COMPUTING
COMMUNICATIONS
VIDEO

MPEG-2 Decoder Design & Test

Conversion to DTV Drives Demand for Digital Set Top Boxes

Consumers are rapidly switching from their old analog TV set top boxes to the newer digital boxes in order to get higher-quality video, higher channel counts, and the extra services provided by digital broadcasters.

Compressed digital video has become a norm because it enables many more programs to be delivered with better quality than the older analog delivery systems. In addition, it is allowing digital programming to make its way into the world of the desktop computer. Already, a few manufacturers are creating digital decoder boards for computers. It is now possible to watch digital TV in a scalable window on the PC while running other applications.

As these video, audio and data technologies converge in the broadcast medium, it becomes imperative that designers of decoder set top boxes have a thorough understanding of the MPEG-2 digital compression standard and the important role it plays in design test. Faced with the complexity of data streams made possible by the MPEG-2 standard, and the fact that encoding, multiplexing, transmitting, demultiplexing and decoding processes may vary over time and with temperature changes, the designer must understand not only how to test the specified boundaries of a product but also its limits.

This application note will focus on the particular issues decoder designers face when testing to the MPEG-2 compression standard.

About the standard

Established in 1994, MPEG-2 is today's dominant digital compression standard because it enables delivery of high quality transmission of multiple programs in a single digital signal, and because it paves the way for high definition TV (HDTV). Its compression algorithm is based on discrete cosine transform (DCT) coding and interframe motion compensation. By removing spatial and temporal redundancies in moving picture signals, MPEG-2 compresses digital video by ratios up to 60:1.

MPEG-2 is defined only for decoder designers and manufacturers. It does not contain any physical layer interface specifications and contains limited service-information specifications. These issues were addressed by the Digital Video Broadcasting (DVB) committee, which augmented MPEG-2 by adding many additional specifications, and by the Advanced Television Systems Committee (ATSC), which also defined how to broadcast high-quality digital video into the home.

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The digital compression process

Encoding, transmitting and decoding are the three major tasks involved with producing MPEG-2 video. Encoding begins with a digital video signal. Encoders with analog inputs, either NTSC or PAL (National Television Standards Committee or Phase Alternate Line), provide internal conversion to a digital data stream of 270 Mb/s. Using MPEG-2 compression, today's encoders can easily compress this data stream down to less than 3 Mb/s. The audio is compressed as well - down to less than 400 kb/s.

In today's broadcast video, most applications utilize a multiplexer to combine several programs together to make a single MPEG-2 transport stream. And since transmission often occurs in environments that add noise or errors, redundancy and error correction are added for robustness.

MPEG-2 integrated receiver/decoders (IRDs) process the incoming signal and convert it into a viewable picture. Professional decoders will provide digital outputs, while consumer decoders convert back to analog. First, the IRD tunes to, down-converts, and demodulates the signal. Next, it decodes the demodulated signal and performs any forward error correction. The resulting signal is a serial or parallel MPEG-2 transport stream. In the third step, the stream is demultiplexed into its component elements, creating individual video and audio streams for the selected program. Lastly, an MPEG-2 decoder chip processes the compressed video and audio streams. The result is an uncompressed digital video signal and an audio signal.

The need for testing

The MPEG-2 transport stream is an extremely complex structure using interlinked tables and coded identifiers to separate programs and elementary streams within the programs. Within each elementary stream there is a complex structure allowing a decoder to distinguish between, for example, vectors, coefficients and quantization tables.

Traditional video testing tools - signal generators, waveform monitors and vectorscopes - are not appropriate for analyzing MPEG-2 systems, except to ensure that the video signals entering and leaving the system are of suitable quality. Instead, a reliable source of valid MPEG test signals is essential for testing receiving equipment and decoders.

Tektronix, long known for manufacturing the finest general-purpose test equipment, has also earned a reputation for design excellence in broadcast video test and monitoring equipment. With expertise in both worlds, Tektronix can provide complete testing solutions for MPEG-2 applications.

