Picture Quality Measurement for Video Applications

Objective versus Subjective picture quality measurements are vital to efficient and repeatable video processing design and evaluation.

Picture Quality Any Time, Any Place

In the past, viewers were constrained to watch television in front of a receiver in their home. Today, people watch video at any time and in any place. A viewer can now browse video on their desktop PC, or watch a movie outdoors on a mobile handheld device, or view HDTV (High Definition Television) in their own home theater system or at Digital Cinemas within a well controlled viewing environment.

Powered by recent advances in video compression technology, the number of ways of delivering content to the viewers is increasing. The video engineer is faced with a challenging environment and is required to maximize the picture quality for each viewing condition across a wide variety of content - while maintaining a key differentiator of quality of service to the end viewer.

This application note focuses on the issues video engineers face when developing and/or evaluating an algorithm, device or video signal path; and the objective picture quality measurement solutions Tektronix® provides to support those requirements.

Tektronix

Enabling Innovation

Picture Quality Measurement For Video Applications
▶ Application Note

Key Concepts

- ▶ Subjective video evaluation is costly, slow and does not produce repeatable results.

- ▶ Automated test equipment can now perform objective tests and accurately track the results.

- ▶ The availability of modern testing technology leads to more efficient design and evaluation of semi-conductors, compression technologies, set-top boxes…even the whole video chain from content providers to consumers.

Video Quality Measurement Standards

The International Standard for measurement of subjective picture quality is ITU-R BT 500. This standard defines a variety of conditions to measure the picture quality of an image, such as:

- ▶ Display type

- ▶ Viewing distance

- ▶ Viewing environment

- ▶ Viewer's characteristics

These categories and others have been chosen to produce consistent results over multiple viewer trials. The standard has also defined specific methods for providing information about the picture quality of an image. However, the standard, as it exists today, does not cover emerging developments in new formats - such as repurposing applications from very high resolution video (such as D-Cinema master formats) down to much lower resolution video for mobile reception, changing the display from CRT to LCD and so on. Designers have to focus on picture quality under a variety of conditions in addition to those defined in the standard. Changes due to each of these viewing conditions can take a very long time for an engineer to evaluate subjectively.

When a video design engineer starts the initial design of any video processing engine, they have to consider the target application and specifications upon which their design will be based. Once the initial beta version has evolved, the designer will start debugging the video processing architecture to ensure that it meets the design specification criteria. Debugging leads to improving and optimizing for specific needs.

Similarly, engineers in charge of a video path (like from a head-end to a set-top box) must consider the effect of all processing and compression/decompression on the viewing experience…while maximizing bandwidth and costs. Other applications include Studios who must ensure their content is delivered as promised.

Whether designing or evaluating system components, engineers must consider changes that can be made to improve the picture quality and to optimize the video output in order to fulfill their particular requirements. Picture quality testing and documentation is required at all stages.

Visual Testing Methodology

Historically, human testing has been performed to subjectively verify the picture quality at the output of each device. These picture quality evaluations would be repeated at each stage of the development process.

However, there are known deficiencies in subjective picture quality testing done by a human viewer. First, the results are not objective. Different people will perceive overall picture quality differently. In addition, subjective testing is not repeatable. For instance the viewers may notice more artifacts in the image earlier in the morning as compared to what they would notice late at night. There are issues of language and description that make it difficult to communicate with the others about what is most important to the quality of the image.

Using subjective methods, differing evaluations can result - even if the same person had evaluated the same material. Recording all these results, to track improvements, has also not been an exact science…until now.

