

# HD and SD Analog Component Video Jitter and Wander Measurements with the VM6000



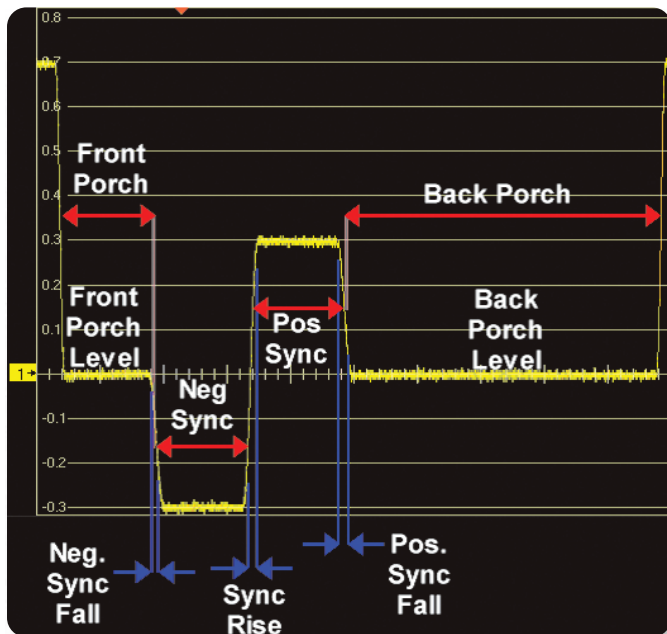
## Requirements for Managing Jitter and Wander in Analog Component HD and SD Video Signals

The successful creation, processing, transmission, and recover of high quality video content depend on reliable synchronization of each element through the signal path. While video elements can be stored, changed, even enhanced in the digital domain, they are organized first as an analog signal input to the camera lens, and finally displayed as analog light to the viewer. Undistorted reproduction of the intended video content or light pattern also depends on accurate timing of video in relation to its accompanying synchronizing elements, and a timing relationship to signal processing elements in the chain of events leading to final display. Variations from ideal timing are characterized as Jitter and Wander.

Since video encounters delays in the path from camera to the viewer's receiver, for processing, program assembly, and transmission, and will often be recorded for a later scheduled broadcast, it travels with its own synchronizing signals. While the system is necessarily designed to tolerate some Jitter and Wander in the signal path, these are generally undesirable terms that degrade the robustness of the video signal, and can possibly cause it to fail.

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► **Figure 1.** HD tri-level sync timing signal.

The simplest result of excessive Jitter may be a visible shaking and possibly rainbow of color in the displayed HD or SD video. The system may be more tolerant of Wander, until system design Limits are reached. For example, Wander may not affect a video display monitor with fast sync processing but could cause a composite recorder to record color phase errors due to tracking the wandering sync-rate with a small phase error. Even with component video the signal is required to not Wander outside the frequency lock range of the downstream video equipment. The effect of either Jitter or Wander may be a complete failure to properly process the signal through the production chain, in the analog or digital domain, and failure to deliver a quality signal to the viewer.

## Video Synchronizing Signals

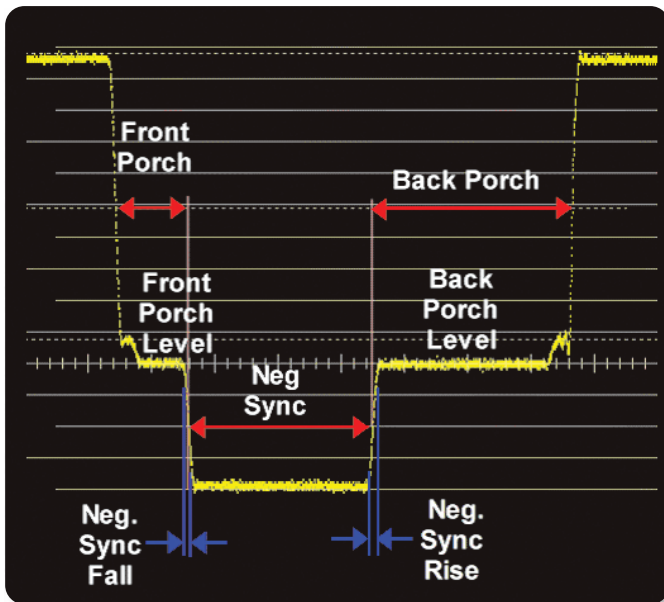
The content of an analog television picture is synchronized in two dimensions; horizontally by a synchronizing pulse that defines the position of the video line starting off the left edge of the display, and a vertical synchronizing pattern that positions the video starting point for a sweep down the display. Between occurrences of these synchronizing signals, everything is free running, and the system is nominally designed to expect a new synchronizing signal as the next one comes along.

