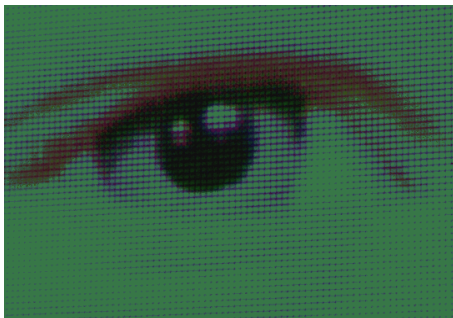
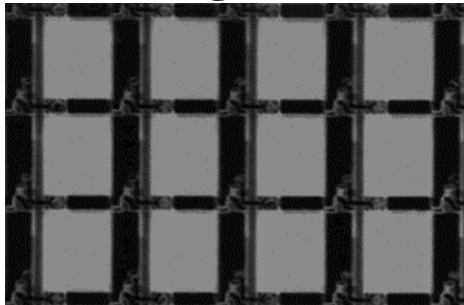


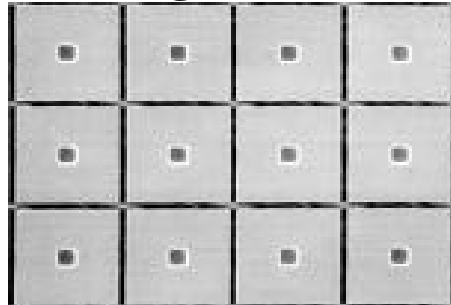


***DLP™ AND DIGITAL DISPLAY INTERFACES:
THE COMPLETE DIGITAL SOLUTION***

Analog LCD



Digital DLP™



See the Digital Difference!

Marc Pyne and Lars Yoder
Texas Instruments
Digital Imaging
June 10, 1999

Introduction

In early 1996, Texas Instruments began shipping Digital Light Processing (DLP) technology into the market place. Back then, the excitement of a new, digital projection technology was embraced by major projector manufacturers as it held promise for breathtaking digital imagery.

But, until recently, there has been no way to take full advantage of DLP as Analog-to-Digital conversion was necessary to connect to today's PC and video devices. Fueled by the recent demand for flat panel monitors, digital connectivity technology and standards have been developed to a point where the preferred candidates are ready to be widely adopted by both the computer and projector industries. Once in place, 100% digital connectivity to a computer and other digital sources like a digital camcorder, DVD player or digital camera will be possible. Liquid Crystal Display (LCD) and Cathode Ray Tube (CRT) display technologies are unable to preserve this digital data flow as they make an analog conversion just before the information is displayed. Unlike the analog predecessors, DLP is inherently digital. This means DLP displays can eliminate the last analog conversion, providing the final link to a complete digital video infrastructure.

Along with the benefits of digital technology, this paper discusses the current status of digital interface standards between PCs, flat panel monitors, and digital projectors. Advantages of a digital interface over the legacy analog interface, comparisons of underlying digital interface technologies, a review of the major digital interface standards, and an outlook for the future of digital connectivity and DLP is also presented.

Why Digital Is Better

The world is going digital, and video technology is following that trend. Digital satellite systems, DVD players, digital camcorders and cameras, and soon HDTV, combined with PC graphics, games and web

content, offer a huge amount of digital source material. This data is processed digitally, and it is a natural conclusion that to complete the digital infrastructure the data should be transmitted and displayed digitally. VESA (Video Electronics Standards Association) and other standards organizations have been pushing the need for a PC digital interface for years, and now with the rapid drop in cost of digital flat panel monitors and projectors, there is a surging interest in the advantages of a PC digital interface.

Using a legacy analog VGA 15-pin connector to couple a PC with a digital display has many obvious disadvantages. The inherently digital PC data must be converted to an analog signal, transmitted over the connector, then converted back to digital inside the display. This adds unnecessary cost and complexity to the display and the PC, and also reduces video quality as noise accumulates from all parts of the analog signal path. With a correctly implemented digital interface, the data viewed on the display is exactly the same as the original source.



Figure 1: Analog vs. Digital Interface

According to some digital monitor manufacturers, going digital is 5-10% cheaper than staying analog. It has been estimated that 60-75% of monitors sold today are bundled with a PC. As more flat panel monitors and digital projection displays are sold bundled with a PC, this provides the perfect setting for rapid acceptance of a digital interface.

Digital Interface Technologies

There are three main technologies on which the current proposed digital interface standards are based: TMDS, LVDS and GVIF.

