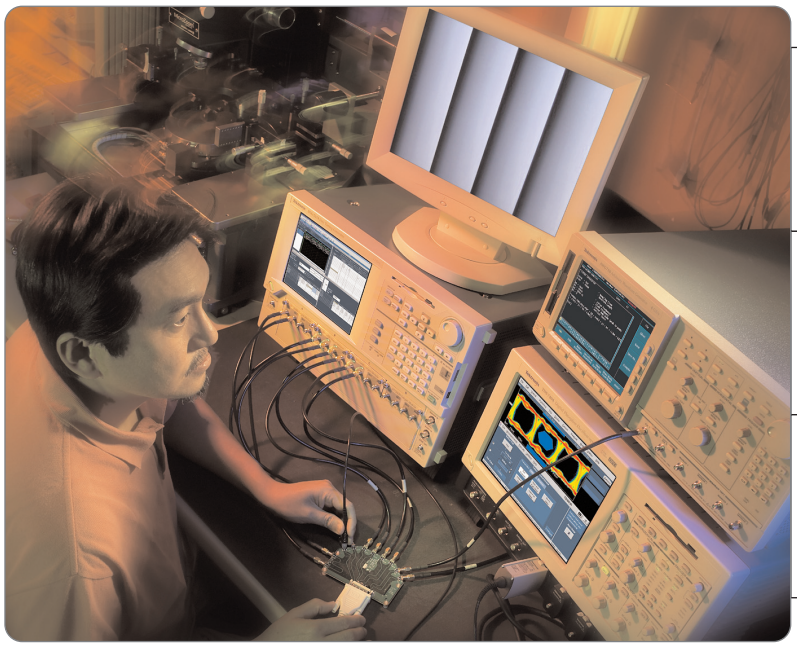
Master Signal Generation for DVI/HDMI with DTG5000 Series Data Timing Generator



COMPUTING
COMMUNICATIONS
VIDEO

▶ DTG5000 Series provides the capability of stress test for high-definition digital display systems per industry standards

Introduction

Higher-end displays are rapidly moving to digital or dual-interface designs, and manufacturers need new tools to ensure that their products will be compatible and will operate at peak performance under less-than ideal conditions. Compliance with digital interface standards for display products is mandatory for their acceptance in commercial and consumer markets.

Until recently, the testing of display interfaces was limited to the use of custom data sources and tedious manual methods – making it impractical to verify performance for the large variety of test conditions specified in compliance standards. The DTG5000 Series of high performance data generators solves that problem by providing a full complement of highly accurate data signals and the ability to precisely control their parameters for automated testing of receiver products over a wide range of operating conditions. Simple, graphical controls and a set of industry standard adapter accessories integrate these new generators into complete test systems quickly and easily.

History of DVI and HDMI

For many years, the only video displays for computers and home electronics were CRT devices that display analog video signals.

For computers, digital video data had to be converted to an analog RGB signal and transmitted to the CRT display via a Video Graphics Array (VGA) interface. Analog signals are difficult to shield and CRT's are bulky, high power consumers with limited range and resolution. The demand for more compact packages, lighter weight and lower power has led to the development of digital displays such as LCD and plasma devices for both portable and desktop applications. The evolution of high definition TV has driven a similar demand for high end flat panel digital displays and new audio/visual devices for the home electronics market.

Computer manufacturers wanted a new interface to support data transfer to the new flat panel displays directly in digital format. While there were many contending interface standards for PC's (VESA, LDVS, DFP, etc), none of had them adequately addressed the high bandwidth/high resolution needs of emerging new products. The Digital Display Working Group (DDWG)*1, an open industry group of over 200 companies lead by Intel, Compaq, Fujitsu, Hewlett Packard, IBM, NEC and Silicon Image, addressed those requirements with standards for digital connectivity for high-performance PCs and digital displays. DDWG introduced DVI (Digital Video Interface), a digital interface that overcomes the performance limitations of analog CRT systems.