Tektronix developed the MTS300 Multi-Standard MPEG Test System specifically for encoder and decoder design and test. Using this system, the decoder designer can perform real-time analysis, deferred-time analysis, and custom transport stream creation and generation for complete characterization of MPEG-2 decoder boards, chips, and related components.

Elementary stream testing

MPEG-2 demultiplexing and decoding chips can be tested directly using the MPEG-2 test system by creating and then generating MPEG-2 transport streams. With an infinite number of possible stream combinations, the challenge is to create enough streams to thoroughly stress the decoder. Each Tektronix Multi-Standard MPEG Test System provides several video elementary streams and a parallel port for playing the streams directly to the IC.

The video decoder can be extensively tested using the MPEG video compliance elementary bit streams created by the Sarnoff Corporation and available from Tektronix. These video elements are the most cost-effective tools for testing a decoder, allowing testing of a wide range of parameters defined within the MPEG-2 standard. To avoid the need for lengthy analysis of the decoder output, the bit streams have been designed to create a plain picture showing the word "VERIFY" when they complete so it is only necessary to connect a picture monitor to the decoder output to view them.

Some tests require the viewer to check for smooth motion of a moving element across the picture. Timing or ordering problems will cause a distorted picture.

This suite of Sarnoff tests may be used to check most of the MPEG-2 syntax elements in turn. In one test, the bit stream begins with I pictures only, adds P pictures, and then adds B pictures to test whether all MPEG picture types can be handled and correctly reordered.

The hierarchical view

When analyzing transport streams being sent to a decoder chip design, the hierarchical view is an excellent starting point because it enables a graphic view of every component in the stream. Figure 1 shows an example of a hierarchic display featured on the Tektronix MTS300.

Beginning at the top left, with the icon for the entire transport stream, the stream splits and an icon is presented for every stream components. The user can easily see how many program streams are present as well as the video and audio content of each.

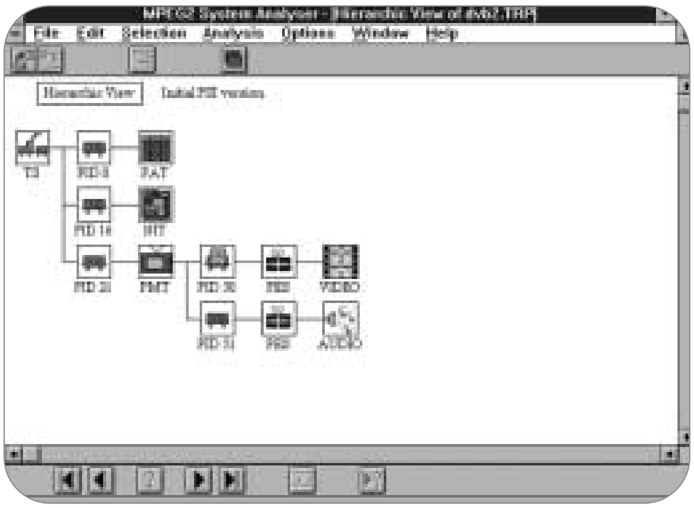

Figure 1. *Hierarchical display of transport stream structure.*

Each icon represents the top layer of a number of lower analysis and information layers.

The analyzer creates the hierarchic view by using the program association table (PAT) and program map table (PMT) in the program specific information (PSI) data of the transport stream. PAT and PMT data are fundamental to the operation of any demultiplexer or decoder. If the analyzer cannot display a hierarchic view, or displays a view that is obviously wrong, the transport stream under test has a PAT/PMT error and it is unlikely the decoder will be able to interpret the stream at all.

A MUX allocation chart may graphically display the proportions of the transport stream allocated to each PID (program ID) or program. Figure 2 is an example of a MUX allocation pie-chart display. The hierarchical view and the MUX Allocation Chart show the number of elements in the transport stream and the proportion of bandwidth allocated. But they do not show how the different elements are distributed in the multiplex. The PID map function displays, in order of reception, a list of the PID of every packet in a section of the transport stream. Each PID type is color coded so it is possible to assess the uniformity of the multiplexing.