1) **Transition Minimized Differential Signaling (TMDS)** is the generic definition of the

PanelLink™ interface technology developed by Silicon Image, Inc. This interface is implemented using an encoder and serializer to format the digital RGB data, which is then transmitted on three twisted pairs, with an additional twisted pair for the Clock signal. Transition-minimized, DC-balanced coding is used for reliable, low-power and high-speed transmission. The low-swing differential voltage (~500mV) minimizes signal degradation from EMI cross-talk. Since the clock is only used as a frequency reference, and not to latch data, and together with multi-channel synchronization, this transmission scheme provides excellent clock skew insensitivity. Three times oversampling in the receiver is used to recover the data.

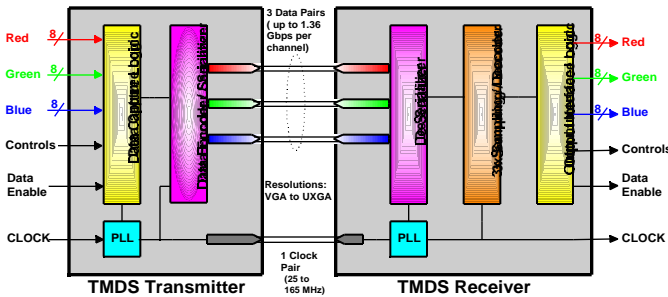


Figure 2: TMDS Digital Interface Block Diagram

It is scalable to UXGA (1600x1200) and beyond, with transmissions over 10 meter on shielded twisted pair cable and more than 2km on fiber channels.

2) Low Voltage Differential Signaling (LVDS) has long been the de facto interface format for notebook PC's. FlatLink™ is TI's name for their LVDS-compliant set of devices, and FPDLink™ is National Semiconductor's corresponding brand name. LVDS is an open standard defined by two key standards approved in November 1995 (ANSI/TIA/EIA-644) and March 1996 (IEEE-1596.3). This protocol is similar to TMDS in that it uses low-swing differential voltages and DC-balancing to provide reliable high-speed transmission of data. LVDS differs from TMDS in that it has no transition control, and data recovery is dependent on the clock signal, and is thus more susceptible to skew. LVDS has the advantage of better EMI

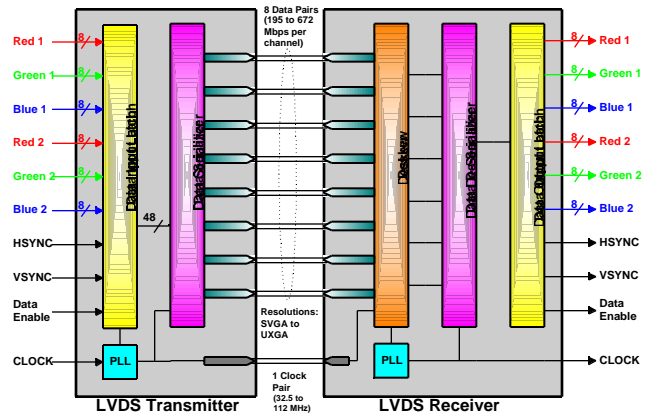


Figure 3: LVDS Digital Interface Block Diagram

characteristics since it does not include the use of power loops as in TMDS.

LVDS currently supports resolutions up to UXGA and beyond, but requires 8 twisted pairs in dual pixel mode operation, plus one clock pair to latch the data, increasing the width of the connector.

3) Gigabyte Video Interface (GVIF) is a digital interface proposed by Sony. The newly developed encoder translates 24-bit RGB data and 6-bit SYNC/CNTL signals into a 30-bit word for serial transmission over just one differential pair using a 1-bit serial 1.95Gb/s transceiver chip set.

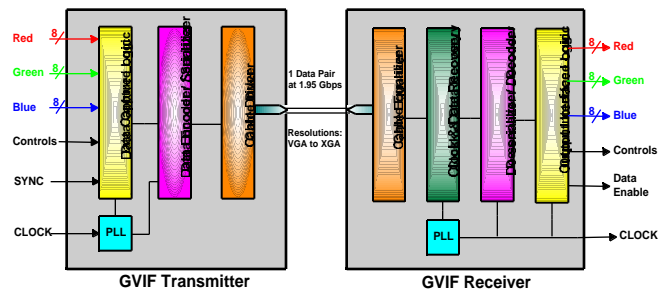


Figure 4: GVIF Digital Interface Block Diagram

It is designed to keep a stable DC balance, and to keep a high data transmission density in the serial data stream to enable easy data and clock recovery at the receiver. Transmission of XGA data over a 20m cable has been demonstrated, but XGA might be the resolution limit. Recent improvements from Sony reduced power consumption from 1.8W to 480mW.

