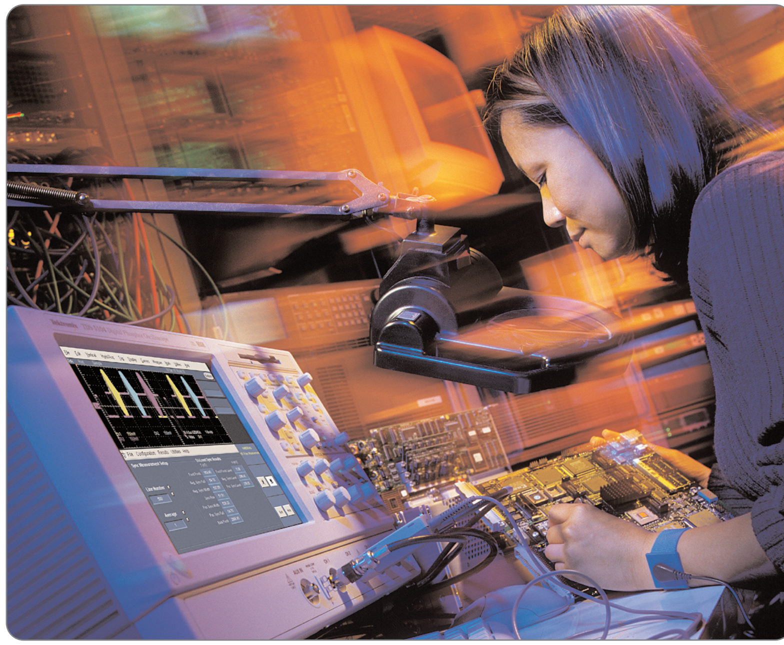
High Definition Analog Component Measurement



COMPUTING
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VIDEO

▶ Requirements for measuring analog component HD signals for video devices

The transition to digital has enabled great strides in the processing of video signals, thus allowing a variety of techniques to be applied to the video image. Despite these benefits, the final signal received by the customer is still converted to an analog signal for display on a picture monitor. With the proliferation of a wide variety of digital devices – set-top boxes, Digital Versatile Disk (DVD) players and PC cards – comes a wide range of video formats beside the standard composite output. It is therefore necessary to understand the requirements for measuring analog component High Definition (HD) signals in order to test the performance of these devices.

When an image is captured by a color camera and converted from light to an electrical signal, the signal is comprised of three components – Red, Green and Blue (RGB). From the combination of these three signals, a representation of the original image can be conveyed to a color display. The various video processing systems within the signal paths need to process the three components identically, in order not to introduce any amplitude or channel timing errors. Each of the three components R'G'B' (Note the ' indicates that the signal has been gamma corrected) has identical bandwidth, which increases complexity within the digital domain. Therefore to reduce the bandwidth required, we convert the R'G'B' signals into a single luma signal Y' made from portions of the Red, Green and Blue as defined by the equations in Table 1. In order to convert the signal back to its R'G'B' components for final display, we need two other color difference signals – B'-Y' and R'-Y'. These signals have a reduced bandwidth, since the detailed picture information is carried by the full bandwidth luma channel. A simple matrix circuit converts between R'G'B' and Y', B'-Y', R'-Y' allowing bandwidth reduction and easier implementation of digital processing. Conversion of Y', B'-Y', R'-Y' into Y'P'bP'r is often done to allow similar dynamic ranges of the luma and color difference signals. Typical amplitude ranges for R'G'B' signals are 0 mV to

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Table 1. Conversion of R'G'B' into Y',B'-Y',R'-Y'

	Y', R'-Y', B'-Y', commonly used for component analog video	
Format	1125/60/2:1 750/60/1:1	525/59.94/1:1, 625/50/1:1
Y'	0.2126 R' + 0.7152 G' + 0.0722 B'	0.299 R' + 0.587 G' + 0.114 B'
R'-Y'	0.7874 R' - 0.7152 G' - 0.0722 B'	0.701 R' - 0.587 G' - 0.114 B'
B'-Y'	- 0.2126 R' - 0.7152 G' + 0.9278 B'	- 0.299 R' - 0.587 G' + 0.886 B'

Table 2. Conversion of Y',B'-Y',R'-Y' into Y', P'b, P'r

		Y', P'b, P'r analog component	
Format	1125/60/2:1 1920x1035 (SMPTE 240M)	1920x1080 (SMPTE 274M) 1280x720 (SMPTE 296M)	525/59.94/1:1 (SMPTE 273), 625/50/1:1 (ITU-R.BT.1358)
Y'	0.701G '+0.087B'+0.212R'	0.2126R'+ 0.7152G'+ 0.0722B'	0.299R'+0.587G'+0.114B'
P'b	(B'-Y')/1.826	[0.5/(1-0.0722)](B'-Y')	0.564(B'-Y')
P'r	(R'-Y')/1.576	[0.5/(1-0.2126)](R'-Y')	0.713(R'-Y')

700 mV. The conversion to Y' gives an amplitude range of 0 mV to 700 mV but the color difference signals each have different amplitude ranges:

R'-Y' is +/-491 mV for 525 or 625 and +/-551 mV for 1125 & 750

B'-Y' is +/-620 mV for 525 or 625 and +/-650 mV for 1125 & 750

To simplify the process, scaling factors are added to B'-Y' and R'-Y' components so that the dynamic ranges of the signals are +/- 350 mV as shown in Table 2. To indicate this, the values are termed P'b (scaled B'-Y' component) and P'r (scaled R'-Y' component).

There are a variety of different measurement parameters that need to be quantified in analog high definition component systems. Some of these will be similar to those measurements done in the composite domain. These types of measurements are detailed in two Tektronix publications: *Television Measurements – PAL Systems (25W-7075-01)* and *Television Measurements – NTSC Systems (25W-7049-03).* However, composite measurements such as Differential Gain and Differential Phase have little meaning within a component signal. Used purely in the composite domain, these tests relate to the measurement of the modulated chrominance gain relative to luma level or the uniformity of chrominance phase to luma level. In analog component video, the chrominance signal is represented by the two separate color difference components. Therefore different measurement methods are employed. The number of different measurements required for quantifying component signals are less than in the composite domain, however the measurements have to be applied to all three components.

