Overview

This white paper describes the ENRGY integrated noise reduction feature on the Harmonic™ standard definition DiviCom® MV50 encoder. ENRGY supersedes and builds on the integrated noise reduction capabilities of the MV45 ClearMotion™ encoder. ENRGY thus represents Harmonic's third generation of integrated noise reduction. The sixth generation standard definition MV50 encoder adds processing power, new filters, and intelligent controls to consistently deliver the highest quality video in satellite, broadcast, and xDSL networks, where bandwidth efficiency matters most.
New Integrated Noise Reduction (ENRGY)

With the MV50 encoder, Harmonic capitalizes on a powerful synergy that couples noise reduction with the compression process. The new pre-processing capabilities of the MV50 together with a combination of new filters, constitute the new ENRGY feature that builds on Harmonic’s second generation integrated noise reduction technology introduced with the MV45 encoder.

ENRGY integrated noise reduction meets the challenge of removing noise when necessary while not affecting clean video content. The MV50 conserves bandwidth by providing better video quality at lower bit rates by integrating its expanded noise reduction capability with more refined algorithms.

ENRGY adds particular value with DiviTrackXE™, the Harmonic statistical multiplexing solution. The multiplexed channels in a DiviTrackXE pool have a strong interdependency and good noise reduction prevents a noisy channel from using additional bandwidth within the pool. By reducing noise, ENRGY makes it possible for channels to run at lower bit rates and provides potential for adding more channels.

ENRGY Evolution

An economical MPEG-2 encoding processor was the catalyst for the cost effective multi-processor encoding strategy Harmonic embraces. Advanced DVxpert™ MPEG-2 processors from C-Cube® Microsystems, Inc. are at the heart of the MV50 encoder. The DVxpert processor offers fully compliant exceptional MPEG-2 compression. Advanced Harmonic encoding techniques extend performance by harnessing the power of three processors.

Harmonic first launched its advanced encoding technique using three MPEG-2 processors instead of one when it introduced its LookAhead technology. The LookAhead architecture enjoys advanced visibility of incoming video content, because the first encoding processor extracts statistics from incoming video almost one second ahead of the main encoding processor. Such video analysis helps the encoder to:

- Make better encoding decisions
- Make better use of MPEG-2 buffer resources
- Apply improved filter control

The third encoding processor is coupled within the LookAhead control loop to work with additional hardware to power this advanced filtering capability.

The MV50 platform builds on a proven architecture while adding power to the compression algorithms, as well as hardware that can support more sophisticated noise reduction and pre-processing.

ENRGY Benefits

External equipment promising to clean up noisy video sources has been available for many years. Unfortunately, many of these systems do more harm than good for picture quality. The challenge has always been to remove noise without adversely affecting content.

Removing noise without damaging the pictures requires both excellent filters and excellent filter control to automatically apply the right level of filtering in the correct areas.
The Harmonic LookAhead architecture places a video pre-processor between two encoding processors to tightly couple video pre-processing with the compression core. The coupling of video pre-processing with compression enables LookAhead statistics to assist in the intelligent and proactive control of filters during pre-processing to provide the highest picture quality at the lowest bit rates. Further, it permits correct temporal as well as correct spatial filtering to be applied to the video, dramatically reducing the likelihood of the filtering introducing picture artifacts.

Other obvious advantages to performing noise reduction within the encoder include reduced rack space, integrated control and lower power requirements. The most compelling advantage of the MV50 ENRGY solution, however, is the integrated architecture that makes it perform so efficiently and pleasingly.

**ENRGY Suite of Filters**

The MV50 combines its compression expertise with a suite of powerful third generation filters to enhance existing Harmonic encoding techniques such as border processing and motion compensated temporal filtering. The following diagram illustrates the ENRGY integrated noise reduction architecture:

**Impulse Noise Reduction Filter**

Occasional video specks or dropouts reflect impulse noise. Impulse noise occurs most commonly in film content, but electromagnetic interference can also cause this effect. Removing impulse noise has a dual benefit in that it:

- Makes the picture look better
- Has a positive effect on compression and adaptation control mechanisms.

