Using PXI Digital Instrumentation for Video Test Applications

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Introduction

The task of verifying or characterizing video components and systems has always been challenging. Typically, testing of video interfaces has been done with special purpose "box" or card modular instrumentation. Regardless of the video format – digital or analog, there are two fundamental criteria for evaluating any video system; the ability to validate the operation and performance of the interface according to a defined set of standards, and the ability to verify that a design can perform beyond established parameters – i.e. tolerate and recover from anomalies.

The former criteria can often be met using common off the shelf test components to generate standard video content using one of the many defined standards, such as a crosshatch or pin cushion patterns. However, for more complex systems, sometimes it is necessary to exercise a video system using a "real-world" image or input, such as testing a video processor in a missile guidance system. Additionally, to objectively evaluate the performance of these systems, it is necessary to provide not only real-world images, but also do it in a consistent, repeatable and deterministic manner - something that can not be achieved using a video source such as a camera or with off the shelf testers.

The latter criteria - characterizing a video system's ability to tolerate and recover from anomalies, often involves varying electrical or timing properties of the transmitted signal. In this case a test instrument is required that operates beyond the performance boundaries of a normal video generator. Both of these extended criteria, the ability to produce real-world images in a repeatable manner, and the ability to vary timing and electrical properties of the video signal, can be met using digital test instrumentation and specialized interface hardware.

Digital Video Overview

As previously noted, video interfaces and systems can be based on analog or digital transmission standards. This paper limits its discussion to digital video standards and interfaces, which are rapidly replacing analog video interfaces. Digital transmission encodes the video content as a series of digital 1's and 0's, accompanied by vertical and horizontal synchronization pulses, a pixel clock and a data enable. The video data (pixels) may be transmitted in serial or parallel formats. Digital video transmission standards include:

- Serial Digital Video Data Transmission
  - DVI (Digital Visual Interface)
    - *Transition Minimized Differential Signaling (TMDS)*
  - HDMI (High-Definition Multimedia Interface)
    - *DVI with High-bandwidth Digital Content Protection (HDCP) content protection*
  - ATSC (Advanced Television Systems Committee)
    - *MPEG-2 compressed and RF modulated*
- Parallel Digital Video Data Transmission
  - Internal Bus
  - Often Custom

Today, the DVI and HDMI standards have become the mainstream video interface standards for consumer and industrial applications, supporting 24 bits / pixel of uncompressed digital data as well as synchronization and clocking signals. A single DVI link supports a physical data rate of 3.96 Gb/s with a second link offering an enhanced data bandwidth of 7.92 Gb/s. Note that the HDMI standard which builds on the DVI standard and employs a content protection encoding scheme, which requires the use of a licensed decoder to extract meaningful data from an HDMI data stream.

The DVI standard employs Transition Minimized Differential Signaling (TMDS), which transmits Red, Green and Blue data (RGB) and a clock signal using a Current Mode Logic (CML) interface, which is similar to the LVDS interface standard.

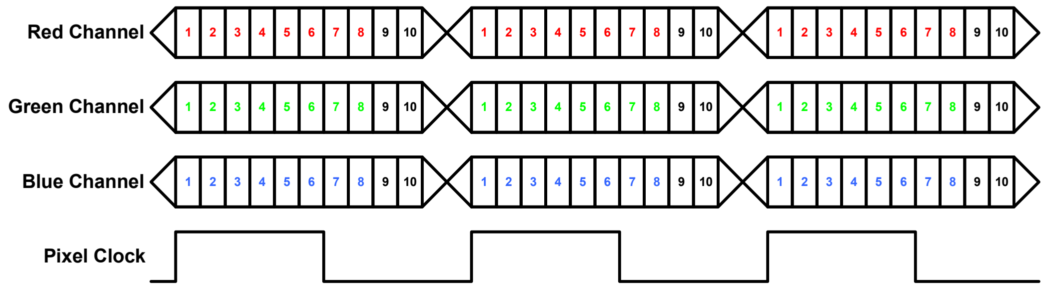

Figure 1 – TMDS Transmission Format

Each of the 3 data channels transmits 10 bits of data and employs a type of 8b/10b encoding (Figure 1). This maintains a DC balance, minimizes electromagnetic radiation, and helps to ensure clock recovery at the receiver regardless of the effects of the transmission media (long cables or inferior cables). The 10-bit TMDS symbol can represent either an 8-bit data value during normal data transmission, or 2 bits of control signals during screen blanking.