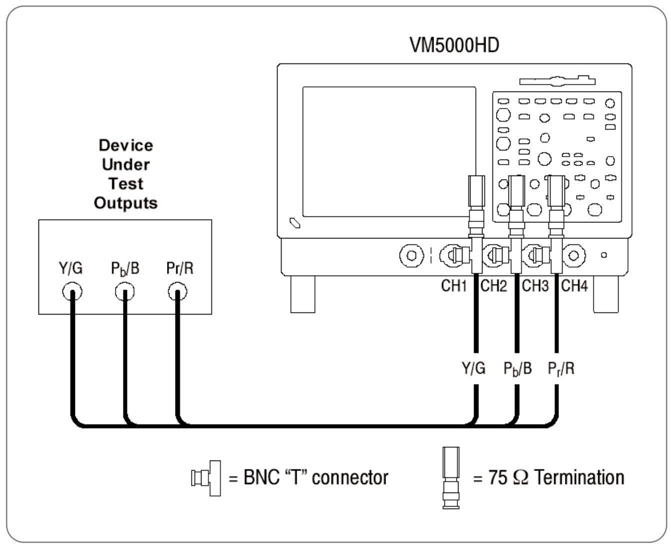
Automated Measurements

Tektronix has developed a measurement package for analog component HD systems, the VM5000HD as shown in Figure 1. Once configured, the instrument can make a series of automated measurements on the device under test (DUT). Connections to the VM5000HD are configured in a variety of ways, depending upon the type of outputs available from the DUT. Within a component system, the sync can be carried on a variety of the channels (e.g., in the Y'P'bP'r broadcast standard definition format sync is always carried on the Y channel and is a bi-level sync signal). However, in HD formats a tri-level sync is used and is typically carried on all channels; in R'G'B' systems the sync can be on one or all of the components, carried as a separate sync (RGBS) or with separate H and V sync (RGBHV), as is typical in the VGA outputs of a PC. It is therefore important to set up the VM5000HD correctly for the appropriate type of input format being used.

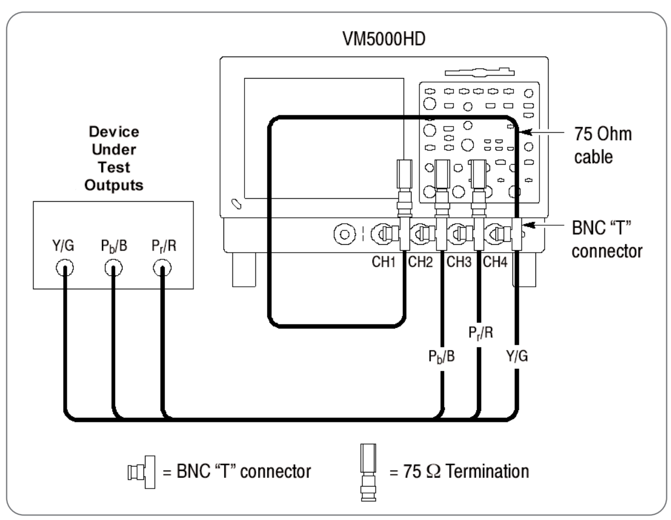
For configurations using either Y'P'bP'r or R'G'B' with composite sync on Y' or Green, the system can be set-up as shown in Figure 2 with the Y' or G' channel connected to Channel 1 of the VM5000HD. This configuration provides for accurate frequency response measurements, but limits the range of the noise measurement to -65 dB (30 MHz) on the Channel 1 input.

For enhanced performance of the noise measurement, the following configuration can be used, as shown in Figure 3. In this case, the synchronization for the VM5000HD occurs on Channel 4. It is important to ensure in the configuration of the VM5000HD that the sync is obtained from the Channel 4 input and not the default Channel 1 input. This configuration allows for the algorithms to maximize the dynamic range of the system for the video signal and perform more accurate low-level noise measurements below -60 dB (30 MHz). However because the sync signal is looped through to Channel 4 there is a slight reduction in frequency response measurements by 0.04 dB at 30 MHz on Channel 1 due to this additional loading. In addition, the cable length in the Channel 1 signal path relative to the other channels will add a corresponding channel delay measurement error. To improve the performance of the measurement, a low capacitance (<12 pF) oscilloscope probe can be used to provide the Channel 4 sync signal. Connect the Y'/G' signal directly to Channel 1 and terminate in 75 Ω, as shown in Figure 2. Connect the probe to the Channel 4 input. Using a BNC T and a probe-to-BNC connector (013-0254-00 P5050 probe) connect the probe tip to Channel 1.

▶ ***Figure 1.*** *VM5000HD for Analog HD Automated Measurements.*



▶ ***Figure 2.*** *Connection of YPbPr/GBR to VM5000HD.*



▶ ***Figure 3.*** *Sync loop through connection on VM5000HD.*

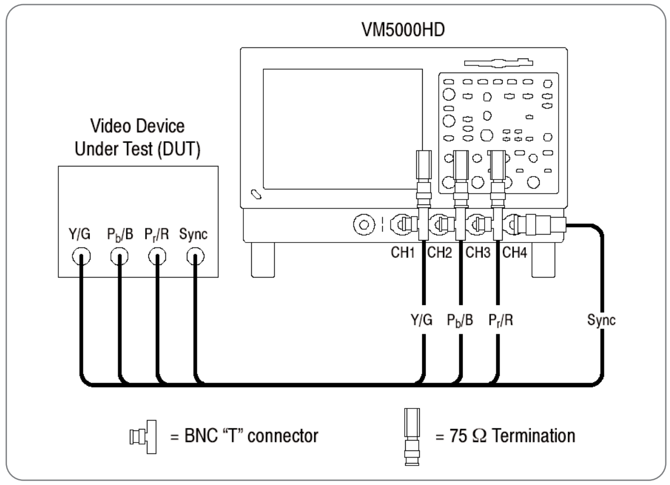
A four-wire system that provides a separate sync output from the device under test can be configured as shown in Figure 4. With this approach, synchronization is obtained directly from Channel 4 and a termination is optional on this input since no measurements are made on this channel.

In the final configuration, a cable is provided to allow direct connection to a PC and correctly interface to the VM5000HD as shown in Figure 5. This cable combines the separate horizontal and vertical syncs from the VGA output into a composite sync so that it can be directly applied to the Channel 4 input of the device. This configuration is commonly used for testing the 5 wire R'G'B' output from the set-top box.

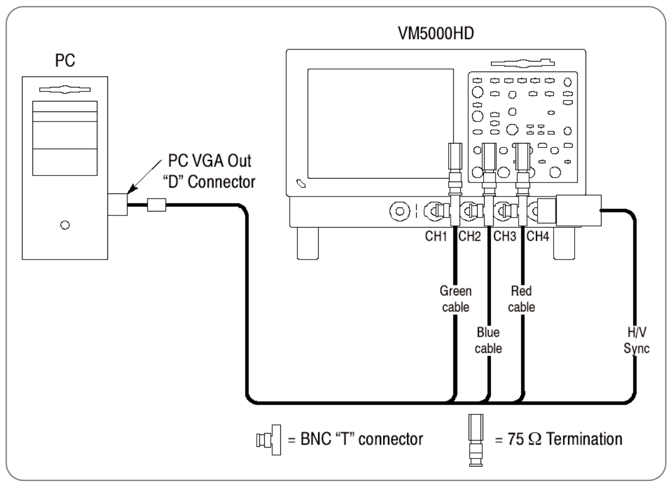
Termination

Improper termination is a very common source of operator error and frustration. If you put two terminators in the signal path, or leave it unterminated, the signal amplitude will be seriously affected. It is therefore essential that you terminate each video signal, using a 75 Ω terminator. When the signal is looped through several pieces of equipment, it is generally best to terminate at the final piece of equipment.