Analog HD and SD horizontal synchronizing signals are unique in that they are the only signal elements with the expected energy content at their average voltage levels. For example, the reference horizontal timing of an HD signal, Figure 1, is midway in the fast transition sync rise from maximum negative in the video signal (negative sync) to the maximum voltage of the positive sync element. The third voltage level in this tri-level sync signal is the back porch level. The back porch provides a voltage reference for the entire video signal, and any voltage in the signal below the reference level is a candidate negative sync element.

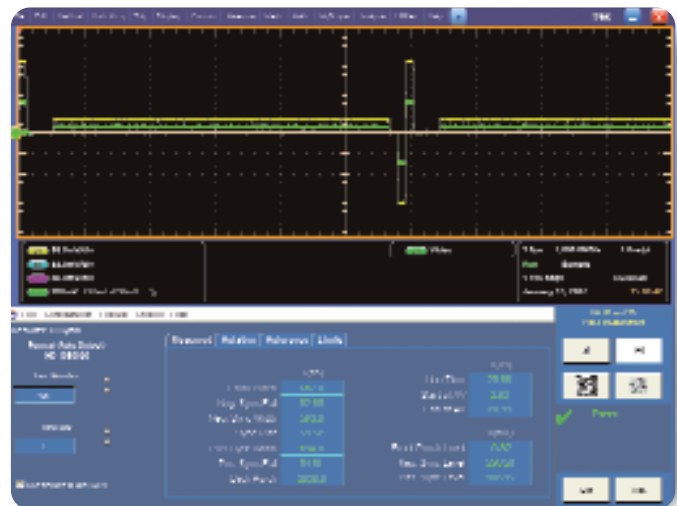
In HD tri-level sync formats the negative going pulse provides an alert to expect the fast-rise reference timing edge.

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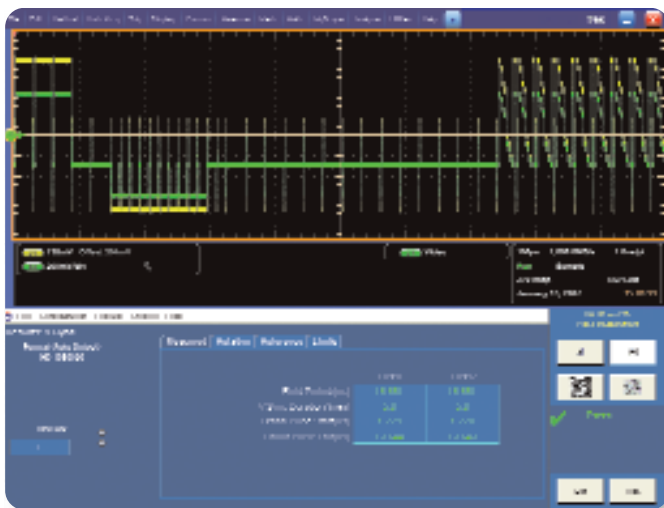
► **Figure 2.** SD bi-level sync timing signal.



► **Figure 3.** VM6000 horizontal sync measurement results for an HD signal.

The vertical synchronizing signal is a regularly occurring pattern within a chain of horizontal sync reference pulses. This vertical synchronizing information is easily recognized by legacy receivers as a change in average sync level, while maintaining energy at one or two times the horizontal rate, and accurately processed in modern digital detectors. This signal identifies the top of the picture and is also measured by the VM6000, Figure 4.

The video signal is self-clocking, and all operations on that signal whether to process or display, must correctly time synchronize with the video. While the end-result video signal is electrical, the signal may even experience mechanical disturbances, such as the relative timing instabilities of a video tape recorder. Some Jitter or Wander will be accommodated by processing and display devices, but there is obviously a limit to explore.



► **Figure 4.** VM6000 Vertical Sync measurement results for an HD signal.

The SD horizontal synchronizing signal, Figure 2, is similar, with a single voltage transition in the negative direction. The horizontal timing reference is the 50% point of the leading edge (sync fall) of the negative synchronizing pulse.