A feature of this encoding method is that the data is serialized and transferred at 10x the pixel clock rate, which is also distributed for synchronization purposes. This makes it impossible to use traditional digital test instruments on the actual TMDS data. The instrument would need to synchronize to the distributed pixel clock and then over-sample the RGB channels at 10x the pixel clock rate (750 MHz for 720P video), which exceeds the capabilities of all dynamic digital test instruments. Fortunately, there are commercially available components that will convert between the TMDS format and parallel digital formats that are compatible with today's digital test instruments (Figure 2).

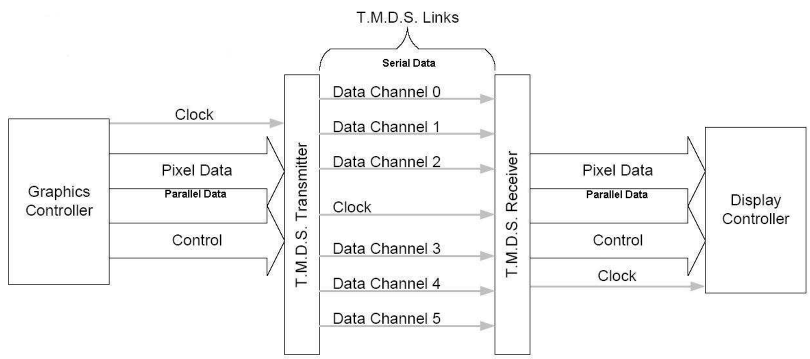

Figure 2 – Parallel-to-TMDS and TMDS-to-Parallel Conversion

Parallel digital video is commonly used internal to a video component or product, such as DVD players, set top boxes and displays; so utilizing the same interface components in a test application that includes TMDS lowers the cost of the system and greatly simplifies the system-instrument interface. Also, converting the TMDS to parallel realigns the data to the pixel clock (one pixel per clock) and slows down the speed of the video bus to a manageable data rate (75 MHz for 720P).
Additionally, not only is the video data translated from a 10x serial stream to a 1x parallel pattern, but the vertical sync, horizontal sync and data enable signals are also extracted from the TMDS stream (Figure 3). These signals are ideal for use as a trigger to a PXI digital instrument for frame capture applications.

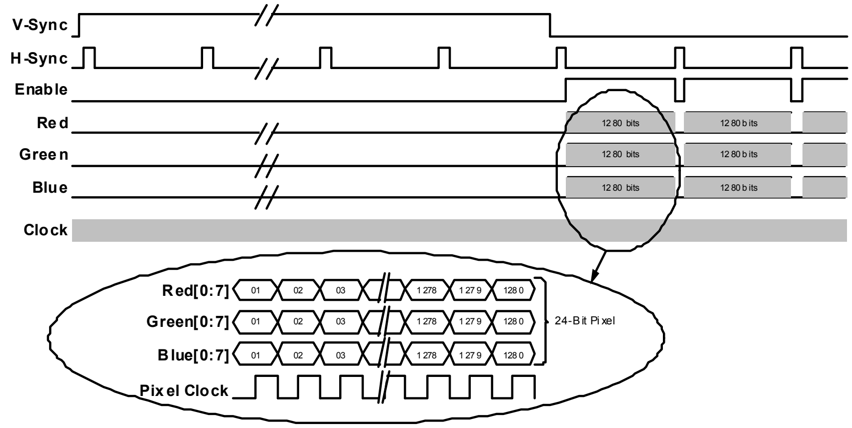

Figure 3 – Parallel Video Data Stream

Digital Video Test Methodology

The testing of video devices and interfaces can employ "standardized" test pattern generators and analyzers to check for compliance to a defined standard. However, the more challenging aspect of video test is to verify how a device responds to a real world image or signal. In this case, the ability to record, store and playback an acquired image becomes a key requirement. And for DVI and HDMI video devices, some type of conversion / adaption hardware will be required to allow the use of commercially available dynamic digital instrumentation. As shown in Figure 4, supporting a DVI interface signal requires de-serializing the signal as well as decoding the 8b/10b encoding scheme. The result is access to 3, 8-bit data channels representing the three primary colors (R, G, & B), horizontal and vertical sync signals, a pixel clock and a data enable signal. These signals can then be recorded, analyzed and played back, providing a known, repeatable digital video source.