In summary, all three interface protocols can support potential digital display interface standards. TMDS offers the advantages of excellent skew insensitivity and wide industry support. LVDS is the proven de facto standard for notebook interfaces, and offers multisource availability. With its single data channel and 20m capability, GVIF offers a long, thin cable that would be attractive for some applications.

The Competing Standards

A number of standards, each with unique connectors, have been developed which are based upon the above interfaces. The past year has seen a lot of turmoil and confusion in this standards arena. Among the standards competing to be the industry wide accepted digital interface are: Plug and Display, Digital Flat Panel, Open LVDS Display Interface, Digital Interface Standards for Monitors, and Digital Visual Interface.

1) Plug and Display (P&D) is a TMDS-based standard promoted by VESA. Late in 1995, a DLP-based monitor project started between TI's Digital Imaging Venture Project Business Group and IBM. Part of the project was the development of a digital monitor interface. Development of this interface continued early in 1996 under VESA, resulting in the P&D Standard. Version 1.0 of the standard was officially released in June 1997. P&D is a 34-pin interface with a MicroCross™ type connector that provides both digital and analog interfaces for video data, together with serial bus options. A digital-only version of the connector has 30 pins.

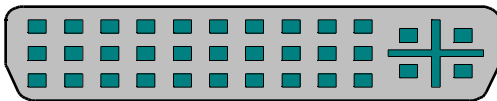


Figure 5: P&D Connector

The general idea behind this standard is that a digital or analog monitor would be connected to a PC with the P&D connector, then with USB support, the mouse, keyboard, printer and even digital audio would plug into the monitor. Support for IEEE-1394 would provide

options for other peripherals such as DVD players, digital cameras and other SCSI devices.

VESA's Extended Display Identification Data (EDID) and Display Data Channel (DDC) standards for display configuration and detection are also supported in P&D. These two standards were developed in 1994 as part of the Plug and Play initiative. EDID defines information stored in the display that describes the display to the host. The current version contains ID and product information, interface and device parameters, and timing descriptions. DDC is the interface that is used to transmit the EDID information to the host. VESA is working to make EDID implementation simpler and more clearly defined.

IBM has been one of the primary backers for P&D, and they currently offer the T55D model flat panel monitor with a P&D interface.

An offshoot of the P&D effort was the VESA PC Theatre Interconnectivity Standard - Version 1, released in September 1998. This standard, which is based on P&D, allows PC and consumer electronics manufacturers to produce compatible PC Theatre computer and display products that work together as a single system. This initiative's main problem is that there exists a different consumer failure tolerance between a PC and a TV. Some of the first PCTV combos suffered from crashes during normal TV viewing. This and other factors led to the demise of first generation PC Theatre systems.

2) Digital Flat Panel (DFP) is also a TMDS-based standard promoted by VESA. Work on the DFP interface started early in 1998 as an initiative under an open industry forum, the DFP Working Group, made up of 13 companies and led mainly by Compaq. The DFP spec was released in August 1998, and it was presented to VESA as a standard proposal. VESA quickly accepted the proposal and started a committee to further develop the standard. Version 1.0 of the standard was released on February 25, 1999.

DFP was originally intended as a transition or "bridge" connector from the analog

VGA connector to the digital P&D connector. It was designed as a simple, purely digital connector with only the essential components necessary for digital display functions. This would allow companies to offer the option of the standard VGA interface and a low-cost digital interface. DFP was designed to be electrically and logically compatible with the P&D interface, with many similar features including support for Hot Plug detection, and EDID/DDC support.

The physical interface for DFP is based on a 20-pin MDR connector, and has been verified for SXGA data over 5m of cable. The DFP connector takes up 1.31 inches of board edge space, as compared to 1.60" for P&D and 1.25" for VGA. Compaq has shown the earliest market presence in terms of implementing the DFP standard. In 1998, their line of Presario PC's with an ATI video card and several flat panel monitors offered DFP support. Many other display and graphics card manufacturers now also offer products with the DFP interface.