The ITU-R BT.500 Standard mitigated these problems somewhat by using an average of the ratings from many people, often around two dozen. Their data is averaged into a score called Differential Mean Opinion Score (DMOS) However, for some applications, when an even larger number of viewers are required to obtain reliable, repeatable and verifiable quality data, the required time, expense and use of resources is often impractical.
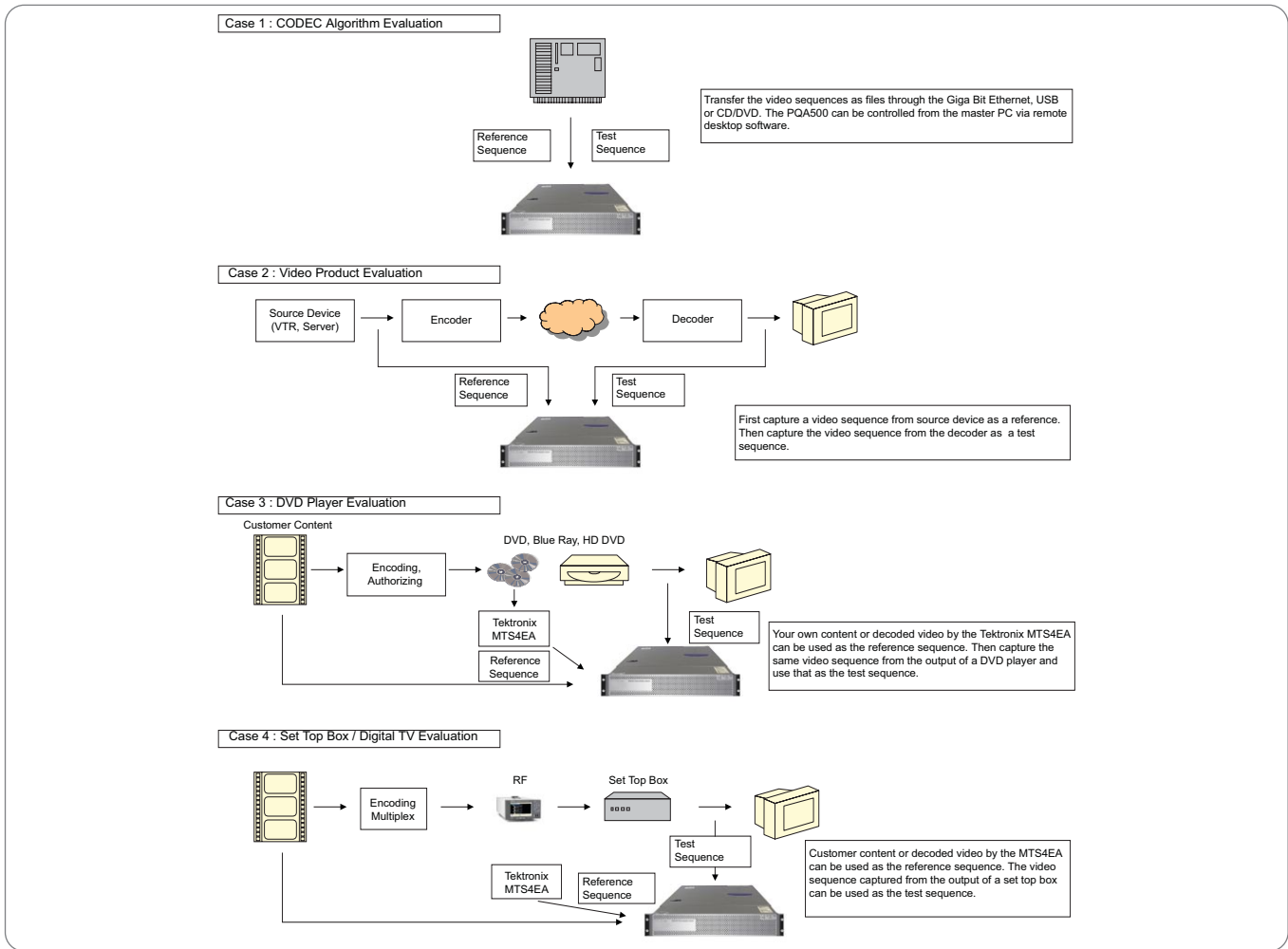
▶ **Drawing 1.** *Tektronix PQA500 Sample Test Cases.*

So, it is too costly to have these measurements done by groups of people repeatedly at each stage of the development process. Yet practical, repeatable and objective picture quality measurements are necessary in the design of video processing systems.

Objective versus Subjective Analysis

The Tektronix PQA500, based on the Emmy Award winning PQA200/300, is the latest-generation instrument providing a suite of repeatable, objective quality measurements that closely correspond with the human visual system. These measurements provide valuable information to engineers working to optimize video compression and recovery, and for those who must design and maintain a level of common carrier and distribution transmission service for content creators and viewers.

In essence, the PQA500 compares a reference frame (taken at the input of the device(s) under test) with a compressed, impaired or processed version of the reference (usually taken at the output of the device). It is equally suited to verify and troubleshoot any block of the video chain because it is video agnostic: Any visible differences between video in and out from any processing components can be quantified and assessed for video quality degradation. 1080i, 720p, 525, 625, CIF, etc. can all be compared seamlessly. Drawing 1 shows the setup for several test cases.

The balance of this application note will discuss some specific picture quality measurements and how and when they may be used.

Picture Quality Measurement For Video Applications
▶ Application Note

File Format	Script Command	File Extension	W, H, Frame rate	Frame Structure Option
CbYCrY (601-422)	CbYCrY_8_8	.yuv	Need to setup	Non Interlace, Field One First, Field 2 First, Planar
YCbYCr (422)	YCbYCr_8_8	.yuv	Need to setup	Non Interlace, Field One First, Field 2 First, Planar
YCbCr 4:2:0 (Planar Only)	YCbCr_420	.yuv	Need to setup	(Not Applicable)
YUV 4:4:4	YUV_8_8_8	.yuv	Need to setup	Non Interlace, Field One First, Field 2 First, Planar
RGB	RGB_8_8_8	.rgb	Need to setup	Non Interlace, Field One First, Field 2 First, Planar
GBR	GBR_8_8_8	.rgb	Need to setup	Non Interlace, Field One First, Field 2 First, Planar
ARIB YUV	(Not Applicable)	.yyy, .rrr, .bbb	Need to setup	(Not Applicable)
AVI	(Not Applicable)	.avi	No need to setup	(Not Applicable)
Vcap	(Not Applicable)	.vcap	No need to setup	(Not Applicable)

▶ **Table 1.** *Supported File Formats.*

Reference Sequences

There are two ways to get video into a Tektronix PQA500 for picture quality measurements.