*1 Digital Display Working Group at www.ddwg.org

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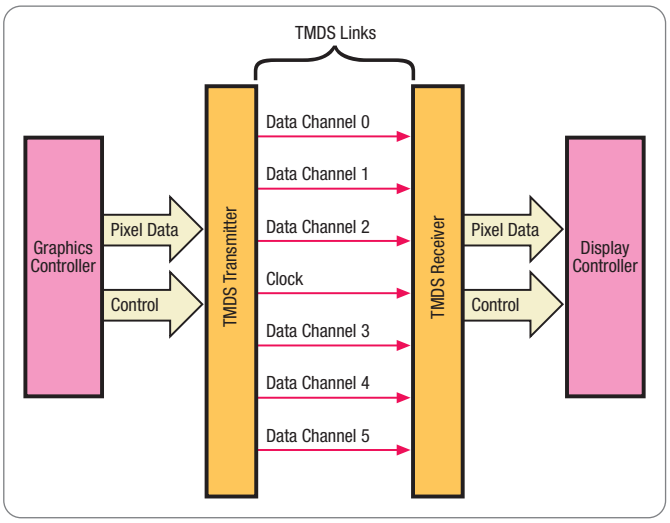
On the home electronics side, manufacturers have the same needs to interface with new digital displays with the added requirement to combine video and audio into a single digital interface for use with digital versatile disc (DVD) players, digital television (DTV) players, set-top boxes, and other audio/visual devices. Backed by some of the industry's biggest names, High-Definition Multimedia Interface (HDMI) enables true high definition audio/video content for consumers. HDMI combines High Bandwidth Digital Content Protection (HDCP) with the core technology of Digital Visual Interface (DVI). HDCP is an Intel specification used to protect digital content transmitted and received by DVI-compliant displays.

HDMI supports standard, enhanced, or high-definition video plus standard to multi-channel surround-sound audio. It features uncompressed digital video, a bandwidth of up to 5 gigabytes per second, one small connector instead of several cables and connectors, and communication between the video source and the DTV. HDMI development is overseen by the HDMI founders*2 that includes Sony, Hitachi, Panasonic, Silicon Image, Philips, Thomson and Toshiba as members.

DVI/HDMI Technical Characteristics

DVI uses the patented PanelLink*3, a high-speed serial interface that uses transition minimized differential signaling (TMDS) to send data to the display. TMDS signals transition between “on” and “off” states using an algorithm to minimize the transitions and avoid excessive levels of electromagnetic interference (EMI) on the cable. The differential signals are +3.3 Volts, terminated in 50 Ω with nominal amplitude transitions of 500 mV (from +2.8 V to +3.3 V).

The basic TMDS transmission line is made up of three data channels and a clock channel. Data is comprised of 8 bit pixels (256 levels) in each of three channels (R/G/B) that are encoded into ten bits to minimize transitions and to remove the DC component. The signals have rise times on the order of 100 picoseconds. A pair of TMDS lines is used to achieve the higher data rates. Figure 1 shows the flow of pixel data from the graphics controller in a PC or home electronics device to the digital display.



▶ ***Figure 1.*** *TMDS Logical Links*4.*

TMDS data rates are from 22.5 Mpps to 165 Mpps (or up to 1.65 G bits per second at maximum clock rate of 165 MHz), and data rate depends on the display resolution. The relationships of display resolution, bit rate and clock frequency are shown in the Table 1.

Table 1. Relationships of display resolution, bit rate and clock frequency

Standard	Display Resolution	Data Bit Rate	Clock Frequency
VGA	640 x 480	252 Mb/s	25.2 MHz
SVGA	800 x 600	400 Mb/s	40 MHz
XGA	1024 x 768	650 Mb/s	65 MHz
SXGA	1280 x 1024	1080 Mb/s	108 MHz
UXGA	1600 x 1200	1620 Mb/s	162 MHz
640 x 480p	640 x 480	252 Mb/s	25.2 MHz
720 x 480p	720 x 480	270.27 Mb/s	27.027 MHz
576p	768 x 576	270 Mb/s	27 MHz
720p	1280 x 720	742.5 Mb/s	74.25 MHz
1080 i	1920 x 1080	742.5 Mb/s	74.25 MHz

*2 High-Definition Multimedia Interface Group at www.hdmi.org

*3 Patent held by Silicon Image, Inc

*4 Digital Visual Interface specification, revision 1.0, 4/2/99, DDWG

HDMI uses physical interfaces that are similar to DVI, with the addition of a DTV format and content copyright protection. It combines an audio signal with the video signals and it specifies a smaller connector that is more appropriate for home electronics devices. The new standard is backward compatible with analog VGA and uses plug and play architecture.