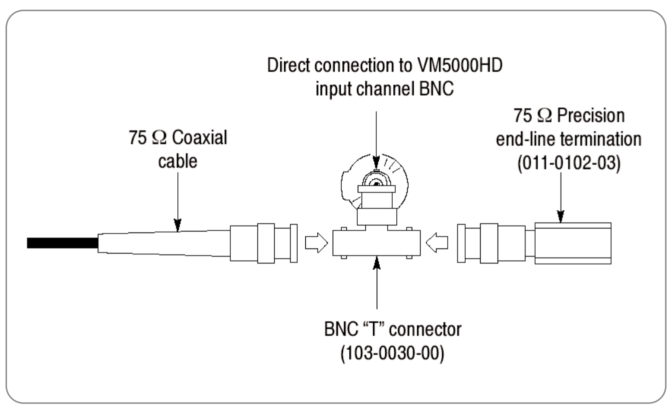
The quality of the terminator is also important, particularly if you are trying to measure small distortions. Be sure to select a terminator with the tightest practical tolerances because incorrect termination impedance can cause amplitude errors as well as frequency distortions. The signals from the device under test should be connected to the VM5000HD via 75 Ω BNC cables that are terminated correctly at the input to the instrument as shown in Figure 6.



▶ ***Figure 4.*** *Component connection to the VM5000HD with separate sync.*



▶ ***Figure 5.*** *PC VGA connection to VM5000HD.*



▶ ***Figure 6.*** *Connection of device under test to VM5000HD.*

▶ ***Figure 7.*** *Matrix Test Pattern.*

Test Signal

The variety of analog component measurements requires different test signals to measure the performance of the system. The single line test signals are repeated for a number of lines. However it is not necessary to apply the test signal over the entire field to check conformance of the system. Therefore different test signals can be produced for a certain set of lines and a matrix pattern is formed from the combination of these various patterns. This reduces measurement time by allowing one pattern to be used for a series of measurements. The measurement instrument then makes the appropriate measurements on specific test lines within the matrix pattern. In designing a matrix pattern, it was necessary to ensure the signal would support R'G'B' and Y'P'bP'r formats. This in turn created the need to compose both a variety of R'G'B' measurement lines and a secondary set of signals suitable for Y'P'bP'r measurements. The matrix pattern used is shown in Figure 7 and is a software package available with the VM5000HD. The next section outlines how a variety of these test signals can be used within the measurement routines.

Automated Measurement using the VM5000HD

The instrument is easily configured to make a variety of analog high definition component measurements, simply select the standard of the video signal supported and the format (Y'P'bP'r or R'G'B'). It is important to choose the appropriate setup for the synchronization of the instrument to either Channel 1 or Channel 4, depending on the type of device under test. The instrument can be setup to configure itself automatically to the appropriate level and type of signal applied to the inputs. This procedure is normally done only once to save time and speed-up the measurement process. Therefore, if the instrument is used for other functions between automated measurements, the auto scale function should be deselected and re-selected or the application should be re-started. The instrument can also perform averaging for each measurement. This is useful if the signal is noisy and results from the measurements are fluctuating. The higher the averaging factor, the more individual measurement results are accumulated into the average, giving a more stable readout. There are a total of six measurement routines, covering 100 parametric measurements, provided with the VM5000HD.

Table 3. Amplitude ranges for various 100% color bar signal formats

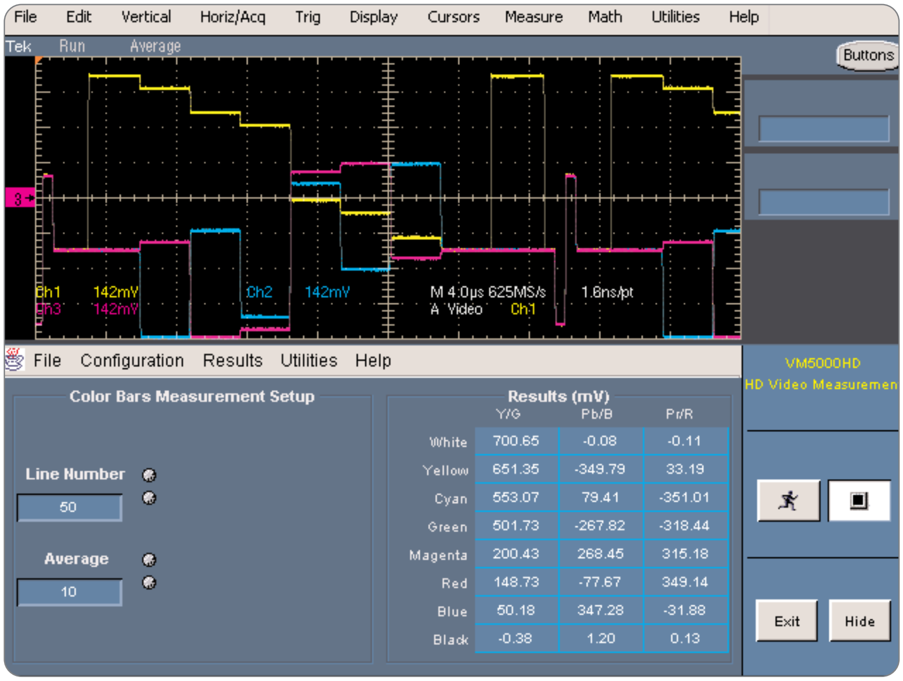
				525p/625p			1080/720		
Color Bar	R' (mv)	G' (mv)	B' (mv)	Y' (mv)	P'b (mv)	P'r (mv)	Y' (mv)	P'b (mv)	P'r (mv)
White	700	700	700	700.0	0.0	0.0	700.0	0.0	0.0
Yellow	700	700	0	620.2	-349.8	56.9	649.5	-350.0	32.1
Cyan	0	700	700	490.7	118.0	-349.9	551.2	80.2	-350.0
Green	0	700	0	410.9	-231.7	-293.0	500.6	-269.8	-317.9
Magenta	700	0	700	289.1	231.7	293.0	199.4	269.8	317.9
Red	700	0	0	209.3	-118.0	349.9	148.8	-80.2	350.0
Blue	0	0	700	79.8	349.8	-56.9	50.5	350.0	-32.1
Black	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Amplitude ranges for various 75% color bar signal formats