The ENRGY impulse noise reduction filter removes impulsive noise from an image sequence. This is a brand-new filter for the MV50 that adds a large measure of sophistication compared to the motion adaptive temporal median filter of the MV45. Improvements are most evident when processing content that contains significant high temporal frequencies (fine non-static detail).
The MV50 supports this processing intensive filter with a two-stage process — first detection and then suppression of the impulse. Most of the processing supports impulse detection. The detection mechanism relies on a three-dimensional comparison process requiring over two billion comparisons per second. ENRGY adaptively couples impulse noise reduction filter mechanisms with LookAhead motion statistics. ENRGY screens the discriminator output using historical data to eliminate impulses that fall outside normal variances. The impulse noise reduction filter processes impulse pixels with a relatively simple mechanism that replaces impulse pixels based on median spatial values of clean pixels. The impulse noise reduction filter can also account for repeated fields from 3:2 film pull down processing. The strongest impulse noise reduction filter setting can be used as a film damage repair mode.

**Motion Compensated Temporal Low Pass Filter**

The ENRGY motion compensated temporal low pass filter removes random (Gaussian) noise. Random noise is the most prevalent type of noise and costs the most in terms of wasted bandwidth. Motion compensated temporal filtering remedies the tendency of traditional temporal filters to introduce annoying trailing artifacts in motion areas. The MV50 encoder adds refined control to the motion compensated temporal filtering that was introduced with the MV45.

Motion compensated temporal filtering accounts for the displacement of each individual block with respect to neighboring frames to apply filtering along the motion trajectory. The result is powerful suppression of random noise without the trailing effects. In addition, the filter also has an adaptation mechanism based on amplitude discrimination that allows significant detail to pass through while still effectively suppressing random noise. Motion compensated temporal filtering requires intensive processing.

**Non-Linear Spatial Filter**

The ENRGY non-linear spatial filter is an innovative new feature for the MV50 that supports motion compensated temporal filtering in the removal of random noise. The filter provides an alternative mechanism that automatically adapts to support motion compensated temporal filtering in spatial regions that motion analysis does not predict well such as fades and dissolves. The non-linear spatial filtering principle has strong natural attributes that avoid creating random edge discontinuities as a processing consequence. The filter can act on select pixels and spatial regions without introducing processing artifacts in adjacent regions that contain texture and edge structure.

The non-linear spatial filter uses a small pixel region to support its frame-based spatial filtering. While pixel comparison provides the basis for non-linear spatial filtering, the filter also bases its adaptive control on LookAhead statistics, inputs from the motion compensated low pass temporal filter, and the noise level estimation. The average luminosity also modulates the filter level to adapt processing to scene brightness. ENRGY couples non-linear spatial filtering and motion compensated temporal filtering so that the non-linear spatial filter phases in and out of operation depending on the performance of the motion compensated low pass temporal filter. ENRGY can support a blend of non-linear spatial filtering and motion compensated temporal filtering to provide optimal quality.
Edge Adaptive Texture Filter
The ENRGY adaptive edge texture filter is a new feature for the MV50 that assists the encoder in aggressive video compression to very low bit-rates. When the encoder is compressing to a very low bit rate, adaptive edge texture filtering recognizes sections of the picture that will be difficult to encode well, and then filters them to reduce compression artifacts. The filter discriminates between regions of texture and image edge structure to preserve, but soften gracefully, texture that would otherwise cost the encoder precious bandwidth to compress.

Temporal Low Pass Filter
The ENRGY temporal low pass filter is a motion adaptive filter that suppresses low level random noise in still or slow moving areas. In simple terms, temporal filtering is an averaging process applied between video frames. The temporal low pass filter has been thoroughly proven on the MV45 encoder and continues with the MV50. The MV50 uses a motion adaptive temporal low pass filter to reinforce the power of motion compensated temporal filtering, resulting in improvements to the look of static background areas.