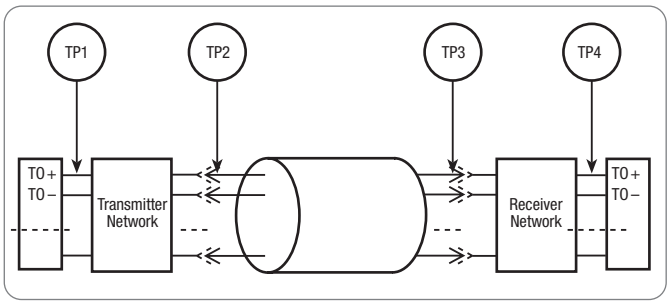
Compliance Testing Tools and Solutions — DTG5000 Series

The goal of compliance testing is to ensure interoperability among the many hundreds of different DVI devices from dozens of manufacturers. By conforming to DDWG/HDMI furnished specifications, a device manufacturer can be confident that his products will be accepted in the marketplace.

Testing should also ensure that the designs are robust enough to withstand the somewhat harsh treatment they can expect to receive in use. As the new displays become more rugged, the devices that use them will be found in less protected environment than they have in the past. Therefore, devices should be tested to comply with standards requirements under a variety of operating conditions, and testing parameters should cover ranges beyond the strict standards limits. Table 2 summarizes the tests used for DVI compliance.

Table 2. DVI/HDMI Test methods

Transmitter (Source device) test
Eye Diagram Mask tests
Jitter measurement
Skew measurement
Rise and Fall time measurement
Receiver (Sink device) test
Receiver sensitivity test
Skew tolerance test
Jitter tolerance test
Cable test
Eye Diagram Mask tests
Skew measurements
Impedance measurements (TDR)



▶ ***Figure 2.*** *Elements of a DVI/HDMI Display Data Transmission System.*

Product developers want to perform self-compliance testing – they clearly have the incentive to ensure interoperation and compatibility. However, they have been skeptical of conventional test methodology that relies heavily on human intervention and judgment. Many of the tests are subjective and prone to misinterpretation, and the methodology has been inherently costly and slow.

Figure 2 illustrates the three major elements of a DVI/HDMI display interface data transmission system – transmitter, cable and receiver. Transmitter signal characteristics can be effectively characterized by measuring signals at test points TP1 and TP2 to ensure that they are within standard timing, jitter and voltage margins. However, measurements of the cable and receiver characteristics (TP2, TP3 and TP4) are more challenging. A stable, accurate and controllable data source is needed to generate the test signals.

One of the key barriers to a practical testing methodology has been the lack of a versatile yet accurate source of data signals. Data signals had been generated by sets of custom devices that covered narrow ranges and/or test conditions. The DTG5000 Series combines the power of a data generator with the capabilities of a pulse generator to provide a wide range and variety of highly accurate test signals for multiple channels using simple graphic controls. The DTG5000 Series is configured from a mainframe and plug-in output modules to provide the desired number and variety of single-ended and differential channels to suit each set of test needs.

The DTG5274 is the mainframe of choice for DVI/HDMI applications because it supports 2.7 Gb/s data rates and offers controllable voltage level, timing, and jitter parameters. Output terminals of the plug-in channel modules are SMA connectors that can easily be converted to DVI/HDMI connectors using optional test adapter accessories.