				525/625			1080/720		
Color Bar	R' (mv)	G' (mv)	B' (mv)	Y' (mv)	P'b (mv)	P'r (mv)	Y' (mv)	P'b (mv)	P'r (mv)
White	700	700	700	700.0	0.0	0.0	700.0	0.0	0.0
Yellow	525	525	0	465.2	-262.3	42.7	487.1	-262.5	24.1
Cyan	0	525	525	368.0	88.5	-262.4	413.4	60.2	-262.5
Green	0	525	0	308.2	-173.8	-219.7	375.5	-202.3	-238.4
Magenta	525	0	525	216.8	173.8	219.7	149.5	202.3	238.4
Red	525	0	0	157.0	-88.5	262.4	111.6	-60.2	262.5
Blue	0	0	525	59.9	262.3	-42.7	37.9	262.5	-24.1
Black	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0

Amplitude Measurements – Color Bars

Amplitude measurements are typically performed using the familiar color bars test signal that switches on and off the R'G'B' components to produce all eight possible combinations. There are a variety of different forms of the color bar test signal, typically either using a maximum dynamic range of 700 mv = 100% or at 75% with an R'G'B' amplitude of 525 mv. Using Tables 3 and 4, the amplitude ranges for the component Y'P'bP'r are given for the various standards of 100% and 75% color bars.



▶ ***Figure 8.*** *Color Bar measurement display of VM5000HD.*

Depending on the type of equipment being tested, a variance in the actual values is allowed within some percentage. For instance, the progressive outputs of DVD players can introduce setup to their outputs that can vary the overall measured results. Variations in the level of the components can introduce different hue and saturation in the displayed picture. The color bar test signal allows the user to check for gain inequalities between the channels and to ensure the signal is not distorted, which could produce severe clipping of the signal.

The Tektronix Matrix pattern uses a 100% color bar signal in order to test the full dynamic range of each component. The color bar pattern is located at the top of the matrix pattern; the line numbers at which it occurs are different for each different standard. The line numbers specified are the default values used to generate the test matrix but some systems under test may line shift the image to a different location.

Format	1080i	720p	480p	576p
Line Location	21-84 584-647	26-153	43-106	45-108

The VM5000HD performs the color bars measurements by first identifying the relative amplitudes of each of the 3 channels. Eight amplitude measurements are made on each channel, giving a total of 24 measurements made in less than half a second; Figure 8 shows the typical measurement results performed on a 1080i signal. The amplitude level of each of the bar levels is measured relative to the back porch. Amplitudes are calculated using waveform averaged values within each identified bar. It is therefore important to ensure that the full video line is displayed in the capture window of the instrument if manual setup has been performed on the unit.

Frequency Response Measurement – Multiburst

This measurement evaluates the ability of the system to uniformly transfer signal components of different frequencies without affecting their amplitude. This amplitude variation is expressed in dB or percent. The reference amplitude (0 dB, 100%) is typically the bar or flag, or some low frequency to which the other frequency components are compared. It is important to know the measured amplitude and frequency at which the measurement was made.

Table 5. Multiburst packet frequencies for each video format

Format	Packet 1 (MHz)	Packet 2 (MHz)	Packet 3 (MHz)	Packet 4 (MHz)	Packet 5 (MHz)	Packet 6 (MHz)
R'G'B' 1080i & 720p	5.0	10.0	15.0	20.0	25.0	30.0
Y' Mixed BW 1080i & 720p	5.0	10.0	15.0	20.0	25.0	30.0
P'b/P'r Mixed BW 1080i & 720p	2.5	5.0	7.5	10.0	12.5	15.0
Y' Half BW 1080i & 720p	2.5	5.0	7.5	10.0	12.5	15.0
P'b/P'r Half BW 1080i & 720p	2.5	5.0	7.5	10.0	12.5	15.0
R'G'B' 480p & 576p	2.0	4.0	6.0	8.0	10.0	12.0
Y' Mixed BW 480p & 576p	2.0	4.0	6.0	8.0	10.0	12.0
P'b/P'r Mixed BW 480p & 576p	1.0	2.0	3.0	4.0	5.0	6.0
Y' Half BW 480p & 576p	1.0	2.0	3.0	4.0	5.0	6.0
P'b/P'r Half BW 480p & 576p	1.0	2.0	3.0	4.0	5.0	6.0

Test Signal

There are three multiburst test signals used – one for R'G'B' using a 100% amplitude and six sinusoidal packets; a 320 mv peak-to-peak amplitude (45.7%) for Y'P'bP'r with half bandwidth frequency packets; and a Y'P'bP'r mixed multiburst signal containing both full bandwidth packets for Y and half bandwidth packets for color difference with 45.7% amplitude

It is necessary to use variations of the test signal so that it is compatible when converted from the Y'P'bP'r domain to the R'G'B' domain. Table 5 summarizes the different multiburst packet frequencies used for the various standards.

The following table shows the default line locations for the various multiburst signals.

Format	1080i	720p	480p	576p
R'G'B' Line Location	149-212 715-775	282-343	173-236	173-236

Format	1080i	720p	480p	576p
Y'P'bP'r Mixed Line Location	277-308 840-871	410-441	269-300	301-332

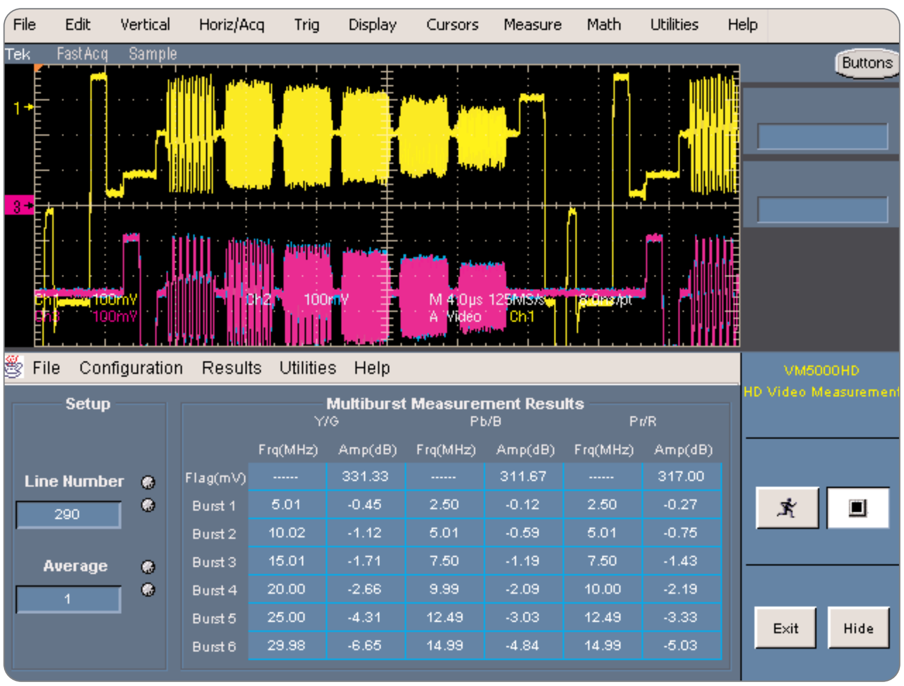
Format	1080i	720p	480p	576p
Y'P'bP'r Half BW Line Location	309-340 872-903	442-473	301-332	333-396