The VM6000 makes automatic measurements of both time and voltage in the horizontal timing interval, Figure 3, and includes additional automatic measurements of Jitter and Wander discussed in this application note.

# HD and SD Analog Component Video Jitter and Wander Measurements with the VM6000

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### Jitter and Wander

**Jitter** is the time arrival errors of the sync components of the signal compared to the ideal expected arrival times. When the self-clocked video is compared with a local, pre-synchronized reference sync pattern, for example, Jitter is the product of how well relative timing coincides. The signals, reference and video, are locked in step, but there may be some wiggle between the two. This is Jitter, usually measured in nanoseconds, (ns). In the case of a final step in the chain, a video display device, the synchronizing signal will be the reference, and picture information will be placed on the display in the position defined by the synchronizing signal.

In a broadcast video signal, Jitter typically occurs at rates from about 20 Hz to many kHz. The lower the Jitter amplitude and frequency, the easier the next stage can synchronize with it. Once characterized, it may or may not be possible to re-clock the signal in the digital domain.

Jitter may occur in the original signal, due to clock and/or sampling instabilities, and may be exaggerated along the processing chain since phase-locked-loops used in clock recovery often have some Jitter gain. Jitter may also be created or amplified in the mechanical tape or disk recording process.

**Wander** is the drift a signal experiences over time, typically defined by a slow rate up to 10 or 20 Hz. This low frequency is often easier to separate from the video synchronizing information which occurs at a higher rate. Video signals broadcast to the public or intended for replay by consumer devices are generally clocked at frequencies well within the limits of display devices. The concern over Wander is to stay within recognized industry standards of frequency offset, then control frequency drift rates to maintain sync alignment with the display and any intermediate processing stages.

Of course Jitter and Wander occur similarly in both horizontal and vertical components of the signal. Since timing errors typically occur at rates much higher than the vertical video rate, bringing horizontal jitter and Wander under control also resolves longer term issues. It is sufficient to measure only horizontal sync Jitter and Wander if the signal format otherwise complies with industry format standards.

### The Terms of Horizontal Sync Jitter and Wander

The horizontal sync Jitter measurement displays rapid (Jitter) and longer term (Wander) timing instabilities in the horizontal synchronizing signal. Using the VM6000 Automatic Video Measurement Set, Figure 5, the operator may select to display the maximum positive and negative peak Jitter over a large number of occurrences given the probability of those peaks occurring, or display a probability for a specified Jitter positive and negative peak magnitude. The user may specify a Jitter Demarcation frequency, setting a high pass filter to remove lower frequency Wander components.

Jitter is measured in terms of rms ns and +/- peak ns from ideal coincidence with the timing of a long-term averaged horizontal sync reference edge. The user may specify frequency components included in the Jitter measurement by selecting a high pass Jitter Demarcation Frequency.

Wander is specified by the parameter's frequency drift-rate in terms of ppm/sec and frequency offset from a mean or reference standard, in terms of parts per million (ppm). The user may also specify a low pass Wander Demarcation Frequency to define the upper Frequency Limit of the Wander measurement, separating the Jitter from the Wander result.

The Wander Demarcation frequency control sets the low pass filter bandwidth, removing the higher frequency Jitter components from the Wander measurement. The Jitter Demarcation Frequency control sets the cutoff of a high pass filter to enable the measurement of the higher speed Jitter components, removing the low frequency Wander components from the Jitter measurement result.

Jitter and Wander demarcation frequency range is extended with greater record length installed in the host oscilloscope platform. For example, increasing the oscilloscope record length from 40 M samples/channel to 200 M samples/channel lowers the selection of Jitter Demarcation from 10 Hz to 2 Hz and the Wander Frequency Drift and Offset Demarcation from 0.25 Hz to 0.05 Hz.

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► **Figure 5.** VM6000 horizontal sync Jitter/Wander measurements.

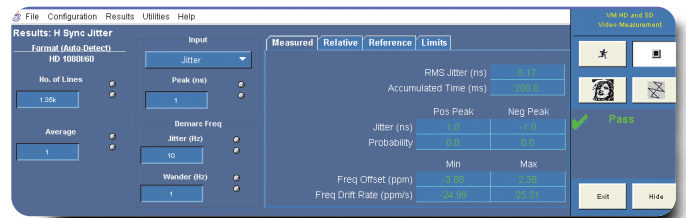
In the RF field, with modulated carriers used for transmission of signals, it is typical to talk about frequency offset to describe the error in the frequency of the oscillator with respect to the nominal expected frequency, frequency drift to describe slow frequency variations, residual FM is used to describe somehow faster frequency variations and phase noise is a term used for very small frequency variations, fast or slow.

