TM-1 Video Out Pixel Clock Sweeping

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Abstract

The Trimedia TM-1 chip is capable of achieving Video/Audio synchronization in a variety of environments. The primary mechanism to accomplish this are the flexible sample clock Direct Digital Synthesizers in Audio In, Audio Out and Video Out.

This application note describes in detail how the Video Out DDS can be manipulated to vary the Video Out sample rate, whilst maintaining quality NTSC or PAL analog video.

Refresher on Analog Video

An excellent overview of the NTSC and PAL composite video signal can be found in "Video Demystified, second edition, by Keith Jack, ISBN 1-878707-23-X". A summary of some key details that matter for the purpose of this application note are summarized below.

In PAL and NTSC analog composite video, a single wire is used to carry synchronization, luminance and chrominance information. To carry the two chrominance components as well as the luminance component, a frequency domain multiplexing technique combined with an orthogonal modulation technique is used. In NTSC-M, the luminance (Y) is limited in bandwidth, while the two chrominance components (U and V) are carried on the sine and cosine of a chrominance subcarrier as follows:

$s(t) = Y + U \sin(2\pi F_{SC}t) + V \cos(2\pi F_{SC}t)$, where F_{SC} = 3.575945 MHz

The receiver reconstructs U and V by re-generating the exact subcarrier phase. To do this, the receiver uses a the 'colorburst' tranmitted in a limited duration interval at the beginning of each horizontal line to phase correct a local oscillator running at approximately the same frequency.

In broadcast quality NTSC, two properties hold for F_{SC}:

1. F_{SC} has an exact relationship to F_H, the line frequency - $F_{SC} = (455/2)F_H$
2. F_{SC} is equal to 3.579545 MHz plus or minus 10 Hz (an accuracy of 3 ppm)

The details of PAL are somewhat different, but two similar rules hold:

1. F_{SC} has an exact relationship to F_H, the line frequency - $F_{SC} = (1135/4+1/625)F_H$
2. F_{SC} is equal to 4.43361875 MHz plus or minus 5 Hz (an accuracy of 1.5 ppm)

In both cases, the first property guarantees that the artefacts of the modulation/demodulation are minimized. The second property sets an overall broadcast accuracy standard.

When a video signal is recorded and played back on a consumer quality VCR, the exact relationship between F_{SC} and F_H is destroyed. The VCR uses a locally generated constant frequency F_{SC}, to generate a composite playback signal. The recorded luminance and chrominance is subject to significant temporal distortion due to mechanical tolerances in the playback process. As a result, most consumer equipment is capable of dealing with video signals in which relationship 1 above is absent.

Since consumer video sources do not have temperature controlled reference oscillators, the tolerance encountered in many video sources significantly exceeds the requirements of property 2 above.

S-Video

In USA video equipment, the S-Video connector standard is often available in addition to the RCA style composite video connector. The S-Video connector carries a separate signal for luminance (Y) and color ($C = U \sin(2\pi F_{SC} t) + V \cos(2\pi F_{SC} t)$). As a result, artefacts due to the imperfect receiver separation of luminance and color disappear. In addition, a higher bandwidth luminance signal is transported, resulting in higher horizontal resolution.

The use of S-Video is highly recommended wherever possible to utilize the high video quality generated by Trimedia based digital systems.

Video Out Pixel Clock and Subcarrier

The Trimedia TM1xxx generates a CCIR656 style time multiplexed YUV4:2:2 digital signal with 8 bits accuracy. A digital encoder, such as the SAA7185 or SAA7125 is used to generate composite video and/or S-Video Y/C signals.

Three distinct configurations are possible between TM-1 and the digital encoder (DENC):

1. TM-1 is used to synthesize the Video Out pixel clock (VO_CLK), which is then used as the DENC main clock (SAA7125/7185 signal LLC)
2. The DENC on chip crystal oscillator is used to generate a free running but accurate pixel clock, and LLC is used as output to drive TM-1 VO_CLK as input.
3. An external clock generation system (for example using a PLL to lock to some broadcast reference signal) is used to drive both DENC LLC and TM-1 VO_CLK.

Method 1 is the recommended method for all systems, since it allows full TM-1 software control over the pixel emission rate. The rest of this application note assumes that method 1 is used.

The DENC performs all aspects of the generation of a composite or S-video signal. As a part of this function, it generates an internal chrominance subcarrier and associated colorburst in the analog video. To this purpose, each DENC uses an on-chip digital sinewave oscillator. The SAA7185 digital oscillator obeys the following property:

$$F_{SC} = F_{LLC} * FSC/2^{32}$$

FSC is the content of an I^2C addressable 32 bit register. The table below shows the recommended values for FSC.

Table 1. Recommended SAA7185 FSC Values for F_{LLC} = 27.000000 MHz

	F_{SC}	FSC (decimal)	FSC(hex)
NTSC-M	3.579545 MHz	569408543	0x21F07C1F
PAL-B/G	4.43361875 MHz	705268427	0x2A098ACB

As the Video Out pixel clock is changed by manipulating the TM-1 VO_CLOCK register, F_{LLC} changes, and the chrominance subcarrier generated by the DENC will change with it, unless the DENC FSC register is changed to counter compensate.

There are now two fundamentally different ways of changing the pixel clock:

1. Change VO_CLOCK by small amounts, and leave FSC unchanged. This method retains F_{SC} property 1: the relationship between line rate and colorburst.
2. Change VO_CLOCK by larger amounts and also change FSC to keep F_{SC} constant. This method retains a fixed absolute F_{SC} frequency.

Both methods will be discussed in detail below.

Method 1 : Small Changes to the Video Out Pixel Clock

Method 1 changes the VO_CLK synthesizer in a small range, and operates the DENC in standard mode:

1. The DENC colorburst value is set nominal as per Table 1.
2. The DENC Colour Subcarrier Generator RESET mode is set nominal (SAA7185 subaddress 70, PHRES bits), i.e. once every 4 fields for NTSC and once every 8 fields for PAL.

The VO_CLK frequency is now changed by manipulating the TM1xxx VO_CLOCK register. The nominal frequency for PAL and NTSC is 27.0 MHz. The allowed deviation is about 50 ppm[1] as described below.

The table below shows experimental data on several different TV receivers and the deviation of the colorburst they can handle in NTSC mode. The TV image turns from a color into a greyscale image as soon as the range is exceeded. This data was gathered by a special version of the Trimedia MPEG-2 decoder, running the Batman sequence, using a test image overlay on Video Out. The test ramps the VO_CLK frequency over a certain range from low to high and back, with a 60 Sec ramp from low to high. The tracking and capture capabilities are identical for S-Video and composite video connections.

Table 2. TV Receiver Colorburst Deviation Capability (measurement accuracy +- 30 Hz)

	low limit capture	low limit track	high limit capture	high limit track
Magnavox TP2782C (standard consumer NTSC TV, with combfilter)	-500 Hz	-520 Hz	+560 Hz	+630 Hz
Philips P05029 IDTV Matchline Multimedia Display	-630 Hz	-700 Hz	+360 Hz	+440 Hz
JVC TM1400SU lab NTSC monitor	-240 Hz	-450 Hz	+500 Hz	+850 Hz
Sony KV20V60 consumer TV	-440 Hz	-450 Hz	+680 Hz	+720 Hz

Based on the above data, it is reasonable to allow for up to 250 Hz deviation (70 ppm) from nominal colorburst for consumer equipment. This corresponds to a deviation of up to 1900 Hz on the 27 MHz VO_CLK value.

The crystal oscilators used on the Trimedia board (such as the Ecliptek EC11 Series HCMOS/TTL Crystal Oscillator family) are available in versions with (over full operating conditions) 50 ppm, 25 ppm or 20 ppm tolerance/stability. It is recommended that a 25 ppm or better version is chosen for the crystal, hence leaving a ca. 50 ppm 'software maneuvering margin' for method1.

Method 2 : Large Changes to the Video Out Pixel Clock

Method 2 changes the VO_CLK synthesizer over a much larger range than method 1, while sending I^2C messages to the DENC to keep the color burst stable in absolute frequency. This method should *not* be used in case Video Out drives the destination using an analog composite video cable. It is an excellent method, that allows 30000 ppm deviation for S-video connected systems.

The DENC is operated in the following mode:

1. The DENC colorburst control register (FSC) is changed at the same time the VO_CLK synthesizer is changed.
2. The DENC Colour Subcarrier Generator RESET mode is set free running, i.e. never reset (SAA7185 subaddress 70, PHRES bits).

1. Parts Per Million, i.e. 70 ppm is a relative deviation by multiplying with 0.999930 - 1.000070

The table below shows experimental data on the tracking range using method2 using S-Video connections. In this case, the TV sets actually loose sync before they loose colour decode capability. It is not recommended that the full tracking range be utilized, due to actually visible image stretching near the end of the range. Experimentally, sweeping from 26.2 to 27.8 MHz in 60 Secs results in no visible artefacts, and no more than 8 mm. shift of a right hand side screen object over the entire range on a 27" TV set. This represents a 30000 ppm deviation capability, which is many orders of magnitude more than should be needed in a real application.

Table 3. TV Receiver S-Video Method 2 Tracking Capability

	low limit capture	low limit track	high limit capture	high limit track
Magnavox TP2782C (standard consumer NTSC TV, with combfilter)	25.8 MHz	25.6 MHz	28.4 MHz	28.5 MHz
Philips P05029 IDTV Matchline Multimedia Display	25.8 MHz	25.4 MHz	28.6 MHz	28.7 MHz
JVC TM1400SU lab NTSC monitor	25.8 MHz	25.4 MHz	27.8 MHz	28.4 MHz
Sony KV20V60 consumer TV	26.2 MHz	26.1 MHz	28.0 MHz	28.1 MHz

In the case of the use of a composite video connection to certain common types NTSC TV receivers, method 2 introduces artefacts. Two artefacts are visible to the casual observer:

1. slanted lines that change angle as the VO_CLK frequency is changed
2. 'shadows' along the right hand side of objects with high colour contrast

The artefacts are present only in TV receivers that use so-called 'glass delay' lines, or other fixed absolute time line delays in the color decoder. In the case of the Philips P05029 IDTV, which uses a line locked clock driven line delay circuit, no such artefacts are observed.

The use of method 2 is hence *not recommended* for systems that use composite video to connect Trimedia's Video out to a video destination. Even with deviations as small as 1 kHz on 27 MHz (40 ppm) visible lines in the image occur. The artefacts become absolutely unacceptable at deviations over 100 kHz on 27 MHz (4000 ppm).

Recommendations

In all systems where deviations are expected to be small, use method 1, which works equally well with S-Video and composite video destinations. Method 1 should always work in cases where a long-term lock is established on a source that by itself is within tolerance.

In systems where large deviations exist, such as when receiving video from a VCR, use method 2 if the destination is connected by S-Video.

In systems where large deviations exist, but where the destination is connected by composite video, or where the connection is unknown, the implementer should implement longterm synchronization by dropping frames, or by an alternate method (see future work section).

Future Work

We need to investigate the possibility of changing the Video Out field emission rate by sending more/less video lines to the DENC. This is an interesting possibility that may provide a better solution for large deviation cases than dropping frames.

The mpeg2ramp Example Program

The mpeg2ramp example program is available for Trimedia internal use. It allows experimentation with both method1 and method2 with a user programmable range. At the time of writing, it was tested only on the TM-1 debug board with SAA7185 DENC and not yet for the TM-1 Reference board. Contact the author for more information.