The VM5000HD has a wide bandwidth of 1 GHz and therefore has an extremely flat frequency response over the narrower bandwidth of video signals, which have a bandwidth of 30 MHz for 1080i and 720p formats, and 12 MHz for 576p and 480p formats. This improves the frequency performance of the instrument to accurately measure the multiburst of the video signal.

The algorithm used to make the calculations is able to perform effectively under noisy conditions, as well as any translation of the native signal through MPEG compression or to other video formats. The six largest frequency isolated peaks are found within the spectrum of the signal. The original test signal has frequency packets that are sufficiently isolated from each other, however if the device under test has performed significant processing, multiple aliased frequencies can be present within the signal. In such a case, the algorithm chooses the six most isolated peaks within the spectrum display. The frequency packets are displayed on the unit in lowest to highest frequency order. The maximum amplitude of the packet is obtained from a cross-correlation between the pedestal area and a windowed complex sinusoidal. Figure 9 shows the measurement made on the mixed bandwidth Y'P'b'P'r signal from a test signal generator with little degradation in signal performance.

Frequency response problems can produce softening of the picture, with vertical edges becoming fuzzy and smeared. This can happen when the device under test lacks a suitable reconstruction filter with sin(x)/x correction for the video signal. This can lead to a roll-off in the fundamental frequency component of the packet, even though

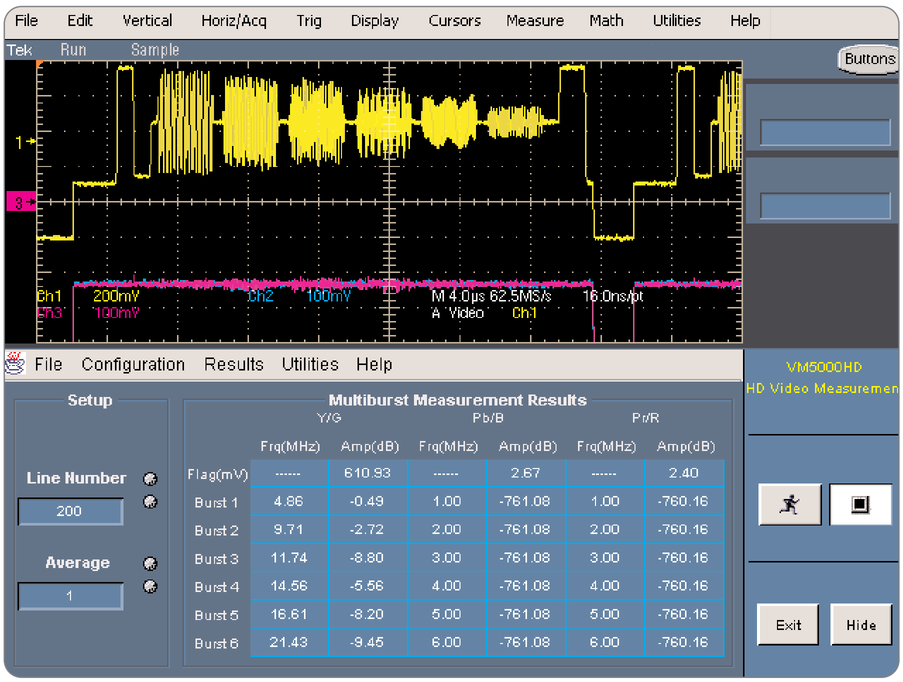
▶ ***Figure 9.*** *VM5000HD Multiburst measurement.*



▶ ***Figure 10.*** *Set-Top box output of a native 1080i signal.*

the envelope of the packet may be flat. In this case, the amplitude results for the highest frequencies may be lower by a few dB, even though the packets may look closer in amplitude on the display. This is because the packet is no longer a pure windowed sinusoid, but has other spectral components. If the extra spectral components are removed by appropriate filtering, the signal envelope will better reflect the actual measurement of frequency response for the processed signal at that particular frequency. Figure 10 shows the results from a set-top box producing a native 1080i output. Notice the gradual roll-off of the increasing frequency packets. Depending on the application of the device, these performance limits may be acceptable.

Generally, conversion from 1080i to 480p changes the frequency by a factor of (1920/720)x(27/74.176) = 0.9707, with frequency aliases above (27 MHz/2) = 13.5 MHz for Y,R,G & B and either 13.5 MHz or (13.5 MHz/2) = 6.75 MHz for Pb & Pr:						
Format	Frequency					
Native 1080i Y’	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz
Full BW 480p Output	4.85 MHz	9.71 MHz	Aliased 14.6 MHz	Aliased 19.4 MHz	Aliased 24.3 MHz	Aliased 29.1 MHz
Native 1080i P’b/P’r	2.5 MHz	5 MHz	7.5 MHz	10 MHz	12.5 MHz	15 MHz
Half BW 480p output	2.43 MHz	4.85 MHz	Aliased 7.28 MHz	Aliased 9.71 MHz	Aliased 12.13 MHz	Aliased 14.56 MHz

