APPLICATION NOTE

Using the Tri-Level Switching Reference Input on NK-3G Routers

Introduction

All Codan Broadcast NK Series video and audio routers are equipped with a switching reference input to ensure that signals are switched with minimum disturbance to the routed signal while maintaining synchronization between routed signals.

NK-3G series SD/HD/3G digital video routers are equipped with a switching reference input which will accept either a composite reference signal, such as PAL or NTSC black burst, with bi-level sync, or a composite or component reference signal with tri-level sync conforming to a number of different video standards. This application note describes the application of bi-level and tri-level sync in the video routing environment when using NK-3G routers.

NK-A, NK-MD, NK-S, NK-D and NK-V series routers are equipped with a switching reference input which will accept a composite PAL or NTSC black burst signal with bi-level sync. Specific details of the reference signals used with these routers are covered in Codan Broadcast Application Note AN-015 "Using the Switching Reference Input on NK Series Routers".

Table 1 summarizes the reference signal formats recognized by NK Series routers.

		Reference Signal Type	
Router Type	**Signal Format**	**Composite Video with Bi-Level Sync**	**Composite or Component Video with Tri-Level Sync**
NK-MD	HD/SD SDI Video	✓	
NK-S	SD SDI Video	✓	
NK-D	AES Audio	✓	
NK-V	Analog Video	✓	
NK-A	Analog Audio	✓	
NK-3G	3G/HD/SD SDI Video	✓	✓

Table 1 – NK Series Router Reference Signal Formats

The reference input on an NK-3G router, which is located on the rear of the Control Card (shown in Figure 1 labeled VIDREF) accepts an analog reference signal on a 75 ohm BNC connector, allowing the use of standard 75 ohm coaxial cable and readily available generation and distribution equipment. A second BNC connector allows the reference to be looped through to other routers.

Figure 1 – NK-3G Router Video Switching Reference Input

NK-3G routers automatically recognize input reference signals conforming to 36 different video standards, automatically adjusting the switching point in accordance with SMPTE RP 168 (refer to FAQ “How Does the NK-3G Router Determine the Switching Point?” at the end of this document). NK-3G routers also include the ability to set a custom switching point.

Reference signal formats recognized by the NK-3G routers can be categorized into three types of imaging systems, defined by the number of lines per frame; 525-line or 625-line standard definition, 750-line progressive, and 1125-line interlaced or progressive, as shown in Table 2. This table also includes reference signal parameters such as frame rate, PCLK (pixel clock) frequency and the number of pixels per line, which are used to calculate the switching point when using the custom switching point option.