1. The first method is file based measurements (shown as case 1 in Drawing 1). This method is very useful when a designer is developing video processing algorithms in a work-station environment where the reference and test video content are already archived on a server system.

All required tasks for picture quality measurement in this case can be done within the PC environment. In this case, the reference video sequence and test video sequence are computer files. They can be easily imported via USB memory, CD/DVD media or Ethernet. Table 1 shows all the file formats currently supported by the PQA500.

► **Figure 1.** *Capture Dialog.*

2. The second method is to use the SDI video input option to capture the video source for reference and test sequences (cases 2 through 4 in Drawing 1). This operation allows engineers to measure the picture quality of real-time video processing through the device or video path. The first step in these cases is to capture the reference sequence from a playout device, such as a video tape machine or video server. Then the designer plays the same material through the device(s) under test and captures the output - again using the PQA500 SDI video option. Figure 1 shows the PQA500 capture screen.

In both cases, a key benefit is that the engineer can use their own video material. The PQA500 does not require a calibration pattern or specific test files in order to make measurements, even for dramatically different resolutions and frame rates. The test video sequence length can be as large as the hard disk capacity of the system.

Debugging Stage

In this early stage, the designer will focus on the differences between the actual output from the video process system and the video signal quality that they might have originally expected. Sometimes, there may be field reversal within the interlace processing of the video signal, or sometimes the processed picture will have picture impairments due to the encoding and decoding processes that are caused by bit over/under flow as the signal is processed. This can lead to the device addressing the wrong pixel data. These errors may happen very often across the entire image or within certain regions of the images.

One method for quickly checking for possible errors within the material is by performing a PSNR (Peak Signal to Noise Ratio) measurement. PSNR shows the RMS ratio between the peak signal amplitude of a signal and the noise accompanying the signal. On the PQA500, the PSNR measurement provides a difference between the two sequences without any filtering and weighting. This measurement method is very useful for finding small pixel by pixel differences between the images. It can be used to quickly lead the designer to some types of errors in the processing algorithm. However, it is not a direct prediction of what the human viewer will perceive as visual differences between images.

Picture Quality Measurement For Video Applications
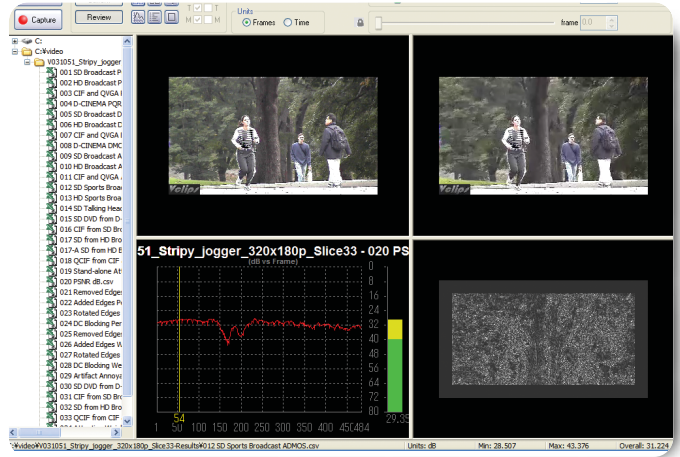
▶ Application Note

▶ **Figure 2.** *Reference Frame.*

▶ **Figure 3.** *Test Frame.*

▶ **Figure 4.** *PSNR Map.*

▶ **Figure 5.** *PSNR Summary View.*

Figures 2, 3 and 4 show the sources and resulting PSNR measurement provided by the PQA500.

The highlighted white areas in PSNR map show the largest differences between the reference and test sequence. The display in Figure 5 contains both the PSNR map and graph of the same information in the PQA Summary View.

By using the brightness and contrast controls available in the Configure Displays menu on the PQA500, the user is offered flexibility to more easily observe these differences.

The graph for PSNR in the summary view has two modes; power of noise with decibel (dB) units and the absolute LSB (Least Significant Bit). The designer can choose either at the summary node in the Edit Measure Dialog.