Stress Testing Receivers

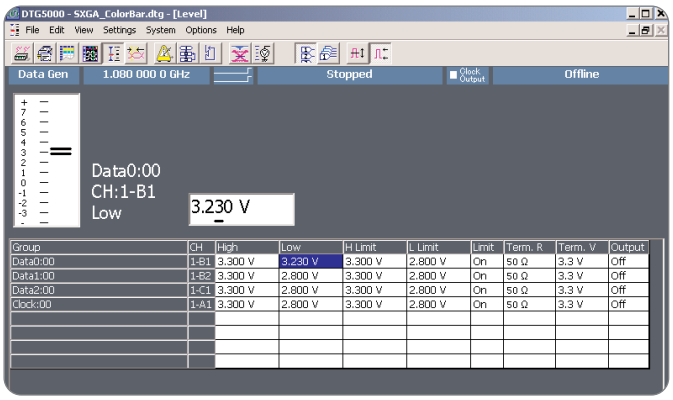
Stress testing is the process of subjecting receivers to a wide range of signals in order to verify their ability to tolerate deviations in voltage, timing and jitter and still operate properly. Accurate, stable test signals must be generated to cover each of the ranges specified in the standards in order to ensure compliance.

Receiver sensitivity

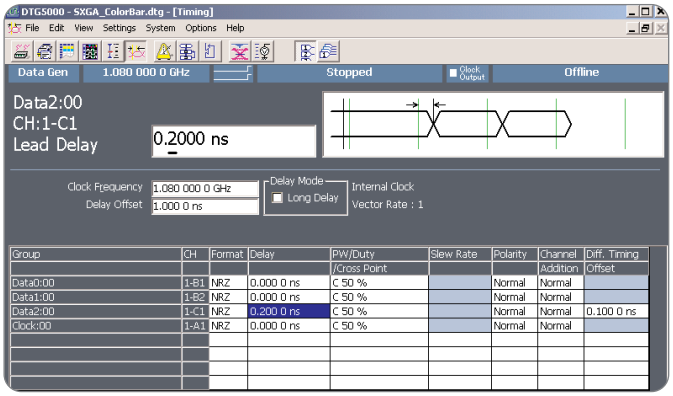
Data signals are varied over a specified range of levels to test the display equipment's ability to tolerate reduced signal voltage. The DTG5274 provides more quantitative and reproducible test results than previous methods that used multiple length cables to attenuate the signals. By providing continuous control of voltage levels in multiple channels, the DTG5274 easily covers all levels within the operating range of the receiver (and beyond) to allow a complete sensitivity analysis. Figure 3 illustrates how easily the sensitivity test signals can be set up in the generator using its graphic voltage setup menu.

Skew between channels (Inter Pair Skew)

DVI/HDMI specifies tolerances for acceptable skew between the four channels in a DVI/HDMI signal – CLOCK, DATA0, DATA1 and DATA2. Receiving equipment must be able to function without error as long as the skew is within the tolerances. The DTG5274 is able to change skew between specified channels in specified increments by simply adjusting the delay value in the timing setup menu (see Figure 4).



▶ ***Figure 3.*** *Voltage setup menu in DTG5274.*



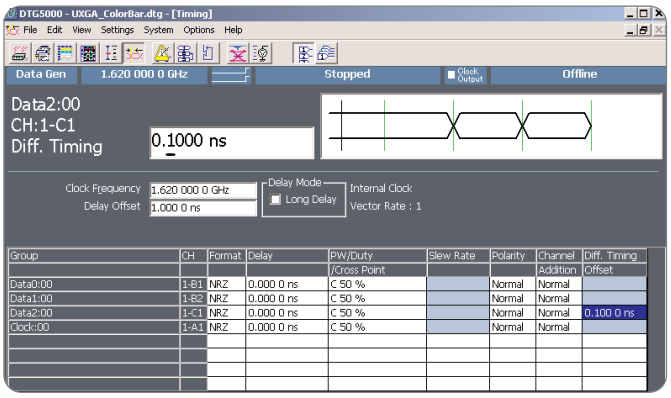
▶ ***Figure 4.*** *Timing setup menu in DTG5274.*

Skew between differential pairs (Intra Pair Skew)