When talking about timing in video systems, the terms residual FM and phase noise are typically lumped into Jitter and the term Wander is used instead of frequency drift-rate.

The video industry typically uses the terms:

- Frequency Offset (ppm) for the static frequency errors
- Frequency Drift Rate (ppm/sec) for the speed of the slow variations (Wander)
- Jitter (ns) for the amplitude of phase noise

Why measure the Jitter and the Wander separately? They represent two different aspects of the frequency variations. For Jitter it is the amplitude that is important. For Wander it is the speed of the variation that is of interest. Also it is interesting to realize that recovery circuitry may be able to follow and track both the static and the slow Wander, but not the Jitter. In fact Jitter is mostly removed from the recovery clock, but remains in the signal. The Jitter has to be controlled and kept as small as possible, and consequently measured separately from Wander.



► **Figure 6.** VM6000 H Sync Jitter measurement results.

## Measuring Sync Jitter and Wander with the VM6000

The horizontal sync Jitter/Wander measurement may run separately, as in a development or trouble-shooting environment, or be included in the full suite of automatic VM6000 signal quality measurements. It is easily customized for specific signal evaluation.

The signal format, in the Figure 5 example 1080i60 (or 59.94), has been automatically detected by the instrument. This Results screen is automatically displayed when the H Sync Jitter measurement is the only measurement being performed, or may be viewed under the Results tab when additional measurements have been selected.

Under the Configuration>Reference & Limits tab, check Enable Relative Result Display, and Enable Limit Testing. This will allow comparison of results with the user re-definable reference files.

In the Input box, we have selected Jitter which will be reported in terms of probability of reaching a peak of 1 ns, entered in the Peak (ns) box. The alternative would allow specification of Probability and display the peak (pos or neg) Jitter achieved with that probability (i.e. the probability of the selected pos or neg peak occurring).



# HD and SD Analog Component Video Jitter and Wander Measurements with the VM6000

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Measured	Relative	Reference	Limits
<input type="radio"/> min <input checked="" type="radio"/> max			
		RMS Jitter (ns)	50.0
		Accumulated Time (ms)	1.0E9
		Pos Peak	Neg Peak
Jitter (ns)		150.0	0.0
Probability		1.0	1.0
		Min	Max
Freq Offset (ppm)		0.0	30.0
Freq Drift Rate (ppm/s)		0.0	200.0

► **Figure 7.** Jitter measurement Limits tab.

Measured	Relative	Reference	Limits
		RMS Jitter (ns)	0.0
		Accumulated Time (ms)	0.0
		Pos Peak	Neg Peak
Jitter (ns)		0.0	0.0
Probability		0.0027	0.0027
		Min	Max
Freq Offset (ppm)		0.0	0.0
Freq Drift Rate (ppm/s)		0.0	0.0

► **Figure 8.** Jitter measurement Reference tab.

Measured	Relative	Reference	Limits
		RMS Jitter (ns)	0.17
		Accumulated Time (ms)	200.0
		Pos Peak	Neg Peak
Jitter (ns)		1.0	-1.0
Probability		-0.0027	-0.0027
		Min	Max
Freq Offset (ppm)		-3.08	2.38
Freq Drift Rate (ppm/s)		-24.99	25.31

► **Figure 9.** Jitter measurement Relative tab.

Demarcation frequencies for this example provide effective isolation between the two measurements, Jitter and Wander. The selection of 10 Hz provides a high pass filter with a steep shoulder at 10 Hz for the Jitter measurement, reporting results of signal timing variations occurring at nominal rates higher than 10 Hz. In general small changes in the cut-off frequency of the measurement filter do not significantly affect the Jitter measurement results since the Jitter spectral components are most often broadband.

A 1 Hz low pass filter has been selected to effectively isolate the Wander measurement from faster signal timing instabilities.

RMS Jitter will also be displayed, along with the measurement time, determined by the number of lines to be averaged.

To the left of the application window, the number of video lines over which we will measure shows a default value of 1350 lines, more than two full fields of video in this format. This value may be set from 10 lines to 1.5 million lines

depending on expected signal characteristics and available measurement time (from seconds to many minutes). In the Average box, you may select the number of complete measurement routines to be included in the final result.