Total Lines/ Frame	Reference Signal Type	Reference Signal Displayed	Frame Rate (Hz)	PCLK (MHz)	PCLKs /Line	Sync	Video Standard Specification	Signal Type
525	4fsc 525/I	NTSC	29.97	14.32	910	Bi-level	SMPTE 244M	SD
	601 525/I		29.97	27	1716	Bi-level	SMPTE 125M / SMPTE 267M	
	601 - 18MHz 525/I		29.97	36	2288	Bi-level	SMPTE 267M	
	720x486/59.94/I		29.97	54	3432	Bi-level	SMPTE RP174 / SMPTE 347M	
	720x483/59.94/P	720x483/59.94/P	59.94	54	1716	Bi-level	SMPTE 293M / SMPTE 347M	
625	Composite PAL 625/I/25	PAL	25	-	-	Bi-level	-	
	601 625/I		25	27	1728	Bi-level	ITU-R BT.601-5	
	601 - 18MHz 625/I		25	36	2304	Bi-level	ITU-R BT.601-5	
	720x576/50/I		25	54	3456	Bi-level	ITU-R BT.799 / SMPTE 347M	
	720x576/50/P	720x576/50/P	50	54	1728	Bi-level	ITU-R BT.1358 / SMPTE 347M	
750	1280x720/60/P	1280x720/60/P	60	74.25	1650	Tri-level	SMPTE 296M	HD
	1280x720/59.94/P	1280x720/59.94/P	59.94	74.175	1650	Tri-level	SMPTE 296M	
	1280x720/50/P	1280x720/50/P	50	74.25	1980	Tri-level	SMPTE 296M	
	1280x720/30/P	1280x720/30/P	30	74.25	3300	Tri-level	SMPTE 296M	
	1280x720/29.97/P	1280x720/29.97/P	29.97	74.175	3300	Tri-level	SMPTE 296M	
	1280x720/25/P	1280x720/25/P	25	74.25	3960	Tri-level	SMPTE 296M	
	1280x720/24/P	1280x720/24/P	24	74.25	4125	Tri-level	SMPTE 296M	
	1280x720/23.98/P	1280x720/23.98/P	23.98	74.175	4125	Tri-level	SMPTE 296M	
1125	1920x1080/60/P	1920x1080/60/P	60	148.5	2200	Tri-level	SMPTE 274M	HD (3G)
	1920x1080/59.94/P	1920x1080/59.94/P	59.94	148.35	2200	Tri-level	SMPTE 274M	
	1920x1080/50/P	1920x1080/50/P	50	148.5	2640	Tri-level	SMPTE 274M	
	1920x1035/60/I	1920x1080/60/I	30	74.25	2200	Tri-level	SMPTE 260M	HD
	1920x1080/60/I		30	74.25	2200	Tri-level	SMPTE 274M	
	1920x1080/30/PsF		30	74.25	2200	Tri-level	SMPTE RP 211	
	1920x1080/59.94/I	1920x1080/59.94/I	29.97	74.175	2200	Tri-level	SMPTE 274M	
	1920x1035/59.94/I		29.97	74.175	2200	Tri-level	SMPTE 260M	
	1920x1080/29.97/PsF		29.97	74.175	2200	Tri-level	SMPTE RP 211	
	1920x1080/50/I	1920x1080/50/I	25	74.25	2640	Tri-level	SMPTE 274M	
	1920x1080/25/PsF		25	74.25	2640	Tri-level	SMPTE RP 211	
	1920x1080/30/P	1920x1080/30/P	30	74.25	2200	Tri-level	SMPTE 274M	
	1920x1080/29.97/P	1920x1080/29.97/P	29.97	74.175	2200	Tri-level	SMPTE 274M	
	1920x1080/25/P	1920x1080/25/P	25	74.25	2640	Tri-level	SMPTE 274M	
	1920x1080/24/P	1920x1080/24/P	24	74.25	2750	Tri-level	SMPTE 274M	
	1920x1080/24/PsF	1920x1080/24/PsF	24	74.25	2750	Tri-level	SMPTE RP 211	
	1920x1080/23.98/P	1920x1080/23.98/P	23.98	74.175	2750	Tri-level	SMPTE 274M	
	1920x1080/23.98/PsF	1920x1080/23.98/PsF	23.98	74.175	2750	Tri-level	SMPTE RP 211	

Table 2 –Reference Signal Video Formats Recognized by NK-3G Routers

Setting the Reference Switching Point in Phoenix

The reference signal connected to an NK-3G router is displayed in Phoenix in the router's configuration, as shown in Figure 2.

If the reference signal is detected as one of the 36 valid video standards, shown in Table 2, the **Reference Signal Type** is displayed. Otherwise, if the reference is not connected or cannot be identified,

an internal reference is generated and “Local (No Reference Detected)” is displayed along with an amber alarm indicator. This is a warning only and will not activate the GPI alarm output.
The Reference Signal Type is displayed as (number of samples) x (number of active picture lines) / frame rate / scanning type. For example, a Reference Signal Type displayed as “1920x1080/50/I” refers to a reference signal with 1920 samples per active line, 1080 active lines per frame, 50 frames per second, interlaced. 525/59.94/I and 625/50/I reference signals are the exception here, displayed as “NTSC” and “PAL” respectively.

There are some video standards in the list of 36 recognized standards with identical sync timing, preventing the automatic format detection from distinguishing between them. In these cases the Reference Signal Type is displayed as a “guess” only, and may not correspond to the actual reference signal format used. Table 2 lists the Reference Signal Displayed for each of the 36 recognized standards.