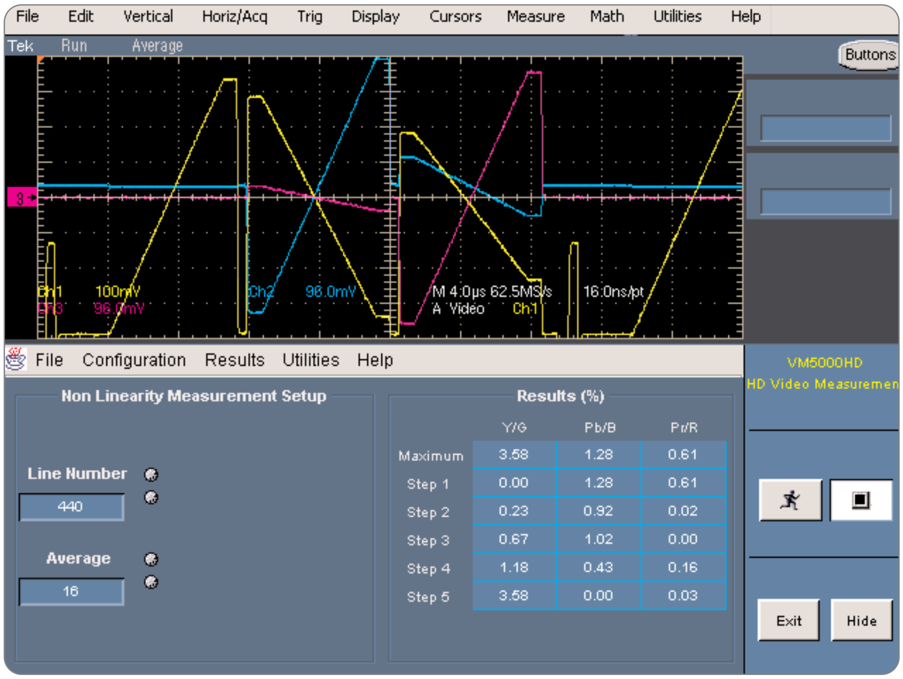


▶ ***Figure 11.*** *Set-top box conversion of native 1080i to 480p standard.*

In various set-top boxes, the native format applied to the unit is digitally converted to another display format. When this happens the original packet frequencies from the native test signal will be transposed to other packet frequencies depending on the algorithm used to perform this operation.

With reference to the chart above, consider the following example for conversion of a native 1080i signal into a 480p display format. The down conversion process will vary depending on the algorithm that is used to re-sample the 1080i signal into a 480p standard and some of the original frequency packets will be aliased into different frequency packets. This will depend on the sampling frequency and filter characteristics of the output device.

The measurement results in Figure 11 show the resultant conversion of a set-top box from 1080i to 480p. In this example, only two packets of the multiburst signal were correctly processed. The other packets were aliased into a variety of different frequency components.



▶ ***Figure 12.*** *Non-Linearity measurement from a set-top box.*

The measurement results show packet frequencies different than the theoretically calculated non-aliased values because they are frequency aliases predicted by Nyquist sampling theory. In addition, the lack of anti-aliasing filtering and/or the lack of reconstruction filtering may cause products to contain multiple frequency components, which may affect the results. Therefore, further analysis is required to characterize the performance of the set-top box, which can be manually done by using the oscilloscope functions of the VM5000HD. However, in such cases the results will show that the frequency response deviates substantially from the norm. Note in this particular test signal there are no multiburst components present in the color difference channels, therefore the display shows the expected frequency packets for the signal rather than calculated values.

Non-Linearity Measurement

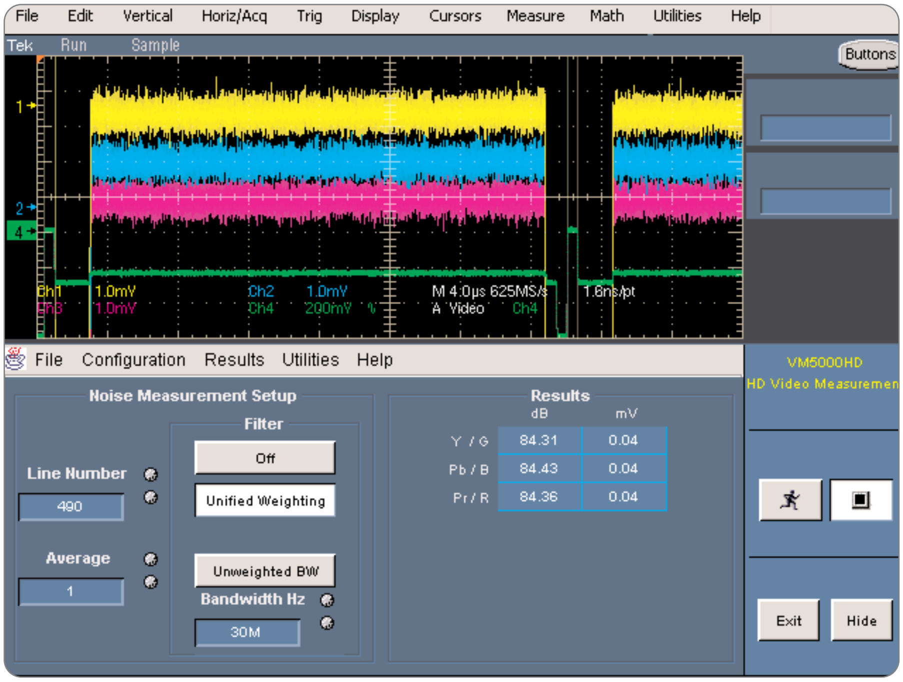
Non-linearity is present when gain of the system changes with amplitude level. This amplitude distortion is a result of the system's inability to uniformly process the component information over the entire amplitude range. Comparing the amplitudes at various steps in increments either of a ramp or staircase test signal, the difference between the largest and smallest measurement is expressed as a percentage of the largest step amplitude.

The test signal used within the matrix test pattern is a valid ramp which can be used for both R'G'B' and Y'P'bP'r. The valid ramp consists of three ramps within the line, the first of which is a luma ramp used for Y',R',G',B'. The second ramp is used to make the P'b linearity measurement and the third ramp is used for P'r. This is located at the following default lines within the various video standards:

Format	1080i	720p	480p	576p
Line Location	404-468 968-1031	539-602	363-476	461-524

The measurement is made at six equal time intervals across the ramp and the results are given as a percentage deviation from the ideal linear increase in the test signal. The measurement results are displayed in Figure 12 for an actual set-top box output. Notice the overall maximum value is displayed along with the measurement of the five locations across the ramp. In this example the luma signal shows some slight soft limiting occurring at the higher amplitude levels, which are probably, within acceptable limits for the performance of the unit.

Most people are not particularly sensitive to luminance non-linearity in black and white pictures. If large amounts of distortion are present however, you might notice the loss of detail in the shadows and highlights. These effects correspond to crushing or clipping of the black and white image. However, color shifts due to channel mismatch can be apparent for R'G'B', for example.