PSNR units of measurement are commonly used in the industry to communicate some aspects about picture quality. In the PQA500, the graph shows the power of noise by subtracting the reference sequence from the test sequence.
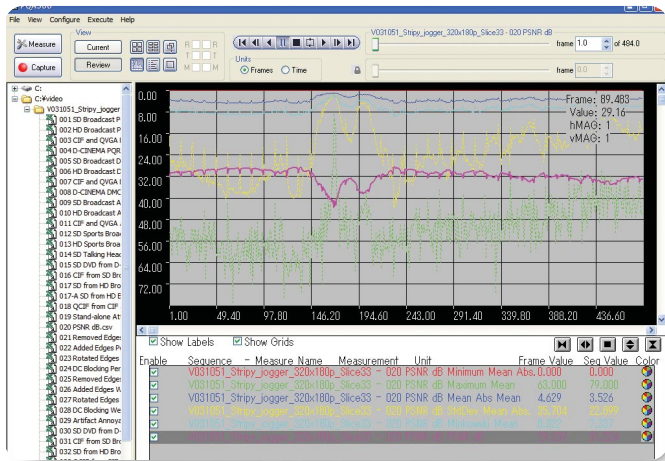
▶ **Figure 6.** *PSNR Graph View.*
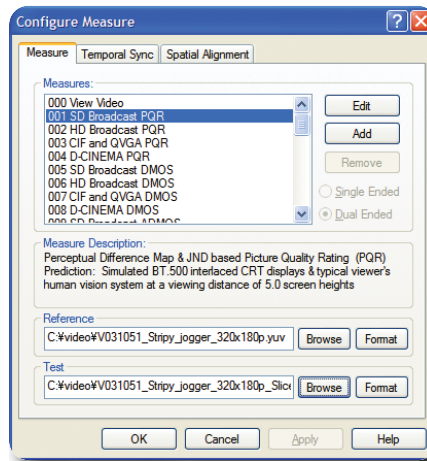
▶ **Figure 7.** *Pre-configured Measurements.*

Absolute LSB units are more useful than power of noise for debugging. Figure 6 shows the differences of LSBs directly.

The graph view provides statistical measurements such as mean, minimum, maximum, standard deviation and Minkowski for each frame. The maximum LSB graph shows the maximum difference of LSBs between the reference frame and the test frame. The designer can check for unexpected/accidental errors very quickly.

The PQA500 provides PSNR measurements with auto spatial alignment. This feature enables the designer to measure the LSB difference and power of noise between sequences with different resolutions. This is very useful for checking video processing that adds varying amounts of rescaling and shifting.

Evaluation Stage

In general, video product design criteria do not focus on specific video content and/or specific applications. The

design is required to produce high average scores for picture quality of a wide range of video content on general applications. At this stage, picture quality measurements are more likely to be based on criteria and specifications such as ITU-R BT.500. The Tektronix PQA500 provides a large set of pre-configured measurements for standard "BT.500" conditions. These built in measurement categories can, with minimal set-up, be easily and quickly put to use to measure the overall picture quality score based on human vision system. Figure 7 shows some of the presets.

Another advantage of the PQA500 is in its ease of measurement repetition. During the design process, many iterations of an algorithm can be made and the picture quality can be quickly evaluated at each stage to see if improvements have been achieved.

► **Figure 8.** *Reference Frame.*

► **Figure 9.** *Test Frame.*

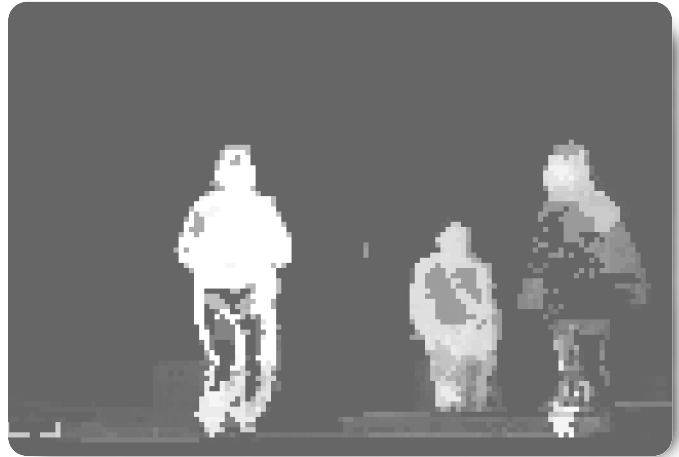► **Figure 10.** *Perceptual Difference Map.*

When the designer chooses the measurement algorithm, they should consider what is to be measured. If the goal is to measure the relative difference of the image compared to the most degraded sequence - DMOS should be used to evaluate the difference from the worst case sequence. If, however, the designer prefers to have a measurement of the absolute difference, then the PQR will be more suitable for this application.

The Perceptual Difference Map created by the pre-configured measurements shows the differences relative to the PQA500's human perception model for each reference video sequence and its associated test video sequence (Figures 8 and 9).

The highlighted white area in Figure 10 shows the greatest difference in human perception. The area of impairments within an image or sequence can be found easily.

Another advantage of the PQA500 is in its ease of measurement repetition. During the design process, many iterations of an algorithm can be made and the picture quality can be quickly evaluated at each stage to see if improvements have been achieved.

The pre-configured measurements for prediction of subjective picture quality provide two kinds of measurement units, DMOS (Differential Mean Opinion Score) and PQR (Picture Quality Rating). DMOS, as discussed above, is the basic measurement criteria set described by ITU-R BT.500 and is commonly used in the industry. It provides a relative result to worst case result as conditioned by a training sequence. The PQR measurement was established by the Tektronix PQA200/300. It shows the absolute difference based on the JND (Just Noticeable Difference) algorithm.