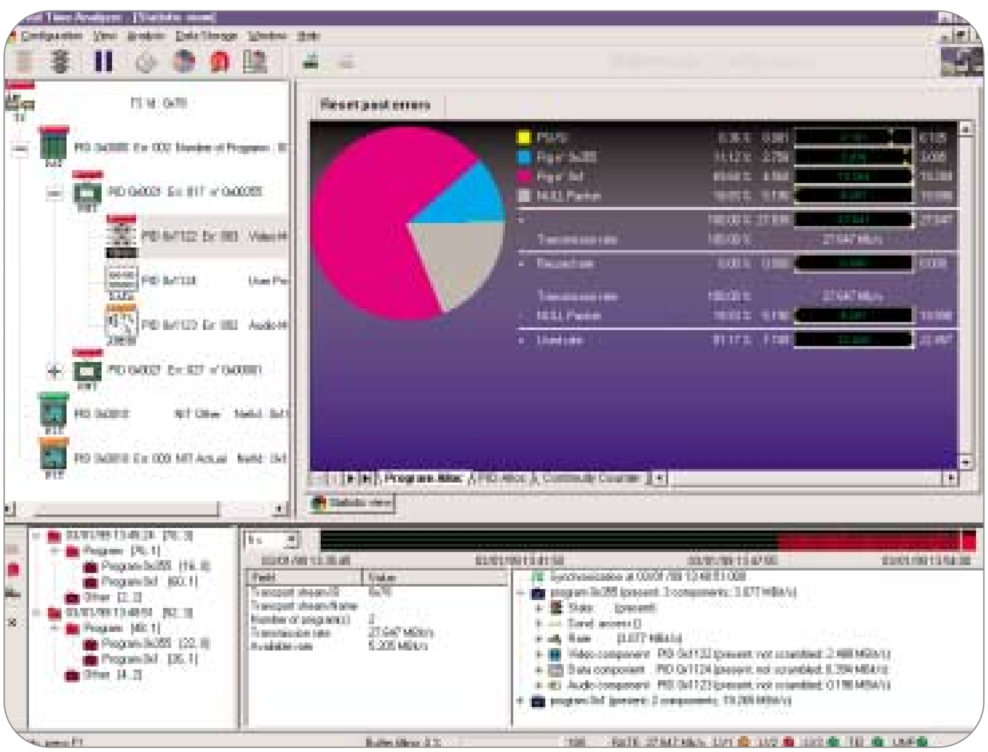

Figure 2: *MPEG transport stream (MUX) bandwidth allocation.*

Data monitoring

Due to the increase in demand on accessing Internet services through cable and satellite communications, IP data monitoring has become an important issue. The Tektronix MTS300 real-time analyzer performs IP monitoring with detailed viewing of EN 301 192 (DVB Data Broadcasting) tables, syntactic control of the tables with error reporting and the ability to monitor data flow of the broadcast session.

Analysis performed include:

- Intra-PSI analysis
- Inter SI/PSI analysis (data broadcast descriptors)
- Consistence of data carousel
- TCP/IP session monitoring

Several new tables are now available within the hierarchical display. Digital Storage Media Command and Control (DSM-CC) from ISO/IEC 13818-6 defines the following types: Multiprotocol encapsulation, U-N messages, and Stream descriptors. EN 301 192 defines the following tables: 1-layer Data carousel, Multi-protocol encapsulation, 2-layer Data carousel, Data Piping, and Data Streaming. Figure 3 shows multiple DSM-CC elements along with their IP traffic sessions.

Timing analysis

To display real-time video and audio correctly, the transport stream must also deliver accurate timing to the decoders. Correct transfer of program clock data is critical because this data controls the entire timing of the decoding process. This task can be confirmed by analyzing the PCR (program clock reference) and time-stamp data.