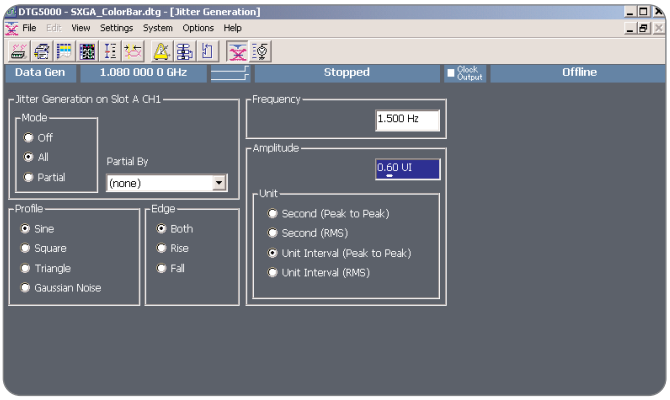
The DVI/HDMI interface uses differential transmission lines, and the standards specify tolerances for timing offset between the differential signals. Each DTGM30 output module for the DTG5274 generates two sets of complementary signals. Two channels of DTGM30 (usually Ch1 (+) and Ch1 (–)) are used to output a single differential pair. Ch1 (+) and Ch2 (+) are used in the Differential Timing Offset function to generate adjustable Intra Channel Skew. Figure 5 illustrates a typical intra-channel skew setup menu.

Jitter tolerance

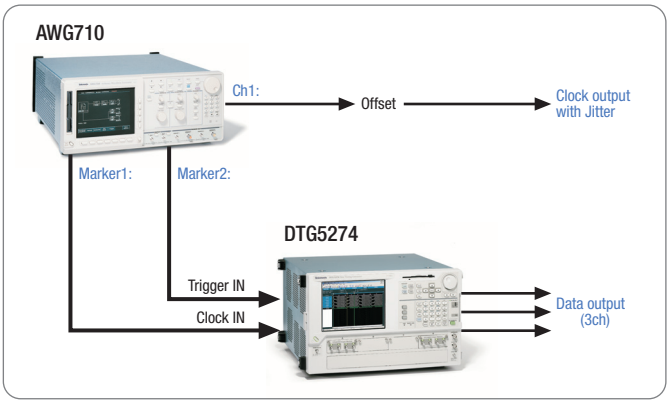
One of the most critical characteristics of a receiver is its tolerance to specified levels of jitter in the transmitted clock signals. The DTG5274 can generate jitter on the DVI/HDMI clock signal for jitter values of less than 1.5 MHz without the need for external equipment using a simple setup menu (see Figure 6). To test jitter tolerance at frequencies above 1.5 MHz, or to evaluate two elements of jitter frequency, an AWG710 arbitrary waveform generator can be connected to the DTG5274 as shown in Figure 7. The combination provides jitter frequencies greater than 10 MHz and multi frequency jitter signals, also defined with simple setup menus.