Horizontal Resolution Filter
The ENRGY horizontal resolution filter, which the MV50 improves on from its MV45 introduction, applies inter-pixel processing to reduce horizontal detail by gently softening the video thus making it easier to encode. The horizontal resolution filter compliments MPEG horizontal subsampling that select 720, 704, 544, 480, or 352 resolutions. For all of these settings, the response of the filter can be trimmed to trade artifacts against picture sharpness.

Filter Control
The ENRGY integrated noise reduction system uses the LookAhead architecture to analyze the incoming video and adaptively apply the most appropriate measure of filtering to optimize compression. The term adaptive refers to the system’s ability to set filter characteristics for optimal noise removal. This is a completely automatic process that removes noise while minimizing artifacts due to the noise filters without operator attention.

Filter Strength
Most operators prefer a limited number of filtering settings. When the Harmonic SNMP network management system is used to set filter strength, ENRGY automatically adapts and scales the filter strength as appropriate to video content. With this ease of control, a single setting, or a limited number of settings can be selected that provide excellent quality for any content that comes into a headend facility.

The Harmonic network management system can be used to customize individual filter strengths and adaptation thresholds.
Noise Level Estimation

ENRGY noise level estimation supports the application of stronger and more consistent filtering where it is needed most.

The human eye is very good at recognizing noise, but this is much more difficult for an encoder to accomplish. The challenge is to distinguish between actual noise and special effects, such as fades and dissolves, to avoid unnecessary filtering. The multi-processor architecture of the MV50 applies effective noise estimation techniques so that it can recognize noisy content and apply a stronger measure of noise reduction automatically.

Border Processing

ENRGY border processing saves bandwidth by providing a means for an operator to selectively discard the outer area of the picture. Television sets are manufactured with a significant proportion of overscan so that viewers typically cannot see the outer sections of the picture. (Often, as much as 14 percent of the picture is not visible.)

The MV50 encoder adds refinements to the border processing feature which was introduced with the MV45. With ENRGY border processing, valuable bandwidth can be preserved by applying higher quantization to the top, bottom, left, and right outer macroblocks.

Measuring Quality

Noise reduction improves compression efficiency and quality for all but the cleanest content. Evaluating video quality is important, but unfortunately there are no metrics that can consistently characterize the measurement of video quality as it perceived by a viewer. The exceptional ability of the human eye to judge video quality is very difficult to model. Although objective measurement tools are available, the results are often inconsistent and can produce misleading conclusions. The most astute operators rely heavily on human eye testing and side-by-side comparison tests. This understanding is reinforced by the findings of the ITU’s Video Quality Expert Group that no existing “video quality” metric is as reliable as human eye testing.

What Effects Should You Look For?

A video compression system will inevitably introduce artifacts at low bit rates, but a superior system will introduce artifacts to a lesser degree. Running a system side-by-side with a reference is a good way to categorize and compare the frequency and severity of compression artifacts. Look for settings that minimize the following effects:

- Edge effects (mosquitoes) — noticeable around object edges
- Blocking or tiling in response to motion or fades and dissolves
- Blocking or tiling in flat or background areas
- Soft definition
- Motion blur or ghosting
- Pulsing effects — annoying and obvious even from a distance
- Non graceful adaptation effects — unnatural looking surprise effects

To learn the most about a system, work it aggressively with difficult content at low bit rates. It is also important to consider a wide range of content types, including movies, sports, animation, and studio programming.
Conclusion

The suite of filters in the ENRGY integrated noise reduction system offers powerful advantages that exceed the capabilities of the most expensive external solutions. With ENRGY, powerful adaptive filter control can be easily applied. They represent Harmonic’s third generation filter implementation.

Testing video to find the most appropriate filter settings is a challenge, so Harmonic provides application notes to help you get set up quickly and see the benefits of the MV50 encoder and ENRGY.

Harmonic strives for continued development in both compression and noise reduction technology that reinforces its position as the premium vendor of MPEG-2 compression solutions. Contact Harmonic for more information about the MV50 encoder and the ENRGY integrated noise reduction system.
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