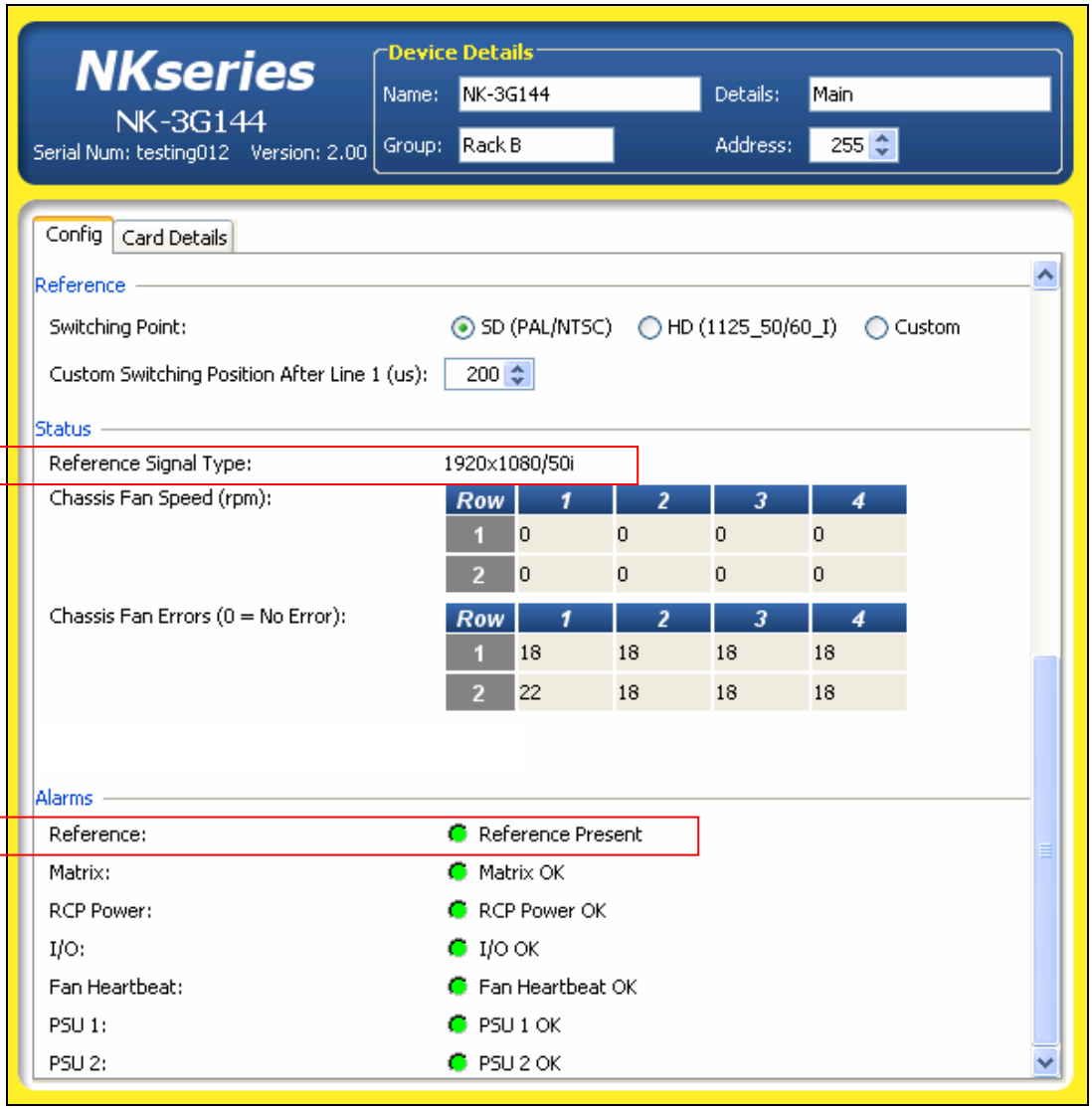

Figure 2 – NK-3G Series Router Reference Monitoring in Phoenix

The switching point for NK-3G routers can be set in the router’s configuration to either SD (PAL/NTSC), HD (1125_50/60_I), or a Custom switching point, as shown in Figure 3. The preset SD and HD switching positions are fixed in accordance with SMPTE RP 168, while the custom switching point is user programmable.

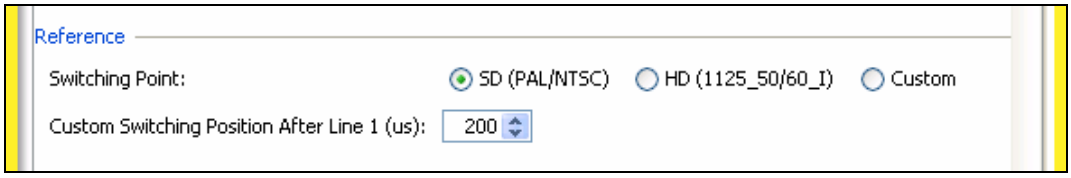

Figure 3 – NK-3G Reference Configuration Options

SD (PAL/NTSC)

The SD (PAL/NTSC) option should be selected when routing 525/59.94/I or 625/50/I SD digital video formats. Table 3 shows the reference signal switching point when this option is selected. Note that, for interlaced signals, even though SMPTE RP168 defines switching points in the first and second fields, this setting uses the switching point for the first field only.

Reference Signal Type	Switching Point of Reference Signal
NTSC 525/59.94/I	Line 10 + 31.8µs
PAL 625/50/I	Line 6 + 32.2µs
All other signal types in Table 2	Frame start + 347µs

Table 3 – NK-3G SD Preset Switching Point

Figure 4 shows the switching position in the first field of an NTSC reference when the SD (PAL/NTSC) preset is selected.