▶ ***Figure 13.*** *VM5000HD Noise Measurement.*

Noise Measurement

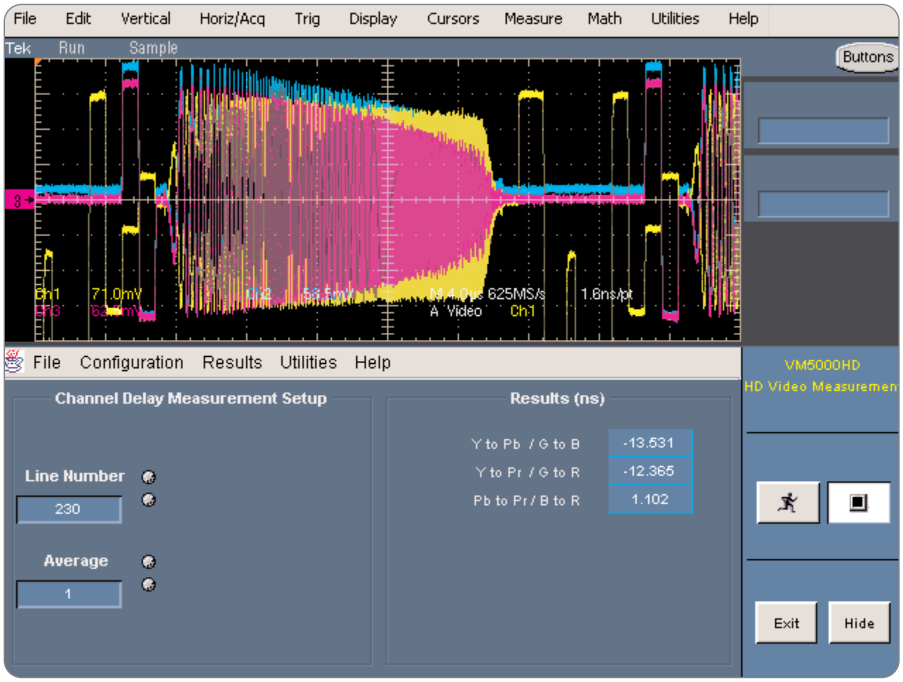
Noise is present within any electrical system and comes from a variety of natural and man-made sources that can either be random or coherent in nature. An excessive amount of noise within the system tends to degrade the signal. In extreme cases, noise can make it difficult for equipment to synchronize to the signal. Errors may become visible at approximately 40 dB signal-to-noise and produces sparkle or snow effects in the picture. The degree of impairment depends on a variety of factors, including spectral distribution of the noise. The CCIR Recommendation 576-2 provides information on weighting filters used to characterize the noise spectrum to better match the visibility of noise in typical viewing conditions. These weighting filters have been modified for each of the video formats used within the VM5000HD to match the “visibility” of noise characteristics.

To measure noise, a pedestal signal is used at a 7.5%, 50% or 100% level for Y’, R’, G’, B’ and 0% for P’b and P’r. These signal are located at the following default positions in the various video standards:

Format	1080i	720p	480p	576p
7.5% Line Location	469-500 1032-1063	603-634	427-458	525-556
50% Line Location	501-532 1064-1095	635-666	459-490	557-588
100% Line Location	533-560 1096-1123	667-745	491-525	589-620

The noise measurement is calculated by first removing line tilt and low frequency distortions. The selected filter, if applicable, spectrally weights all AC signal content. The resulting RMS voltage is calculated along with the signal-to-noise ratio expressed in dB using a 700 mV peak signal value.

The measurement in Figure 13 shows the noise calculation obtained from a reference generator into the VM5000HD. Obviously, this is significantly better than what would be expected from a set-top box under normal operation, but shows how the algorithm is able to work over a very wide dynamic range. Note that the sync was obtained from Channel 4 of the instrument, which allows a greater dynamic range to be used for Channel 1. If Channel 1 is used for sync, the noise figure for Y’/G’ will be slightly less accurate.



▶ ***Figure 14.*** *Channel Delay Measurements from a set-top box.*

Channel Delay Measurement

Channel delay measurements are used to verify the relative timing of the three video channels. It is important when making this measurement to ensure that the cables used to connect the DUT and VM5000HD are of the same length for each signal path otherwise errors in the results can occur, since channel delay is typically a function of relative cable lengths of the channels. Thus it is important to either trigger on Channel 1 or use a high impedance, low capacitance, high frequency probe connected to channel 4 and probing the signal on channel 1 via a terminator and BNC T-piece. The delay can arise through inequality in the different paths for each signal.

In video systems, a Bowtie signal has been used to characterize the delay between each channel. (For further information please refer to the Tektronix application note *Solving the Component Puzzle, 25W-7009-02*.) However, this requires a special test signal, which may be degraded by processed systems such as MPEG compression or noise. Therefore, an algorithm was developed within the VM5000HD which detects cross-correlation between the channels using a standard sweep signal. Additionally, other types of highly correlated signals such as multiburst or chirps or even live program material can also be used. If a measurement cannot be performed on the signal selected because of the lack of cross-correlation between the channels, the display will show "---" for each channel and an associated "low correlation between channels" warning message may be observed.

The measurement finds the maximum cross-correlation of the transitions of the signal between each pair of channels. The delay corresponding to maximum cross-correlation is obtained and displayed in time. A variety of test line signals can be used for Channel Delay provided there is good correlation between the channels. The following test signal lines contain sweep signals for use with R'G'B' or Y'P'bP'r formats at the default locations.

Format	1080i	720p	480p	576p
RGB Line Location	117-148 680-711	219-282	139-170	141-172
YPbPr Line Location	213-244 776-807	347-378	235-250	237-268

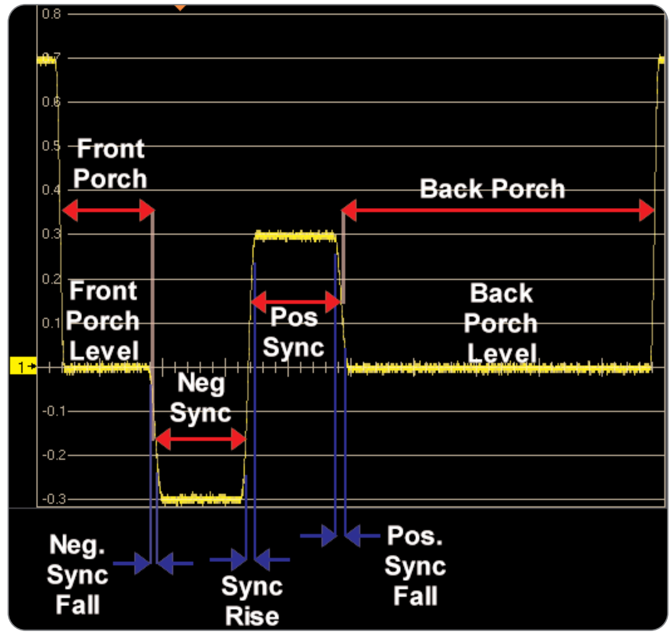
The measurement results are shown in Figure 14; each channel delay is compared against the other. The positive number for the measurement of channel Pb & Pr indicates that there is a delay in Pb with respect to Pr of 1.1 ns. A negative value of the measurement of Y to Pb indicates there is an advance of Y with respect to Pb of 13.53 ns. The delay measurement result is the time shift required to obtain maximum cross-correlation between the respective parts of the signals. This shift or delay may, in some cases, be frequency dependent. Group delay portraits may be obtained by measuring the delay of various narrow band signals.