▶ ***Figure 5.*** *Differential Timing Offset setup menu in DTG5274.*



▶ ***Figure 6.*** *Jitter setup menu in DTG5274.*



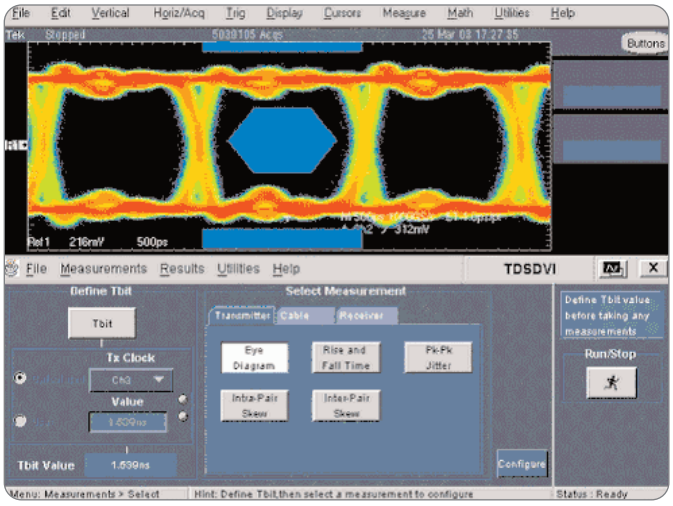
▶ ***Figure 7.*** *Connecting an arbitrary waveform generator to increase range and variety of jitter signals.*

```
'Jitter Generation'
clock    = 3.7125e9    'Sampling Clock
size     = 148500      'Waveform Length
k00      = 1e6         'Jitter Frequency 1
k01      = 10e6        'Jitter Frequency 2
k1       = 74.25e6     'Clock Frequency
k20      = 500e-12     'Jitter Amplitude 1
k21      = 500e-12     'Jitter Amplitude 2
k3       = 5           'Vertical Scale

"PM-740M-7M1M.wfm" =
k3 * sin(2 * pi * k1 * (time + k20/2 * sin(2 * pi * k00 * time)
+ k21/2 * sin(2 * pi * k01 * time) ))

"output.wfm".marker1 = "marker.wfm".marker1  'Clock for DTG5274
"output.wfm".marker2 = "marker.wfm".marker2  'Trigger for DTG5274
```

▶ ***Figure 8.*** *The setup file for AWG710 to generate jitter with two frequency elements.*

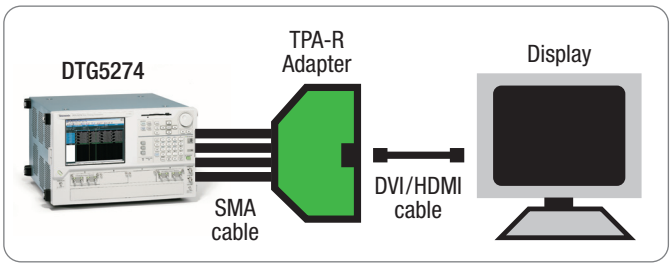


▶ ***Figure 9.*** *Typical eye mask test result.*

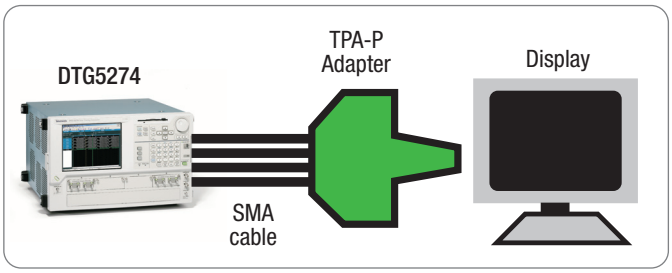
Evaluation of DVI/HDMI cables

DVI/HDMI cables can be characterized in two ways – TDR and eye pattern testing using data signals. TDR techniques use digital sampling oscilloscopes to measure the impedance characteristics of cables with great precision, but this type of test cannot verify waveform quality. The DTG5274 can produce standard DVI/HDMI signals for use as test data in eye mask testing to reveal the true waveform performance of the cable.

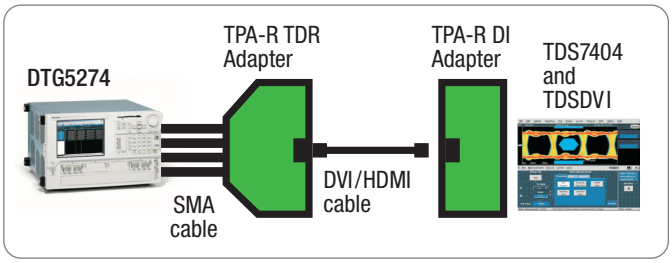
First, transmitter performance can be verified by inserting the test data signals ahead of the transmitter (point TP1 in Figure 2) and performing the eye mask test at the output (TP2). Once transmitter performance is confirmed, the test data signals can be inserted at the beginning of the cable (TP2) and eye mask testing performed at the end (TP3). If jitter violates the eye mask, the cable has insufficient bandwidth. If the signals have insufficient level, the cable loss is too high.