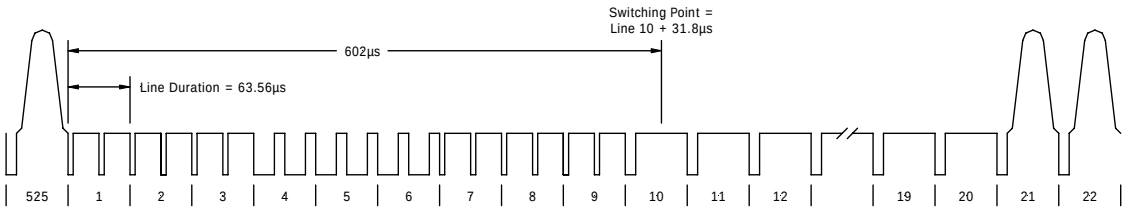

Figure 4 – Switching Point of NTSC Reference using SD (PAL/NTSC) Preset

Figure 5 shows the switching position in the first field of a PAL reference when the SD (PAL/NTSC) preset is selected.

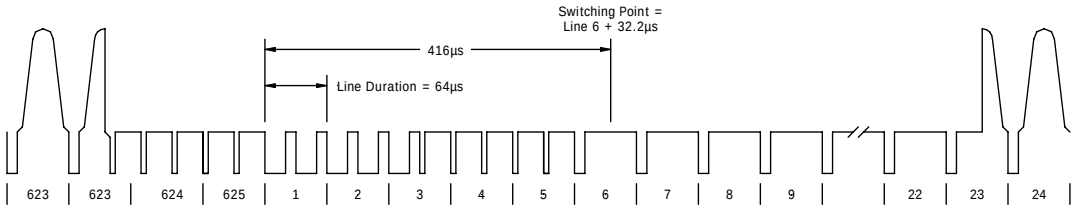

Figure 5 – Switching Point of PAL Reference using SD (PAL/NTSC) Preset

If a reference signal other than NTSC or PAL is used, the switching point will be a fixed delay of 347µs from the start of the frame of the reference signal. The line number within the reference signal at which switching occurs will depend on the reference signal format, and can be calculated using data from Table 2. For example, when using an 1125/50/I tri-level reference with the SD (PAL/NTSC) preset selected, the switching point will occur at line 10, calculated as follows:

From Table 2, we determine that the PCLK for 1920x1080/50/I is 74.25 MHz, and the pixels / line is 2640.

The duration of each line is:

2640 / 74.25 MHz = 35.56µs

The line number at which switching occurs is:

Line 1 + (347 / 35.56) = line 10.758

The number of PCLK intervals from the start of line 10 is:

.758 x 2640 = 2001

Figure 6 shows the switching position in the first field of a 1920x1080/50/I reference when the SD (PAL/NTSC) preset is selected.

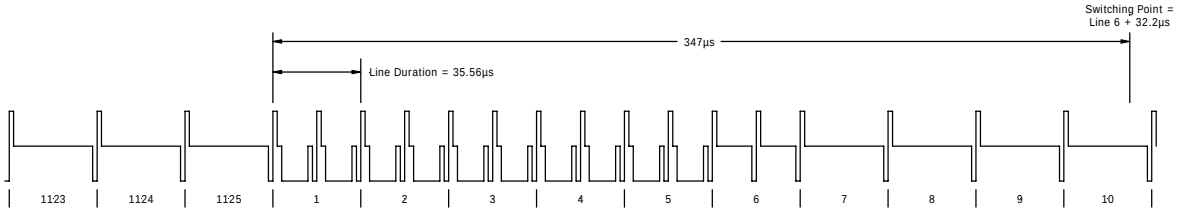

Figure 6 – Switching Point of 1920x1080/50/I Reference using SD (PAL/NTSC) Preset

Since SMPTE RP168 defines a switching point of line 7, PCLK interval 625-1070 for switching 1920x1080/50/I video, the above calculation shows that the SD (PAL/NTSC) preset would not make a good choice of switching point when routing 1920x1080/50/I video. A more suitable switching point would be the HD (1125_50/60_I) switching point preset, described below, which uses a fixed switching point of line 7 + 750 PCLK intervals, suitable for most HD signal formats.

HD (1125_50/60_I)

The HD (1125_50/60_I) option should be selected when routing 1125-line or 750-line HD signals switching at the SMPTE RP168 defined switching point of Line 7. Table 4 shows the reference signal switching point when this option is selected. Note that, for interlaced signals, switching occurs in the first (odd) field only. If a reference signal other than NTSC or PAL is used, the switching point will be a fixed delay of 750 PCLK intervals from the start of line 7 of the reference signal.