Horizontal Blanking Timing Sync

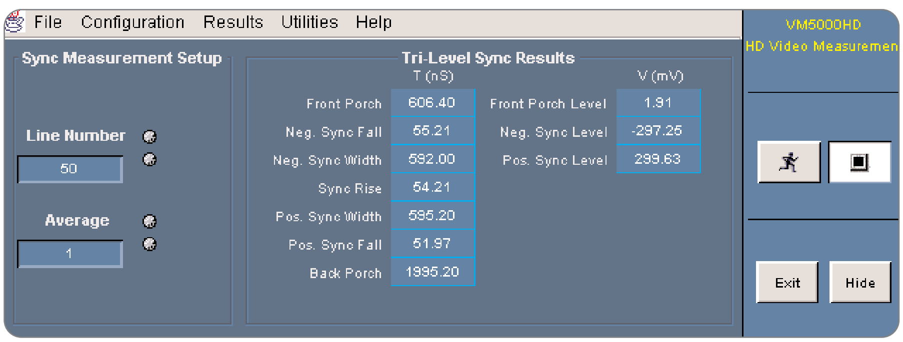
The final measurement made by the VM5000HD is to check the signal timing and amplitude for the horizontal blanking interval of the appropriate video standard to ensure that synchronization signals conform to the standard. Any of the active lines within the matrix test signal can be used to perform this measurement; if another signal is used, the active video signal amplitude should be greater than 7.5% in order to measure front and back porch accurately. If the signal is not of the appropriate amplitude, the VM5000HD may not be able to make front and back porch width measurements.

All amplitudes are measured relative to back porch. Timing intervals are measured at the 50% point of the rising or falling edges of the signal. Rise and fall time measurements are made at the 10% and 90% points. Figure 15 shows the relative positions of the measurements made by the VM5000HD.

The results are displayed as shown in Figure 16. The various specifications for the timing interval of each video standard is shown in Table 6.



▶ ***Figure 15.*** *HD Tri-Level Sync Timing Measurements.*



▶ ***Figure 16.*** *VM5000HD Sync measurement results.*

Table 6. Typical timing measurements for various video formats

Format 1080i 59.94	Nominal (ns)	Minimum (ns)	Maximum (ns)
Front Porch	606.67 (45T)	566.22	728
Neg. Sync Fall	53.93	33.7	74.15
Neg. Sync Width	593.18 (44T)	552.74	633.63
Sync Rise	53.93	33.7	74.15
Pos. Sync Width	593.18 (44T)	552.74	633.63
Pos. Sync Fall	53.93	33.7	74.15
Back Porch	1995.25 (148T)	1954.81	2116.59

Format 720p 59.94	Nominal (ns)	Minimum (ns)	Maximum (ns)
Front Porch	942.76 (70T)	902.36	1063.97
Neg. Sync Fall	53.87	33.67	74.07
Neg. Sync Width	538.72 (40T)	498.32	579.12
Sync Rise	53.87	33.67	74.07
Pos. Sync Width	538.72 (40T)	498.32	579.12
Pos. Sync Fall	53.87	33.67	74.07
Back Porch	2962.96 (220T)	2922.56	3048.18

Format 480p 59.94	Nominal (ns)	Minimum (ns)	Maximum (ns)
Front Porch	590	490	690
Neg. Sync Fall	70	60	80
Neg. Sync Width	2330	2230	2430
Sync Rise	70	60	80
Pos. Sync Width	-	-	-
Pos. Sync Fall	70	60	80
Back Porch	2190	1990	2490

Measurement Reporting

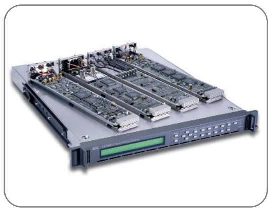
Once the measurements have been completed, it is possible to generate a report of this data to various other applications for inclusion in test reports. For instance, the data can be incorporated within a spreadsheet application. Table 7 shows part of the generated report for the luma channel of the color bar test. The spreadsheet application has minimum and maximum 5% limits applied to the luma signal. The conditional formatting of the spreadsheet allows the cell to be green if it is within the limits and red if it falls outside the limits. This aids in quickly identifying errors within a set of measurements.

Table 7. Measurement report

VM5000HD Video Measurements Results Report				
Additional Information				
Date				
Time				
Format:	1080I/60			
Color Space:	YPbPr			
Color Bars				
Line	50			
Average	10			
Y Level (mV)		Min	Max	Spec
White	700.58	665.00	735.00	700.0
Yellow	651.08	617.03	681.98	649.5
Cyan	552.76	523.64	578.76	551.2
Green	501.92	475.57	525.63	500.6
Magenta	200.24	189.43	209.37	199.4
Red	148.52	141.36	156.24	148.8
Blue	49.87	47.98	53.03	50.5
Black	-0.51	-0.40	0.40	0.0

Conclusion

High definition analog component measurements can now be carried out on a range of standards by using the VM5000HD Automated Measurement Set. Measurements that would otherwise take several hours to perform manually, or simply could not be performed at all (e.g., noise weighting), can now be performed quickly, accurately and repeatedly via the algorithms used within the VM5000HD.



TG700 Multiformat Video Generator

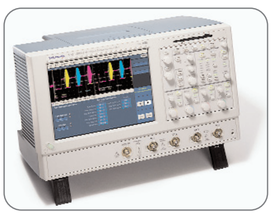
- Multiformat analog and digital test signal generation
- Modular expandable platform
- Ideal channel configuration and performance to support reference generator needs

VM700T Video Measurement Set

- Unparalled noise, frequency response, gain, phase, and delay measurements
- Outstanding waveform monitoring
- Instrument of choice for major consumer and professional video equipment manufacturers in R&D, as well as for production video test applications

MTX100 MPEG Recorder and Player

- Easy to control, cost-effective generation of known streams for driving additional inputs into a re-multiplexer
- Provide stimulus to a modulator



VM5000HD Automated Video Measurement Set

- Fast, accurate, repeatable video measurements
- Fully automated, comprehensive component analog video measurements
- Supports HDTV progressive scan and PC format signals (YPbPr and RGB)
- Acquisition bandwidth and high sample rates for HDTV signals
- Extensive documentation capabilities
- Standard GPIB and LAN remote control capability

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