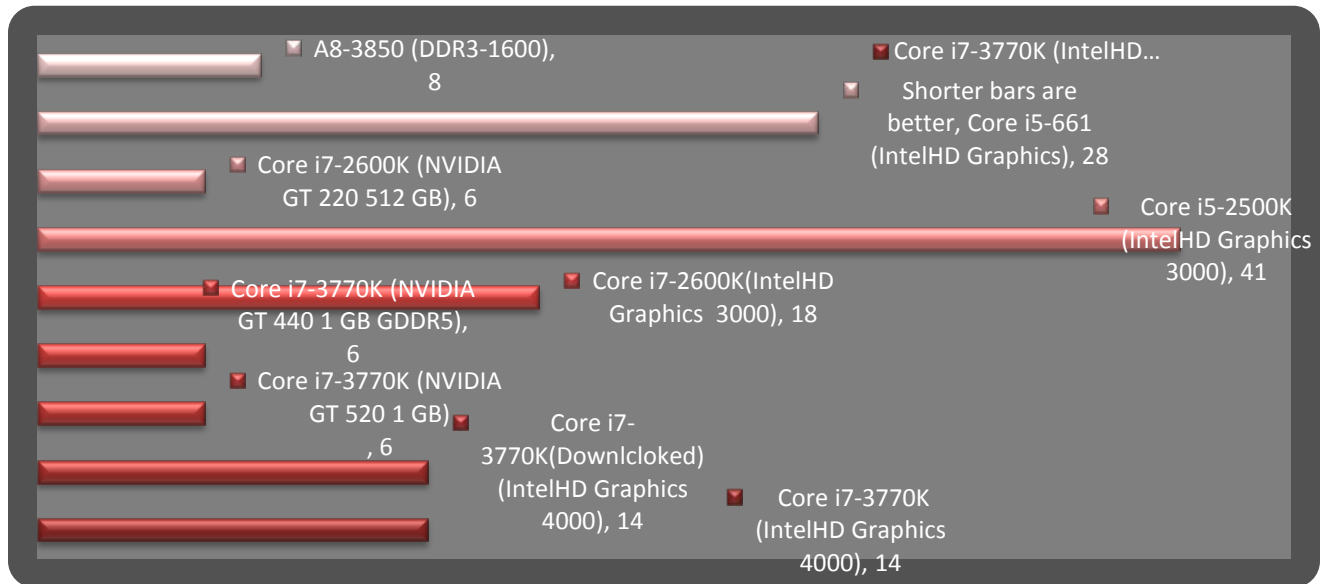
Computer Optimization

The amount of data the computer must process determines the hardware requirements. In order to get the best decoding and rendering performance on a PC, all hardware components must work in coordination. If one lags, it becomes the bottleneck that limits the overall performance. It is difficult to compare the performance of various computer systems simply by looking at their specifications. Therefore, tests were developed that allow a comparison of different systems, and benchmarks were designed to mimic a particular type of workload on components and systems as a whole. As shown in Chart 2 the combination of the CPU Core i7-3770K and the NVIDIA GT 520 1GB video card uses only 6% of computer resources, while the combination of CPU Core i5-2500K with video card Intel HD Graphics 3000 uses 41% of computer resources.

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Chart 2. Utilization Scores for CPU and GPU Combinations

The following is the link to the benchmarks that help in choosing the best components for optimum rendering and decoding:



<http://www.hardwarezone.com.sg/feature-ivy-bridge-3rd-gen-intel-hd-graphics-does-it-really-matter/performance-and-conclusion>

Summary

Rendering and decoding are two processes in the PC that require the most computer resources. CPU, DDR RAM and GPU (video card) are the core components that perform video processing on the PC. In order to have high quality video on a display, all hardware components must not only have sufficient bandwidth to process video files, but also must work in coordination with each other. Higher video resolutions require greater amounts of data to be processed. An increase in the number of cameras in the system increases the data that needs to be transferred through a PC, and ultimately increases hardware requirements.

About CohuHD

CohuHD is a leading manufacturer of high-definition video systems designed to satisfy the demanding performance requirements of critical infrastructure applications. CohuHD solutions integrate the latest high-definition video imaging and compression technologies into our ruggedized camera products. CohuHD is a high-value solutions provider for monitoring in the most critical, sensitive environments. We focus on providing the most reliable, rugged, outdoor PTZ cameras on the market. For more than 50 years, we have manufactured in the U.S.A. the most reliable, rugged video cameras available. For more information on CohuHD’s products, please visit www.cohuHD.com. Follow us on [youtube.com/cohuhd](https://www.youtube.com/cohuhd), twitter.com/cohuhd, [linkedin/company/cohuhd](https://www.linkedin.com/company/cohuhd), and [facebook.com/cohuhd](https://www.facebook.com/cohuhd).