PCR data from a multiplexer may be precise, but demultiplexing may put the packets of a given program at a different place on the time axis, requiring that the remultiplexer edit the PCR data. Consequently, it is important to test for PCR jitter after the data is remultiplexed. The system graphically indicates the times at which PCRs were received.

Futher, each PCR can be opened to display the PCR data, as shown in Figure 4. To measure jitter, the analyzer predicts the PCR value by using the previous PCR and the bit rate to produce interpolated PCR, or PCRI. The actual PCR value is subtracted from PCRI to give an estimate of the jitter. The figure also shows the time since the previous PCR arrived.

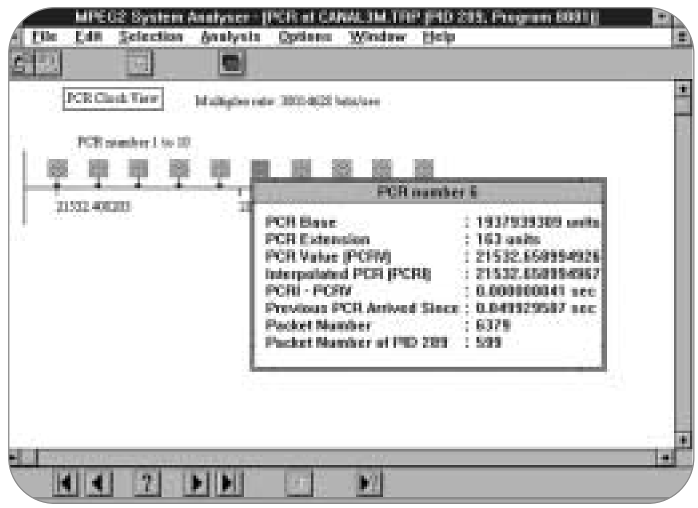

Figure 4: *Graphical PCR timing relationships display, overlaid with specific information on one PCR.*

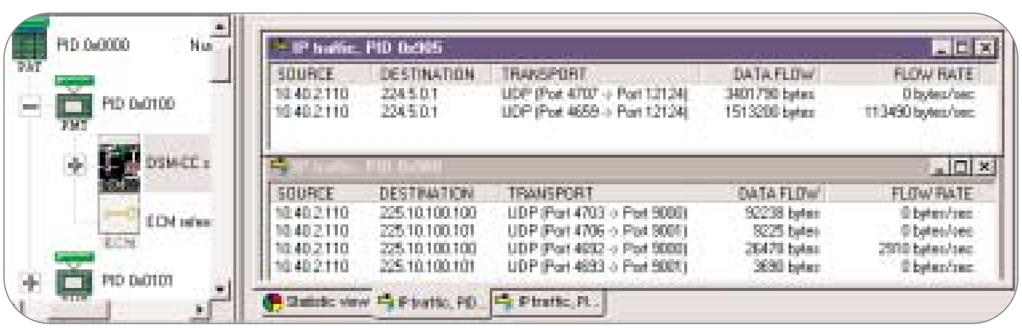

Figure 3: *Multiple DSM-CC elements with IP traffic information.*

An alternate approach, shown in Figure 5, provides a graphical display of PCR jitter and PCR repetition rate, which is updated in real time.

Figure 5: *Real-time graphical display of PCR jitter and repetition.*

Once PCR data is known to be correct, the video and audio time stamps can be analyzed. Figure 6 shows a time-stamp display for a selected elementary stream. The time of arrival, the presentation time, and, where appropriate, the decode times are all shown.