Reference Signal Type	Switching Point of Reference Signal
NTSC 525/59.94/I	Line 7 + 2.0µs
PAL 625/50/I	Line 4 + 34.2µs
All other signal types in Table 2	Line 7 + 750 PCLK intervals

Table 4 – NK-3G HD Automatic Switching Point

Custom

The Custom option can be used to set a switching point at an arbitrary delay in µs after the beginning of line 1 of the reference signal. The Custom switching point option in the NK-3G router's configuration is shown in Figure 3. The delay in µs is entered in the **Custom Switching Position After Line 1 (µs)** field.

For NTSC reference signals, the switching point can be set anywhere from 192µs from the start of the frame (line 1) to the end of the first field (line 263.5).

For PAL reference signals, the switching point can be set anywhere from the start of the frame (line 1) to the end of the first field (line 313.5).

For all other interlaced reference signal types, the switching point can be set anywhere in the first field.

For all other progressive reference signal types, the switching point can be set anywhere in the frame.

A summary is shown in Table 5.

Reference Signal Type	Switching Position	Line Duration
NTSC 525/59.94/I	192µs – 16,683µs	63.56µs
PAL 625/50/I	0µs – 20,000µs	64µs
All other interlaced signal types	0µs – End of First Field	Various
All other progressive signal types	0µs – End of Frame	Various

Table 5 – NK-3G Custom Switching Point

The switching position in µs can be calculated from the line number and PCLK intervals of a reference signal using data from Table 2.

Custom Switching Point Example

Suppose we want to set the switching point for routing 1920x1080/50/P. SMPTE RP168 defines the recommended switching point as Line 7, pixel clock intervals 625-1070. Assume we want to set the switching point at Line 7, PCLK interval 750, and we will use a 1920x1080/50/P tri-level reference signal:

From Table 2, we determine that the PCLK for 1920x1080/50P is 148.5 MHz, and the pixels / line is 2640.

The duration of each line is:

2640 / 148.5 MHz = 17.77µs

The duration from the beginning of the line to pixel 750 is:

750 / 148.5 MHz = 5.05 µs

The switching point from the start of frame is:

6 x 17.77 + 5.05 = 112µs

NK-3G Tri-Level Reference Frequently Asked Questions

What is tri-level sync?

Tri-level sync is a type of synchronization pulse encoded into an analog HD video signal defining the start of each frame and the start of each line of video. In a broadcast or video production facility, a video reference signal with tri-level sync is used to synchronize equipment to a common frame rate. Tri-level sync evolved from traditional bi-level sync to meet the need for higher data rates and tighter jitter requirements in HD video formats. Tri-level sync covers all the frame rates found in HD video formats which are not covered by bi-level sync. Figure 7 shows a frame of an 1125-line, progressive HD video with tri-level sync.

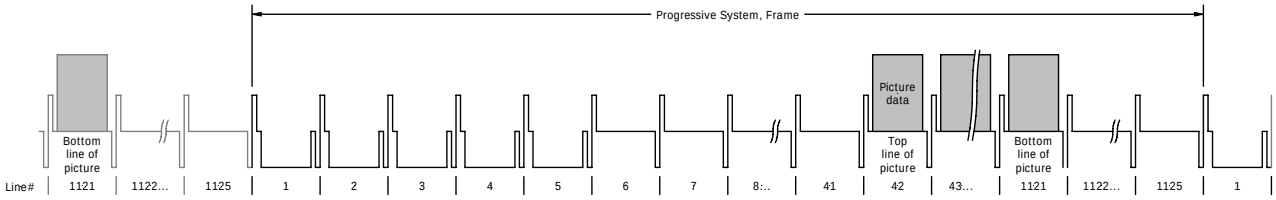

Figure 7 – 1125 line Progressive HD Video Signal with Tri-level Sync

Figure 8 shows a frame of 1125-line, interlaced or segmented frame HD video with tri-level sync. Note that for interlaced or segmented frame signals a frame comprises two fields with a different number of lines (563 and 562).