▶ **Figure 12.** *Reference.*

▶ **Figure 13.** *Attention Map.*
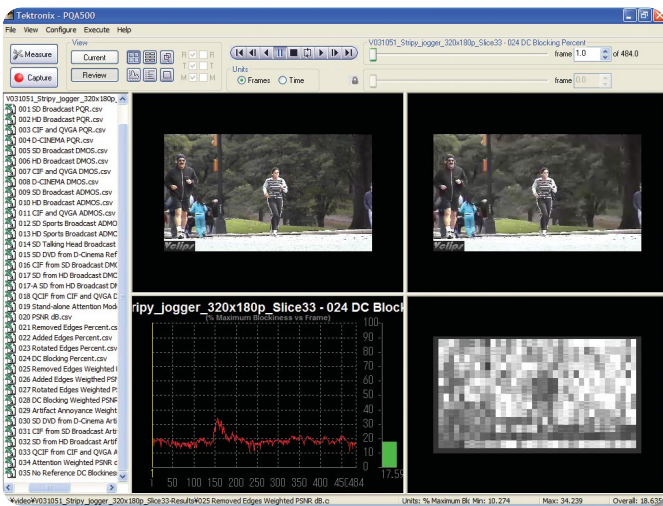
▶ **Figure 11.** *DC Block Measurement Summary View.*

Improvement Process

If the designer discovers impairments within the image, they will have to consider methods to improve performance by tuning their algorithm and/or video processing circuits. The PQA500 provides an artifact detection reporting mechanism that will highlight a variety of different changes to edge transitions within the image or sequence. Image edge defects typically caused by digital video compression technologies include blurring, ringing/mosquito noise, edge Blockiness and DC Blockiness. These various artifact types can also be combined as weighting parameters for PSNR and DMOS/PQR measurements with a wide variety of configurations options. Figure 11 depicts one way to quantify blockiness.

Optimizing Stage

If the video processing device (or the designer) is more concerned with focusing on specific content like sports, news and drama, the PQA500's Attention model can be useful for seeking further improvements. The Attention model predicts the human visual system's general focus of attention on the subject matter within the images. The Attention model can be used to further define (weight) the PSNR and DMOS/PQR measurements. For example, if the target video content is a football game, then most viewers would likely pay more attention to the player and location of the ball within the action of the scene. They would be less likely to pay attention to the grass and the stadium which is in the background. Similarly, if the video material is a news program, then most viewers would pay attention to the face of the announcer and again not as much to the background. The attention weighted measurement provides picture quality results relative to the region of the image that is predicted to be of greater focus for the human viewer. If that measurement result is worse than the result without any attention focus, the designer may assign more bit resources (processing power) to the predicted regional area in order to give viewers a perceived improvement to the picture quality. Figure 12 shows the reference, Figure 13 shows an attention measurement.

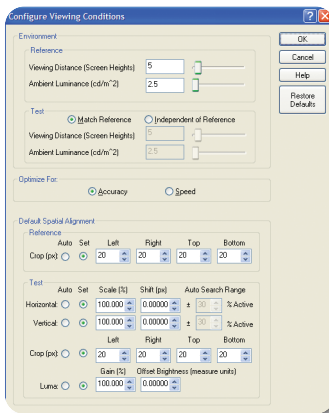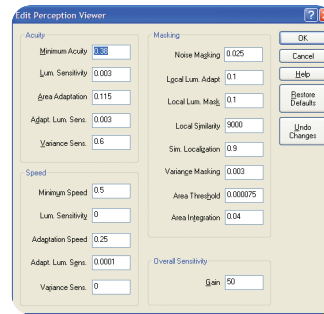# Picture Quality Measurement For Video Applications
▶ Application Note
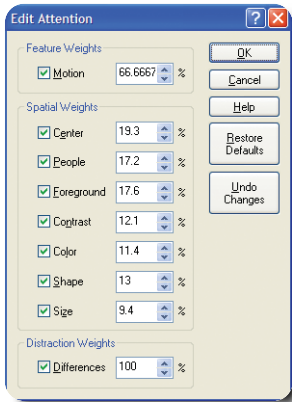
▶ **Figure 14.** *Attention Dialog.*

▶ **Figure 16.** *Viewing Conditions Dialog.*

▶ **Figure 15.** *Custom CRT Display Dialog.*

▶ **Figure 17.** *Perception Viewer Dialog.*

The weighting parameters used within the attention model are also user configurable. The designer can modify the weighting parameters in order to assess changes in his assumptions about the content or the type of human viewer. Figure 14 shows some of the weighting controls on a Tektronix PQA500.

If the video processing device focuses on specific application such as D-Cinema, mobile reception or watching a movie on a PC monitor, a series of other user configurable measurements allow the designer to test and improve the performance for each viewing application. For example, if the target video application is for mobile reception, the viewer will be expected to watch the video under brighter ambient light instead of the ITU-R BT500 standard condition.

In this case, the designer may modify the viewing environment parameters to simulate the typical viewer's situation and quickly compare the result with the viewing conditions assumed by the reference situation. If the difference is less than expected, the designer may consider assigning the bit resources to other information within the picture. Alternatively, if the target application for the device or content under evaluation is a home theater system, then the viewer could expect a higher picture quality under the well controlled viewing environment. So, the designer may consider modifying viewing environment parameters, selected viewer characteristics and worst case training sequence DMOS settings, and then pay attention to the small differences.