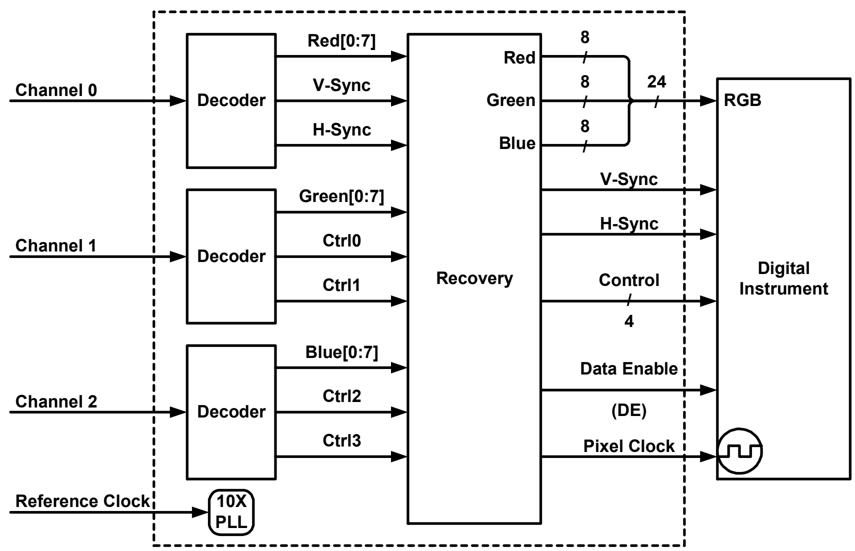

Figure 4 – TMDS to Parallel Conversion (De-Serializing)

To implement a digital video test setup, one needs to understand the requirements and performance needed to support the digital data and clock interfaces detailed in Figure 4. For parallel video data transmission, the minimum clock rate for the digital instrument is typically defined by the pixel clock and, assuming the parallel data is converted from or consistent with TMDS parameters, can range up to 165 MHz. The frequency of the pixel clock is a function of the resolution of the image and the image refresh rate. Some common video formats utilizing TMDS signaling and their approximate pixel clock rates, are:

- 720p (1280 x 720) – 55 MHz to 75 MHz
- 1080i (1920 x 1080) – 62 MHz to 80 MHz
- 1080p (1920 x 1080) – 125 MHz to 162 MHz

Pattern Depth

The pattern depth required by the digital instrument to capture the video image is directly proportional to the number of pixels in the image. Table 1 lists the common TMDS video formats and the approximate pattern buffer depth (vectors) required to store one frame of video. Note the difference between the *number of vectors* needed to store a captured image, and the *memory size* needed to store a captured image – the two are often confused.

Video Format	Number of Vectors / Frame	Memory Size
720p	921,600	2.8 MB
1080i	1,382,400	4.2 MB
1080p	2,073,600	6.2 MB

Table 1 – Video Formats and Vectors / Frame

For applications that digitize an analog signal, the vector depth is determined by the image size multiplied by the sample rate of the ADC. If you were to digitize one field of NTSC video at a 50 MHz sample rate and at a 120 MHz sample rate, you would require the following number of vectors, respectively:

- 833K Vectors @ 50 MHz sample rate
- 2M Vectors @ 120 MHz sample rate

Since NTSC is interlaced, twice the number of vectors listed is required to capture a full video frame (two fields).

Some PXI digital instruments such as the Geotest GX5280 and GX5290 series are designed to allow pattern memory to be reconfigured so that the memory behind unused pins can be made available to the active pins, effectively increasing your pattern depth. Typically, these instruments allow a halving of the channel width with a doubling of vector depth. Such an instrument with 32 channels @ Y pattern depth could be reconfigured to 16 channels @ (Y x 2) pattern depth, or even 1 channel @ (Y x 32) pattern depth. If you were capturing a B&W image with 16-bit resolution and your digital instrument were 32 channels wide by 64M vectors deep, you could reconfigure the instrument to provide 16 channels with 128M vectors depth. Utilizing this otherwise wasted memory provides an obvious advantage when capturing multiple frames of full-motion video.

Channel Width

The channel width requirement of the digital instrument is defined by the resolution of the pixel. A pixel of 16 million colors transmitted across a TMDS link is represented by 8-bits on the Red, Green and Blue channels, resulting in a minimum digital channel width of 24 bits. When you add in channels to capture the V-Sync, H-Sync and Enable signals, and the three TMDS Control signals, a total of thirty channels are required. This is valid for 60 Hz refresh rates.

If instead you are working in an environment utilizing a 72 Hz refresh rate, then you must use the TMDS Dual-Link, which doubles the number of data channels transferred per clock cycle. Employing PXI digital instrumentation that supports 32 channels such as the Geotest GX5280 or GX5290 series offers the ideal configuration since only one card is needed to support operation at 60 Hz. For a dual-link TMDS configuration, a second digital card can be added with synchronization accomplished by the PXI local bus for synchronization.

Clocks and Triggers

When capturing digital video images, it is important that the digital instrument be able to synchronize to the video data stream so that image data is not over sampled or missed. This requires the instrument to be able to accept an external clock, and to trigger on a synchronization pulse – typically V-Sync. Without an external clock, the instrument would need to operate at 2x the measured pixel clock in order to guarantee that the Nyquist limits are not violated – eliminating most digital instruments for high-end video capture applications.