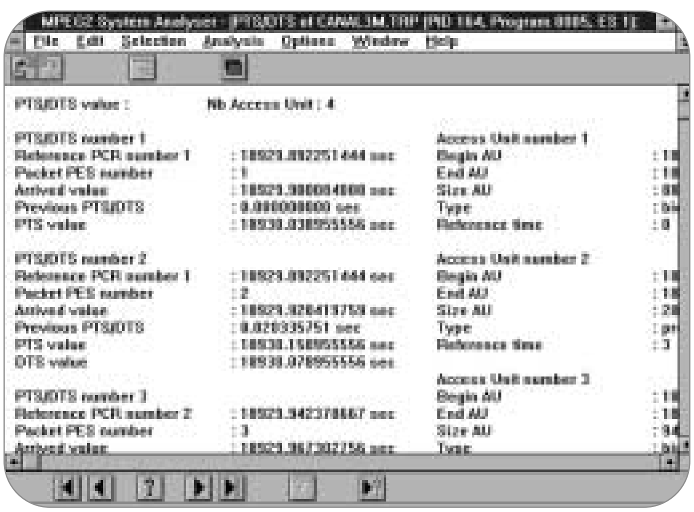

Figure 6: *Details of time stamp information for a selected ES.*

Jitter generation

The MPEG-2 decoder creates a continuous clock by using the clock samples in PCR data to drive a phase-locked loop. The loop needs filtering and damping so the jitter in the received PCR's data does not cause instability in the clock.

To test phase-locked loop performance, a signal with known jitter is required. The MTG300 and MTS300 can generate simulated jitter. Because these two generators are both reference generators, they have oven-stabilized crystal oscillator circuits for maximum stability and accuracy. To create the effect of jitter, the timing of the PCR data is not changed at all. Instead, the PCR values are modified so the PCR count they contain is slightly different from the ideal. The modified value results in phase errors at the decoder that are indistinguishable from jitter.

The advantage of this approach is that jitter of any magnitude can easily be added to any program stream simply by modifying the PCR data and leaving all other data intact. Other programs in the transport stream need not have jitter added. In fact, it may be best to have a stable program stream to use as a reference.

Picture quality analysis

The best measure of any digital decoder is the viewer's satisfaction with the image received. So the final and critical step in characterization of a decoder design is analyzing the quality of the final video picture. It is important to determine if a design's compression process has degraded the picture quality to the point where it is noticeable to the home viewer.

Traditionally, the quality of analog and full-bandwidth digital video systems was evaluated indirectly by measuring the distortions of static test signals. Compressed digital TV systems pose a more difficult measurement challenge. Picture quality changes dynamically based on the data rate, picture complexity and encoding algorithm employed. The static nature of traditional test signals does not provide true characterization of compressed digital video quality. Natural test scenes that are far more complex than test signals must be used to stress the capabilities of compressed video systems.

Until recently, those working with compressed digital video had to use ad hoc methods or costly, time-consuming and subjective human viewer trials to measure picture quality. With the PQA300 Picture Quality Analysis System, Tektronix makes such subjective measurements obsolete.

The PQA300 allows the designer to perform analysis of picture quality with repeatable objective measurements that directly replicate subjective human visual assessments. This provides invaluable information to enable optimum video compression without compromising picture quality.

The PQA300 measures a 2-second portion of a 5-second video test sequence. The output of the decoder under test is then stored and analyzed with DSP-accelerated hardware on the 2-second sequence. The measurement results in a single numeric value of picture quality called Picture Quality Rating (PQR). Utilizing a human vision system model, JNDmetrixTM, based on years of research by the Sarnoff Corporation, the PQA300 contains the three necessary dimensions for evaluation of dynamic and complex motion sequences: spatial analysis, temporal analysis and full color analysis.

In addition to reporting the Picture Quality Rating, the PQA300 features an animated map whose intensity is related to the perceived differences between the original and the captured image (See Figure 7). This provides invaluable information for evaluation and optimization of digital video compression systems

Conclusion

Pioneering work in MPEG test and picture quality analysis makes Tektronix the obvious choice when testing and evaluating MPEG-2 based decoder designs. As communications standards converge - with audio, data, images and video merging in new networks - innovative test equipment from Tektronix will ensure the integrity of the overall information system. The powerful MTS300 Multi-Standard MPEG Test System and the PQA300 Picture Quality Analysis System make the characterization, test and analysis task much more manageable for the digital designer, while delivering the finest test performance available.

Figure 7: *Map Display.*

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