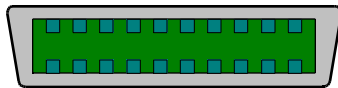


Figure 6: DFP Connector

3) Open LVDS Display Interface (OpenLDI) is based on the LVDS technology. An industry consortium known as the Visual Interface Consortium International (VICI) was formed in mid 1998 to promote the LVDS interface technology. VICI originally consisted of about 15 companies, led mostly by National Semiconductor. NSC released version 0.9 of the specification on February 24, 1999.

LDI has a 36-pin MDR connector and uses a dual pixel mode to support resolutions up to QXGA and includes USB and DDC/EDID support.

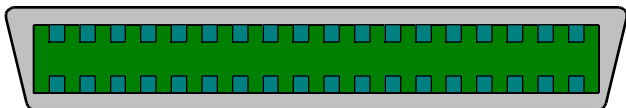


Figure 7: LDI Connector

Silicon Graphics and Number Nine teamed up to release in January 1999 an NT workstation with the 1600SW flat panel display that uses LDI for its interface. This is currently

the only desktop digital display on the market with an LDI interface.

4) Digital Interface Standards for Monitors (DISM) is a group of standards developed by Japanese panel, connector and monitor manufacturers. The group, which has grown to 23 member companies, became a working group under Japan Electronic Industry Development Association (JEIDA) in May 1998. Version 1.0 of the standards was released on February 26, 1999 as JEIDA-59-1999.

DISM is different from the other proposed standards in that it accepts all three competing technologies, TMDS, LVDS and GVIF, as its standard data-transfer formats. The group of proposed standards includes 6 different digital interfaces with 14, 20, 26 and 36-pin connectors.

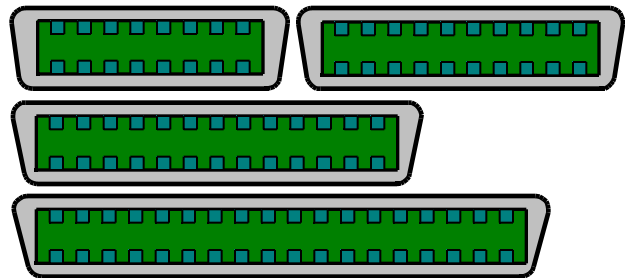


Figure 8: DISM Connectors

All are MDR connectors and some include USB support. The first target of these standards is to realize a data transfer of UXGA resolution at 158.4MHz over a 10m cable. Interfaces for other flat panels, such as plasma displays, LED's and DMD's are next on DISM's agenda.

5) Digital Visual Interface (DVI) is the newest contender in the digital interface arena. DVI is the recently announced standard being developed by the Digital Display Working Group (DDWG). This working group is driven by Intel and was announced at the Intel Developer Forum (IDF) in September 1998. The goal of this consortium, which also includes Compaq, Fujitsu, Hewlett Packard, IBM, NEC and Silicon Image, was to quickly crank out a comprehensive standard and technology roadmap for a "universal" digital display interface. Revision 1.0

of the specification was released April 2, 1999. It is expected that DVI products will appear in the market later this year.

Two other levels also exist within the DDWG. The first is the Participants Level, which consists of companies who have early access to standard revisions. They can also provide feedback to the Promoters about the standard. Texas Instruments is a member of this level. The third level is the Adopters Level. This is for any company who plans to use the standard in their products.

DVI is a TMDS-based interface that will be electrically compatible with both DFP and P&D, but with claims of offering a more complete solution than the VESA standards. DDWG hopes that this standard will unify a very divisive market by offering an interface to solve today's problems, but also plan for the long-term needs of the industry. It will resolve high level issues such as frame-rate control, copy protection, color management and control of scaling and gamma correction. It will also solve current IP concerns since it will be based on "open intellectual property." This means that participating companies agree to royalty-free, reciprocal licensing of patents and other forms of intellectual property that are needed to implement the interface portion of the standard.

There are two versions of the DVI connector. The integrated version (DVI-I) uses a 29-pin MicroCross™ connector and includes both digital and analog RGB connections. The digital only version (DVI-V) has 24 pins and would initially be packaged together with a VGA connector to offer both digital and analog connections. Both connectors also support

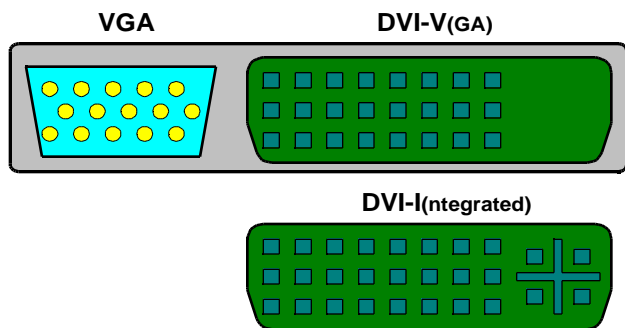


Figure 9: DVI Connectors

DDC/EDID standards.