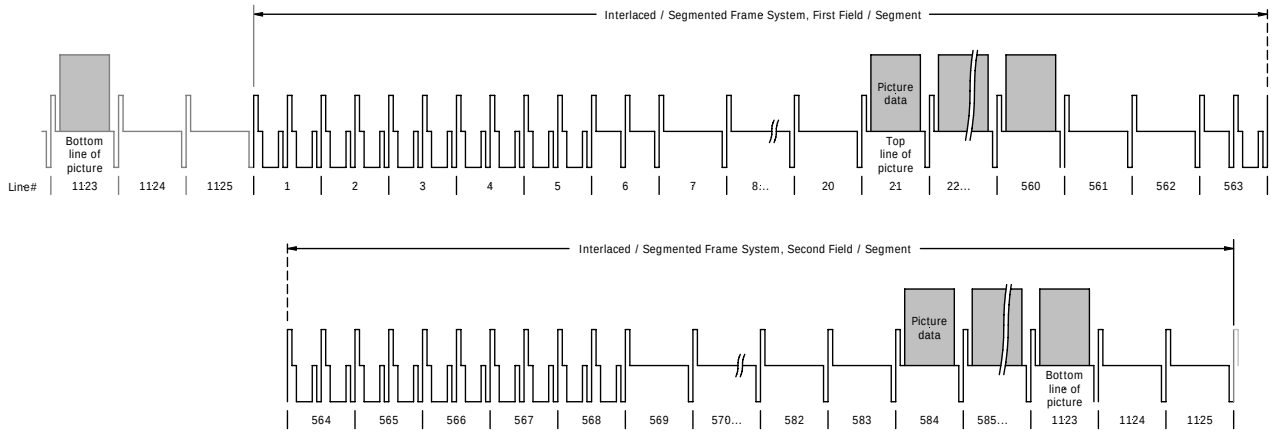

Figure 8 – 1125 line Interlaced / Segmented Frame HD Video Signal with Tri-level Sync

Why tri-level sync?

In SDTV signals, *bi-level* sync has been traditionally used to define the start of each line using the 50% point of the leading edge of a 300mV negative going pulse, as shown in Figure 9. This introduces an unwanted DC component into the signal, and the relative timing of synchronization pulses is susceptible to changes in gain, DC reference and frequency response.

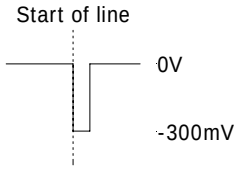

Figure 9 - Bi-level sync pulse

Tri-level sync uses the 50% point of a pulse with both positive and negative excursions of 300mV about a DC ground reference as shown in Figure 10. This eliminates the DC component in the signal and makes detection of the sync signal a much more robust process virtually immune from changes in gain, DC reference and frequency response. The zero crossing is easy to detect and results in less jitter.

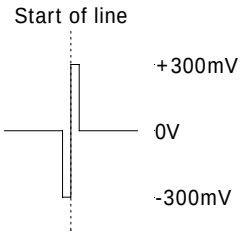

Figure 10 - Tri-level sync pulse

How is tri-level sync generated?

Tri-level sync is generated as part of an analog HD component video signal, or as a specific tri-level reference signal generated by a Sync Pulse Generator (SPG). An SPG may have separate outputs for multiple formats of tri-level sync and colour black reference, and may include test signals, audio reference signals and time code. An SPG may be genlocked to a video reference such as composite PAL or NTSC, a precision clock reference, or it may run in stand-alone mode from its own internal clock.

How is the tri-level sync reference signal format selected?

A tri-level reference is selected with the same frame rate as the routed video signals. This allows signals with a different number of lines per frame or different scanning standards (interlaced or progressive) to be switched using a common reference. For example, an 1125/50/I reference, which has a frame rate of 25 Hz (and a field rate of 50 Hz), can be used as a reference when routing 1125/50/I, 1125/25/P, 750/50/P or 625/50/I.

How does the reference signal sync relate to sync in the routed signal?

NK-3G series routers pass SD or HD SDI digital video signals, which do not contain tri-level sync. The sync information in the digital data stream of the routed signal is not used by the router to determine the router's switching point, but rather it is passed through the router without being processed and is used by other equipment which processes or reconstructs the video image, for example, a monitor. The switching point is determined by the reference signal, selected to ensure that the crosspoint switch is made at an appropriate point (line and clock cycle) in the routed video data stream so as to cause minimum disturbance to the routed signal. The switching point is selected to coincide with a region of non active video from the start of each frame, as defined in SMPTE RP168.

Can tri-level sync be used as a reference when routing SD signals?

Tri-level sync can be used as a reference when routing SD signals provided the routed signal is frame compatible with the reference signal, as outlined in Table 6. When using tri-level sync as a reference for routing SD signals, the SD (PAL/NTSC) preset switching point in the NK-3G router's configuration should be selected, as discussed later in this application note.