Figures 15 through 17 show some GUI controls for optimizing environmental parameters.
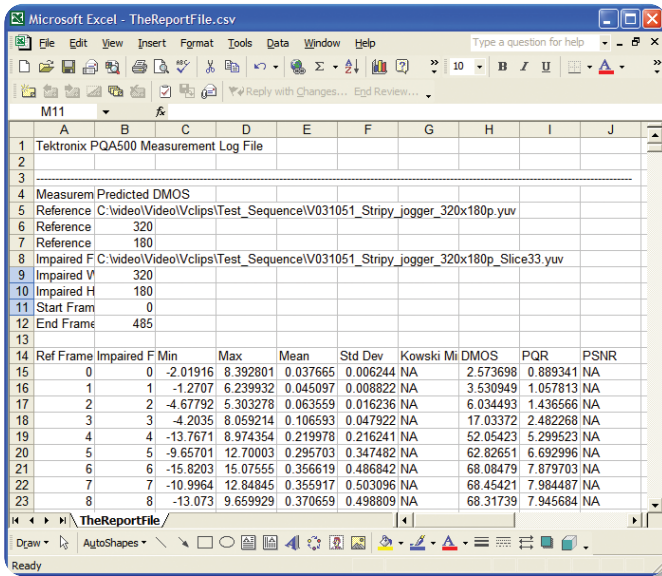
► **Figure 18.** *Measurement Results.*

► **Figure 19.** *XML Script.*

Reporting & Data archive

After the evaluation, engineers often have to provide and archive quality reports for their clients and managers. The PQA500 provides all the measurement results within a standard .csv file format. The designers can quickly and easily use this data format to make their evaluation reports with common spread sheet application software. Figure 18 shows one example of a spreadsheet containing PQA500 results.

Even Faster Testing

Through all of the design and evaluation processes, engineers must evaluate their video processing systems with a variety of video sequences. They also have to evaluate the video process system with a variety of different formats and conditions in order to quantify multiple picture quality results. Those tasks should normally be done with each parameter change. If they have to run each operation on an individual basis through the PQA500 UI (User Interface), this can dramatically slow the process.
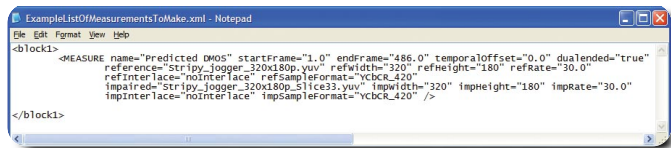
To support more rapid testing, the PQA500 has the ability to automate this process via XML script execution. PQxml.exe is an executable DOS program which executes the xml script written by the designer. Figure 19 shows an example script.

Scripts enable the engineers to concentrate on their design work and not on repetitive instrument operation tasks. Individual measurement results are stored for review just as they would be when created via the UI. In addition, an overall report may be created within the script (or nested scripts) which include results of all measurements taken during the .xml script execution. Thus large sets of measurements may be set up and run in the background.
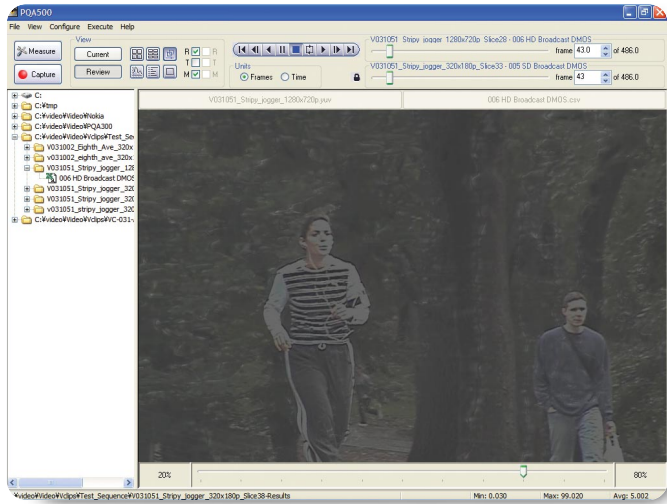
Picture Quality Measurement For Video Applications