The DVI connector is similar to the P&D connector in shape and layout. The main difference is that the P&D support for USB and 1394 is dropped to support two sets of TMDS channels in DVI. The first set of TMDS channels supports resolutions up to UXGA (165 MHz). Beyond this specified "cut-over" frequency, both sets of channels are used to support pixel bandwidths to 330MHz and higher. Dual channel mode can also be used to support high color depth (greater than 24 bits of color per pixel.) With the dual channels, DVI can easily support more than 5 million pixels per second.

Standard	Supporting Organization	Protocol	Resolution Limit	Pin Count	Cable Length	Products In Market
P&D	VESA	TMDS	UXGA	30/ 34	5m	1
DFP	VESA	TMDS	UXGA	20	10m	20+
LDI	VICI	LVDS	QXGA	36	10m	1
GVIF	Sony	GVIF	XGA	14	20m	?
DISM	JEIDA	All 3	UXGA	14- 36	10m	?
DVI	DDWG	TMDS	QXGA	24/ 29	10m	3Q99

Table 1: Comparison of Digital Interface Standards

The Future: A Universally Accepted Digital Interface

Currently it's like the old VHS versus Betamax question. The dueling standards all have advantages and disadvantages, and as various companies pick sides, much of the debate is political in nature. LVDS and GVIF are viable solutions for certain market segments, but in the desktop PC industry, TMDS has emerged as the preferred interface technology. Now the industry is waiting to see which TMDS-based standard will come out on top.

DFP has the advantage of being a simple, low-cost solution with products already out on the market, but it can only handle resolutions up to UXGA. P&D offers a very comprehensive

interface, but is considered by many to have too many implementation options; a simplified version may serve as a monitor-side connector. The DVI standard has generated a huge amount of industry interest, and many manufacturers have committed to develop products with this interface. Over 90 companies have submitted participant agreements to the DDWG. Supporters of DVI claim it will cover the digital display interface needs for the next ten years.

Summary

Many companies have adopted a wait-and-see attitude before committing to any given interface. Others will continue with their current development path, and depend on the use of adapter dongles to support different interfaces while preserving the installed product base.

Adoption of a universal digital display interface standard will be a gradual process. But regardless of which standard is chosen, Digital Light Processing by Texas Instruments is well positioned to preserve the quality and clarity of digital information. DLP completes the digital video infrastructure and delivers on the promise of “digital is better.” With DLP, you can see the digital difference!

Contact Information

Marc Pyne

Technology Development
Digital Imaging
Texas Instruments Inc.
P.O. Box 869305, M/S 8477
Plano, TX 75086
phone: (972) 575-0011
email: marc-pyne@ti.com
<http://www.ti.com/dlp>

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Acronym Glossary

ANSI	American National Standards Institute
CRT	Cathode Ray Tube
DDC	Display Data Channel
DDWG	Digital Display Working Group
DFP	Digital Flat Panel
DISM	Digital Interface Standards for Monitors
DLP	Digital Light Processing™
DMD	Digital Micromirror Device™
DMI	Digital Monitor Interface
DSS	Digital Satellite System
DVD	Digital Versatile (Video) Disk
DVI	Digital Visual Interface
EDID	Extended Display Identification Data
EIA	Electronic Industries Association
EMI	Electro-Magnetic Interference
GVIF	Gigabyte Video Interface
GTF	Generalized Timing Formula
HDTV	High Definition Television
IDF	Intel Developers Forum
IEEE	Institute for Electrical and Electronics Engineering
JEIDA	Japan Electronic Industry Development Association
LCD	Liquid Crystal Display
LDI	LVDS Display Interface
LSB	Least Significant Bit
LVDS	Low Voltage Differential Signaling
MDR	Mini D-Ribbon
MSB	Most Significant Bit
P&D	Plug and Display
TIA	Telecommunications Industry Association
TMDS	Transition Minimized Differential Signaling
VESA	Video Electronics Standards Association
VICI	Visual Interface Consortium International

Display Resolutions (columns x rows)

VGA	640 x 480
SVGA	800 x 600
XGA	1024 x 768
SXGA	1280 x 1024
UXGA	1600 x 1200
HDTV	1920 x 1080
QXGA	2048 x 1536