	Reference Signal Type		
Field or Frame Rate	**525/59.94/I (NTSC)**	**625/50/I (PAL)**	**Tri-Level Sync**
59.94P, 59.94/I, 29.97/PsF, 29.97/P	✓	X	✓
50/P, 50/I, 25/PsF, 25/P	X	✓	✓
23.98/PsF, 23.98/P	X	X	✓
60/I, 30/PsF, 30/P, 24/PsF, 24/P	X	X	✓

Table 6 – Reference Signal / Routed Signal Compatibility

For example, if routing 625/50/I SD signals, as well as 625/50/I bi-level sync reference, any of the following HD tri-level reference signals can be used; 1125/50/I, 1125/25/PsF, 1125/25/P and 750/25/P. These reference signals are compatible because they share a frame rate of 25 Hz and, even though the number of scan lines is different, line 1 occurs at the same horizontal reference point for all signals, as shown in Figure 11.

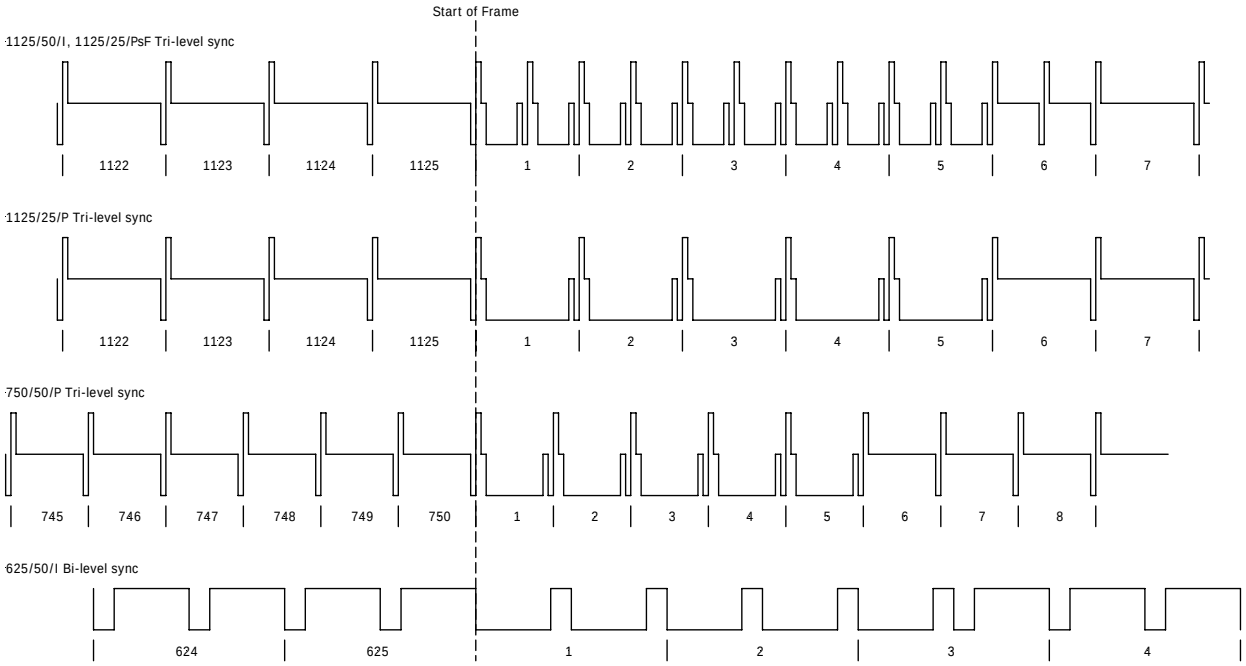

Figure 11 – Reference Signal Alignment for 50 Hz systems

If routing 525/59.94/I SD signals, as well as 525/59.94/I bi-level sync reference, any of the following HD tri-level reference signals can be used; 1125/59.94/I, 1125/24.97/PsF, 1125/24.97/P and 750/24.97/P. Note that these signals all align at line 1 except 525/59.94/I, whose start of frame occurs 4 lines prior to the point where it aligns with the other signals, as shown in Figure 12.