▶ **Application Note**
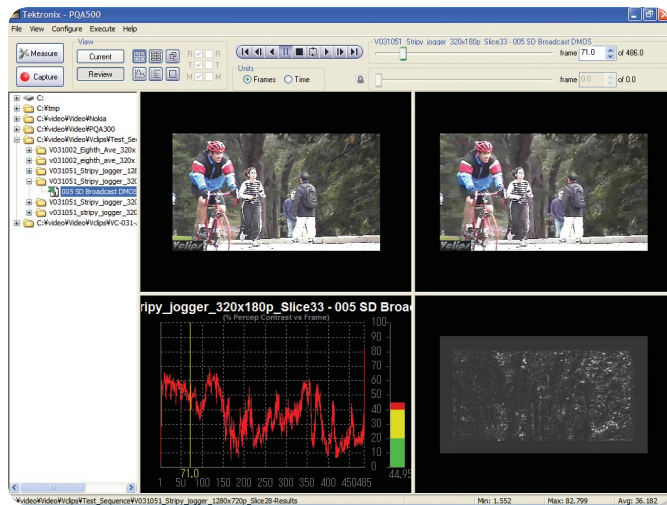
▶ **Figure 20.** *Summary View.*
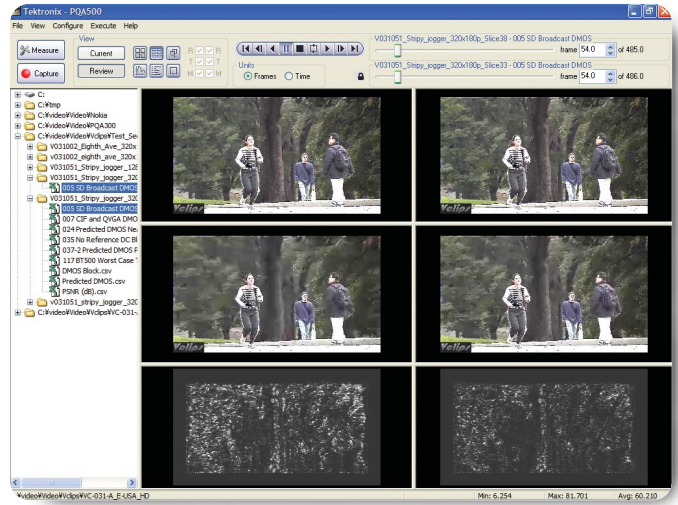
▶ **Figure 22.** *Tile View.*



▶ **Figure 21.** *Overlay View.*

Multiple Result Display Modes

The PQA500 provides 6 different result displays for checking the measurement results.

1. The Summary View provides the basic Reference / Test / Map display, with a graph of the measurement. The designer can check the overall measurement result, and can quickly navigate to a video frame of interest using UI tools provided. Figure 20 shows the Summary View.

2. The Overlay View displays the two targeted sequences with the test and reference images directly overlaid. This enables the designer to find small differences at exact locations within the images. This display also works between two different pre-measurement files. For example, the designer could see the differences between the sequence "before modification" and the sequence "after modification" in order to quickly investigate the effectiveness of the modification. Figure 21 shows the Overlay View.

3. The Tile View displays 2 pre-measured sequences with tiling for reference, test and map sequences. This view provides a side by side display. It is very useful for comparing between the map made by the original design and the map made by an updated design. For example, the designer can make quick comparisons between the non-weighted perceptual difference map and the artifact weighted perceptual difference map in order to see which impairments are dominant. Figure 22 shows the Tile View.
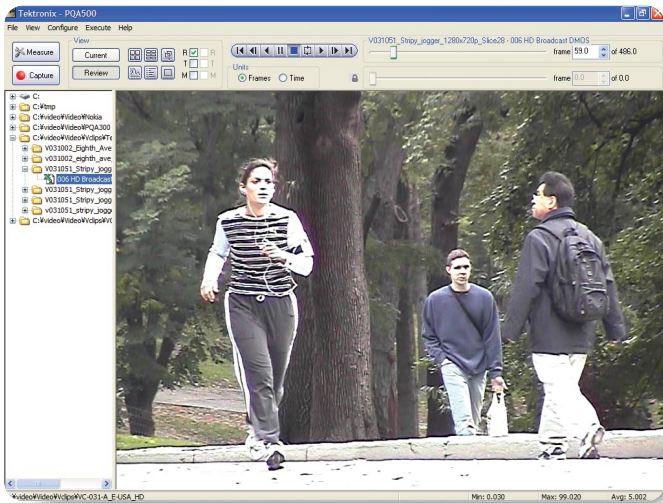
► **Figure 23.** *Full Display View.*
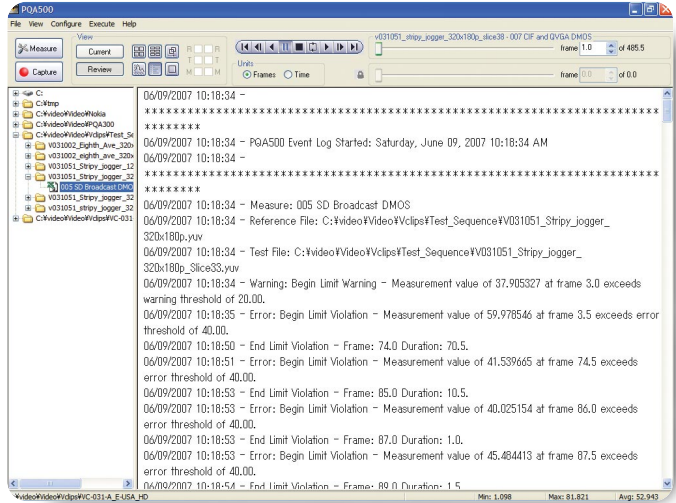

► **Figure 25.** *Event Log View.*
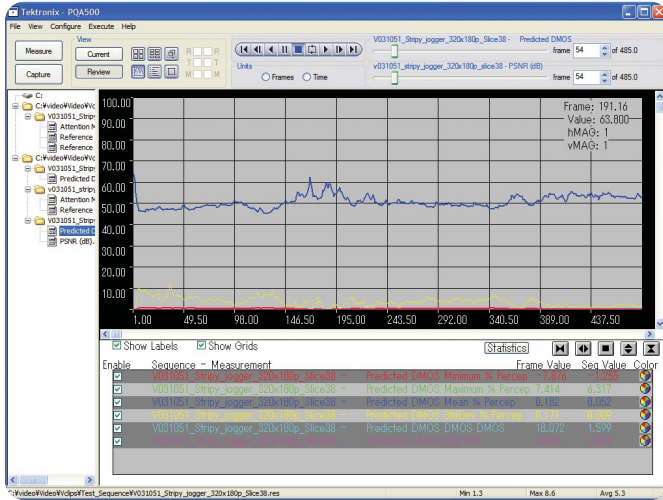
► **Figure 24.** *Graph View.*

4. When the video content has high resolution and/or high frame rates, the designer usually needs to view the sequence as close as possible to "real time" sequence speeds. The Full Display Mode will provide the fastest video update with largest display area. Figure 23 shows the Full Display View.

5. The designer can use a spread sheet application to view and sort the various measurement results. The Graph View is one of the tools available to quickly view the results. In addition, the designer can view multiple measurement result in one graph. It is often very useful to see the relationship between a set of different measurements. If the designer selected two pre-measured results, the graph will show all of the selected results sets. This enables the designer to compare easily before update and after update. All measurement results are available in a .CSV file format. Figure 24 shows the Graph View.

6. Each measurement can be set up to generate warning and error messages when a particular measurement parameter exceeds a configurable threshold. The Event log shows the measurement events that were over the threshold. In addition, it shows extended measurement information such as date/time and ref/test file names. The designer can use this log for archiving evaluation data. Figure 25 shows the Event Log View.

Picture Quality Measurement For Video Applications

▶ **Application Note**

▶ **Figure 26.** *MTS4EA GUI.*

▶ **Figure 27.** *Vclips Example Scene.*
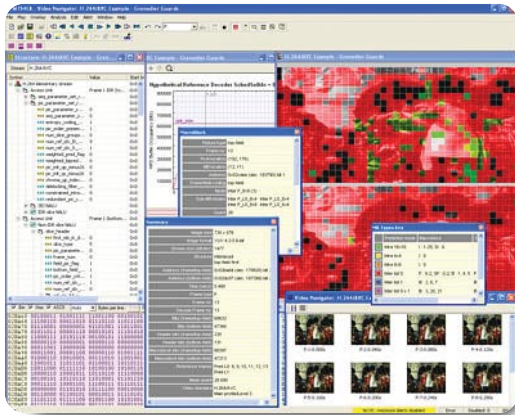
Need more tools?

If the designer needs to measure a compressed file directly, the Tektronix MTS4EA is a comprehensive and detailed tool for assessing the syntax and protocol of a compressed video elementary stream. In addition, MTS4EA has tools that facilitate extracting the video elements to uncompressed files in a YUV format. These extracted files from the MTS4EA software can then be used by the PQA500 for analysis and provides a very comprehensive test, measurement and evaluation solution for the CODEC designer. Figure 26 shows the MTS4EA GUI.

Additionally, general video processing devices should be capable of producing highly reliable images for a variety of different video clips and be able to keep the level of the picture quality required by the clients and viewers. It is very important to evaluate the video processing with a variety of different video sequences. Tektronix Vclips provide a wide variety of scene content selected for Encoder and Decoder designs. A detailed set of descriptions are provided with each of the Vclip file sets. These content descriptions provide the necessary information that will help in the designer's evaluation work. The PQA500 can also view/process reference and test images made with Vclip Encoder series YUV files directly, as shown in Figure 27.

Conclusion

Expanding video applications are providing new business opportunities for everyone. That said, recent advances in video applications have placed more complex and potentially more time-consuming problems before the designer. Human based, subjective picture quality analysis is now too slow and costly. The Tektronix PQA500 provides a comprehensive set of picture quality measurement tools allowing the designer to rapidly and objectively debug, evaluate, improve and optimize video processing systems and devices.

Demonstration of the Tektronx PQA500

Contact your authorized Tektronix representative for a demonstration of the Tektronix PQA500 at **www.tektronix.com/video**

Read on...

For more reading on the Tektronix PQA500 please visit:

http://www.tek.com/site/ps/0,,25-20585-INTRO_EN,00.html

To see the PQA500 Data Sheet, visit:

http://www.tek.com/site/ps/25-20585/pdfs/25W_20585.pdf

To request a demonstration, quotation or sales call please visit:

http://www.tek.com/Measurement/cgibin/framed.pl?Document=/Measurement/cgi-bin/live-quote.cgi?PRODUCT=PQA500&FrameSet=1products

To see the entire Tektronix portfolio visit the website at:

www.tektronix.com/video

For Further Information
Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

Tektronix
Enabling Innovation