▶ ***Figure 10.*** *Connection between DTG5274 and display using a DVI/HDMI cable and a TPA-R adapter.*



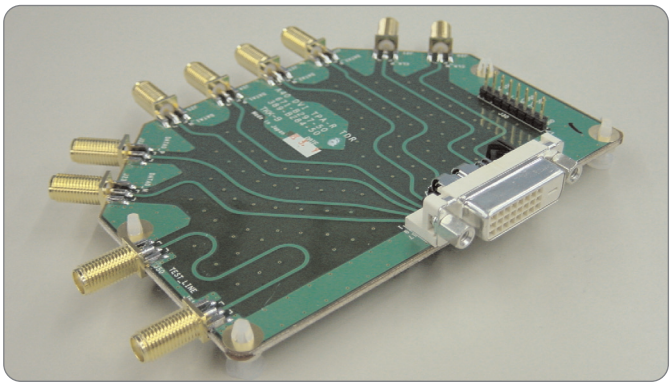
▶ ***Figure 11.*** *Direct connection between DTG5274 and display using a TPA-P adapter.*



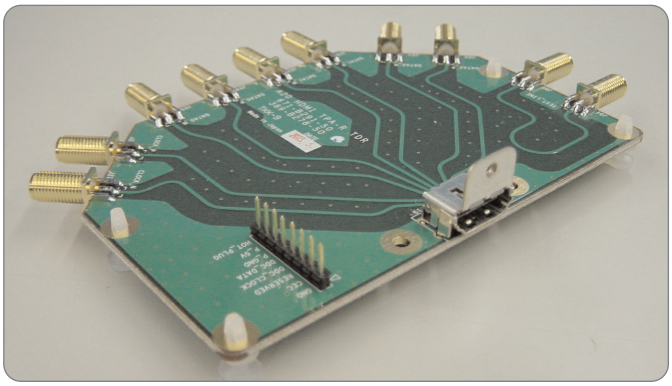
▶ ***Figure 12.*** *Connections for characteristic measurement of DVI/HDMI cables using a TPA-R TDR adapter and TPA-R differential adapter.*

Getting Connected

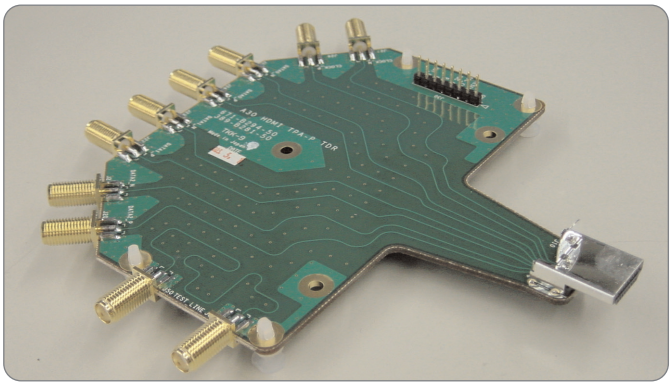
Reliable connections are the key to maintaining precision and signal integrity – especially at high data rates. The DTG5000 Series offers a complete suite of interconnection options for DVI/HDMI devices (see Figures 10-12).



▶ ***Figure 13.*** *DVI TPA-R adapter.*



▶ ***Figure 14.*** *HDMI TPA-R adapter.*



▶ ***Figure 15.*** *HDMI TPA-P adapter.*

Three types of adapters are used in the connections. One is a TDR adapter that converts an SMA connector to DVI/HDMI, one is single end adapter to measure with active probes, and another is the differential adapter to measure with differential probes. Adapters are supplied in sets for HDMI TPA-R and TPA-P and for DVI TPA-R

Conclusion

Compliance testing of display interfaces is no longer limited to the use of custom data sources and tedious manual methods. The DTG5274 high performance data generator solves the problem by providing a full complement of highly accurate data signals and the ability to precisely control their parameters. Testing to DVI/HDMI standards receiver products over a wide range of operating conditions can now be automated using simple, graphical controls and a set of industry standard adapter accessories.

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