The measurement of H Sync Jitter/Wander is performed when the measurement is selected under the Configuration>Measurements tab and the Run button is activated.

Measured results are reported in the information box, Figure 6, under the Measured tab. For this signal, the Jitter value is reported as 0.17 ns RMS, over an accumulated time of 200 MS. Jitter did not reach +/- 1 ns during the measurement, so the probability of reaching a requested peak value was very small. In this case, we might want to set the Peak value in the Input box to a smaller value to further explore the probability.

Three additional tabs available once a measurement is run; Limits, Relative, and Reference:

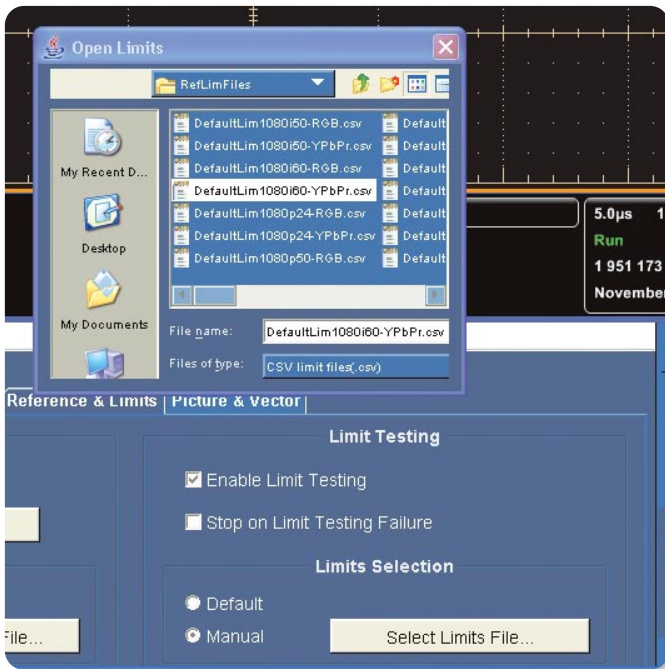
**The Limits tab**, Figure 7, will show the minimum or maximum value allowed by the user in the VM6000 user-configurable Limits File for this format. When Limit Testing is enabled under Configuration>Reference & Limits, the maximum or minimum Limits are displayed. If a measured value is within these Limits, the value in the Measured and Relative displays will be green color.

**The Reference tab**, Figure 8, will show an ideal value expected by the user. This value will be compared to the Measured value to create entries under the Relative tab.

**The Relative tab**, Figure 9, shows Measured value deviation from the Reference value, and provides a quick indication of deviation from ideal.

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► **Figure 10.** Manual selection of a Limits File.

## Reference and Limits Files

Default Reference and Limits Files for each pre-defined component video format are supplied with the VM6000 for user convenience and may be modified to fit the user's specification application. The appropriate file is automatically determined by default when a format is selected, or a user-created file may be loaded manually under Configuration> Reference & Limits>Limits (or >Reference) Selection. Select Manual, and Select Limits File (or Select Reference File) to see the RefLimFiles directory. To display these files, select file type .csv. Save the default file for possible future reference and modify a copy of the original file. The modified file will become the default file if the original filename is retained. If saved under a new filename, the file may be accessed manually.

To access a Limits File manually, under the Reference & Limits tab, Enable Limit Testing and select Manual. Clicking on Select Limits File brings up a user directory containing RefLimFiles and other user information. Select Files of type: CSV Limit Files (.csv), to see available files.

Note that Reference and Limits Files are both in the same user directory, and that Reference Files can similarly be recalled in the Relative Result Display box at the left of the Reference & Limits display. The Relative Result display also provides the opportunity to capture actual measurement of a device under test, which may then be saved for comparison with future measurements.

## Summary

Measurement, evaluation and documentation of Jitter and Wander in standard and high definition component analog video is critical efficient product development and production quality control.

The Tektronix VM6000 Automated Standard and High Definition Measurement Set provides the tools to evaluate Jitter and Wander as part of a full suite of comprehensive, time-efficient automated measurements through product development and production. Measurements that otherwise be skipped for lack of efficient tools.

The VM6000, with its automated horizontal sync Jitter/Wander measurement can reduce development, validation, and production time, while providing an important economic measure of customer satisfaction.

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### For Further Information

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