Using the V-Sync to begin the capture process guarantees that the acquisition begins at the beginning of the video frame. Without this capability you would have to start the capture asynchronously and capture two frames of data in order to guarantee that one full frame was captured. The captured data would then need to be post processed, in order to find the V-

Sync signal, strip all the captured information prior to V-Sync, and all the captured information after the end of the frame, in order to produce one complete video frame image.

Electrical Interface, Control and Software Tools

Other aspects to consider include interfacing to the UUT's signals, which may require an instrument with a differential or LVDS interface, or perhaps programmable I/O levels. The application may also dictate the need to control the direction of the instrument's individual I/O channels so that it can be configured for capture during one test sequence, and playback during another test sequence. The ability to loop a captured image during playback could also be critical in order to maintain an active video interface with valid image data.

Central to any automated test application, video or otherwise, is the ability to setup and control the test apparatus. And more specifically, one needs to consider the performance of the overall test system when loading / unloading mega-vectors of memory across the PXI bus. Utilizing efficient memory transfer algorithms and a high throughput control interface, such as PXI or the higher performance PXI Express interface, are important considerations for minimizing overall test times.

Example: Video Test Application

The following examples illustrates how you can use PXI digital instrumentation to interface with commercial, off-the-shelf DVI receivers and transmitters for the purpose of recording and playing back video images. The test components include a custom DVI crosspoint-switching unit / digital interface which interfaces two GX5283 Dynamic Digital I/O instruments – one to record data, the other to play back. A block diagram of the system is depicted in Figure 5.

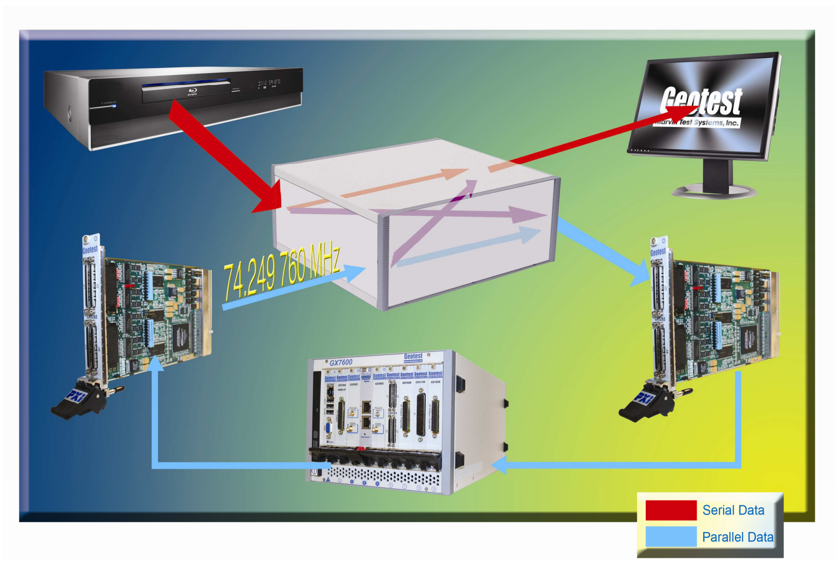

Figure 5 – DVI Cross-Switch and Dynamic Digital Record / Play Back Demonstration System

The Crosspoint-Switch and Digital Interface was designed specifically for use with the Geotest GX528x and GX529x series of digital instruments and supports 24 bits / pixel, 1280 x720 resolution when used with the GX5282 or GX5292 digital instruments (74.249760 MHz clock rate); and1600 x 1200 resolution when used with the GX5283 or GX5293 digital instruments (165 MHz pixel rate). The digital system configuration also supports the use of an external clock input, which offers flexibility for supporting a variety of video formats.

The software environment employs ATEasy – an integrated Test Executive and Test Development suite and supports overall execution and control of the complete application. The application provides the following functionality:

- Frame-Capture of full motion 720p video stream
- Conversion of captured frames to .BMP Format
- Frame Editing
- Editing of .BMP files using MS-Paint application
- Creation of new video frames or editing of existing video frames
- Digital instrument support using DIOEasy – a waveform display and editing tool
- Continuous Playback of Captured/Edited Frame
- Re-Capture of a playback frame

- Pixel by pixel comparison of captured/edited frames

Summary

By combining high performance PXI digital instrumentation in conjunction with off the shelf software tools, a flexible and cost effective digital video test solution can be developed. These capabilities can be used to capture video and playback HD video signals – providing a repeatable and reliable method to verify and test (to the pixel) the integrity of video imaging, transmission, and display products.