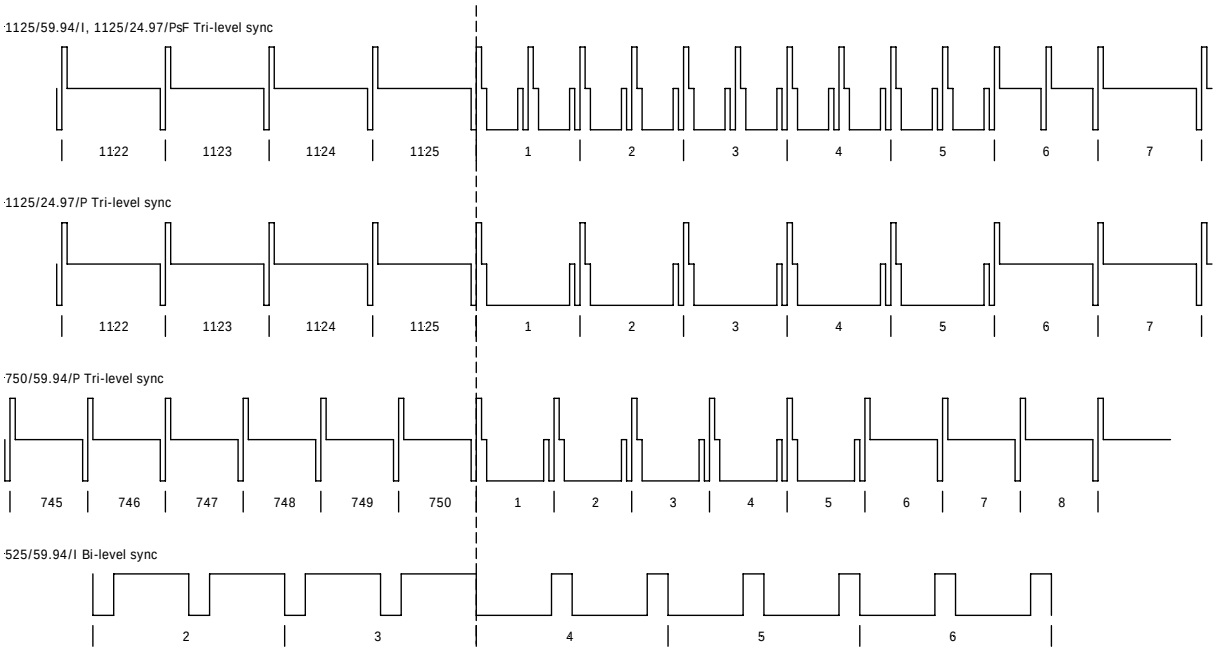

Figure 12 – Reference Signal Alignment for 59.94 Hz systems

Can bi-level sync be used as a reference when routing HD signals?

A signal with bi-level sync, such as PAL or NTSC can be used as a reference when routing HD signals provided the routed signal is frame compatible with the reference signal, as outlined in Table 6. For example, 625/50/I (PAL) can be used as a reference for 1125/50/I, 1125/25/PsF, 1125/25/P, 750/50/P and 750/25/P HD signals, while 525/59.94/I (NTSC) can be used as a reference for 1125/59.94/I, 1125/29.97/PsF, 1125/29.97/P, 750/59.94/P and 750/29.97/P HD signals. For HD signals with frame rates of 23.98, 24, 30 and 60 Hz there is no bi-level sync format available and tri-level sync must be used.

How Does the NK-3G Router Determine the Switching Point?

The router's control circuitry uses the sync information from a reference signal with bi-level or tri-level sync to determine the switching point. The sync information is decoded by the router using a sync separator, which identifies the reference signal as either NTSC, PAL, 525/I, 525/P, 625/I, 625/P, 750/P, 1125/I, 1125/P or 1125/PsF. The reference signal can be a composite or component video signal, from which the sync separator extracts timing signals corresponding to the start of each frame, the start of each field (for interlaced signals) and the start of each line. Clock generation logic uses this timing information to determine the video format of the reference signal and to generate the appropriate timing for crosspoint switching to occur. Figure 13 shows vertical switching pulse derived from the sync separator and clock generation logic.

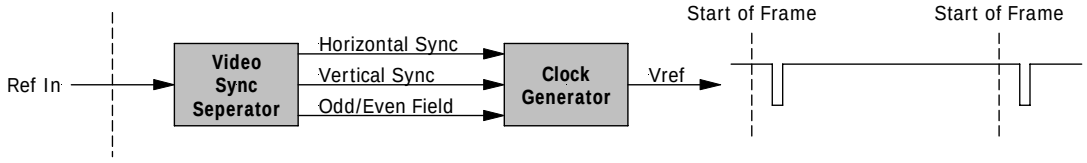

Figure 13 – NK-3G Router Reference Sync Detection

What happens if there is no reference connected to a router?

If there is no reference connected to an NK-3G Series router, an internal clock generates a switching pulse every 40ms, ensuring that a valid switch will occur at least within this time period.

References:

Codan Broadcast Application Note AN-015 - Using the Switching Reference Input on NK Series Routers

SMPTE Recommended Practice RP 168-2002 – Definition of Vertical Interval Switching Point for Synchronous Video Switching

SMPTE STANDARD 274M-2003 for Television – 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates