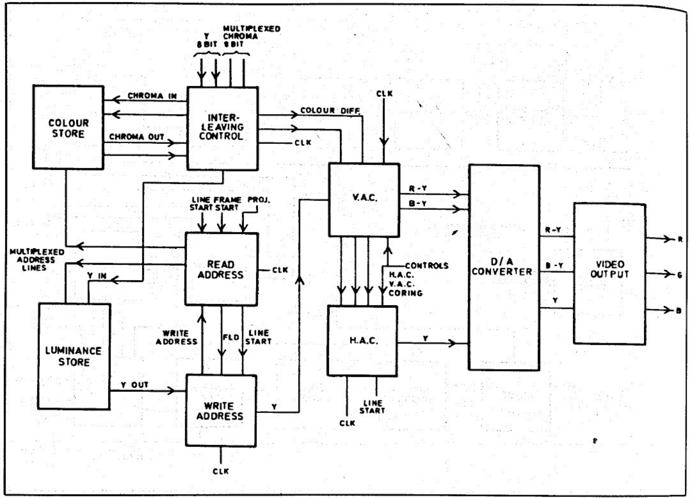

Figure 4. The sequential-to-interlace converter.

convenience in monitoring, and when using existing color encoders, D/A conversion back to analog red, green, and blue signals is performed. The whole of the signal processing is controlled by a microprocessor which also interfaces with the control logic and capstan servo to ensure correct operation and timing of the storage system.

Servo Systems

Three servo systems are used:

1. capstan servo;
2. spooling servos;
3. light control servo.

The capstan servo is responsible for moving the film at the correct velocity and phasing to provide the whole of the vertical scanning of the picture. This obviously requires a high degree of both mechanical and electronic precision to avoid picture unsteadiness and vertical non-linearities.

The capstan revolves at approximately one rev/sec on 16-mm film and at 2.5 rev/sec on 35-mm film. It is directly driven, and the system is especially designed to have adequate inertia controllable at very slow speeds; yet it is capable of being started and locked up in approximately 100 msec. The motor has many poles to prevent cogging and carries a 5000-line optical tachometer at the rear. Velocity-lock is achieved by comparing the number of master-clock (12.8 MHz) pulses occurring between successive tachometer pulses against a pre-set number. Positional information for framing and phase lock are obtained by comparing film frame information from the sprocket pulse generator to pulses generated from television-frame pulses and the film "racking" or "framing" circuits. The phasing-error signal is fed into the velocity servo as an offset. A microprocessor assesses the effect this offset has on the velocity drive and adjusts the preset count requirement to take care of film stretch or shrinkage. This enables tight velocity lock to be maintained. Changes of standard film gauge or speed are performed by a change of preset count and by division of either tachometer or clock pulses. "Shuttle," which is continuously variable between 1/5 speed and the fast rewind speed, is achieved by the use of a variable, preset number obtained by A to D conversion from a variable dc.

The spooling servos control the film tension and remove spooling drag from the capstan. Direct-drive, high-torque, printed-circuit motors are used. The shafts of the compliance arms carry slitted disks which are part of a spiral curve. These slits control the position of the light falling on optically variable resistors, and cause progressive forward or reverse drive to be applied to the spooling motors as the arms move away from their correct tension position.

The light-control servo is a positional servo that controls the variable N.D. disc. It receives control via the main microprocessor system from either the light-control knob or the automatic system.

Conclusion

The aim of this paper has been to give an outline of the design philosophy and some of the systems used to produce a device which breaks new ground in terms of performance predictability and freedom from adjustment or routine maintenance.

The VHD Videodisc System

By Toshiya Inoue, Tsuneyoshi Hidaka, and Vincent Roberts

The VHD (Video High Density) system plays a 10.2-in. grooveless conductive plastic disc. Each disc contains one hour per side of high quality, color video programming with stereo sound. The VHD system will also play a digitally recorded, ultra high-fidelity pulse-coded modulated Audio High-Density Disc (AHD). The AHD disc will be available approximately one year after the introduction of the VHD Videodisc system.

Before development began, basic criteria for the VHD system were established as follows. First, both the videodisc and videodisc player should be compact. Second, the playing time must be long enough for a feature film. Third, two sound tracks should be available so that stereo sound or bilingual sound can be reproduced. Fourth, the operation must be simple and flexible, with a variety of playback modes available to the user through the VHD player. And finally, there should be a wide variety of software available. Another important consideration is the capability to play a digital audiodisc on the same player used for the VHD videodisc.

In the VHD system, the disc rotation speed is 900 rpm in the NTSC standard and 750 rpm in the PAL/SECAM system. Two TV frames (4 fields) are recorded per revolution, with the sync aligned radially on the disc. The track pits are recorded on the disc in spiral form outside-to-inside with 1.35 μm of track pitch. The dimensions of the pit are about 0.8 μm in width and 0.3 μm in depth.

The VHD videodisc system uses a grooveless capacitance pickup. Video and two audio signals are recorded on the surface of the videodisc in the form of micropits. An electrode is attached to the rear of the stylus and can pick up capacitance variation, between the stylus electrode and the conductive disc. Because no actual mechanical grooves are on the videodisc surface to guide the stylus, the pickup stylus is controlled by an electro-tracking servo system. The tracking signal is placed on both sides of the micropits of the video and audio signals. During playback, the stylus electrode picks up the video and audio signals as well as two tracking signals in the form of capacitance variations (Fig. 1).

Encoding/Decoding System

One of the biggest differences between the videodisc medium and magnetic tape or magnetic discs is in the linearity of the recording signal. There is no linear portion on the nonmagnetic videodisc. Rather, it is a two-state device with the properties of

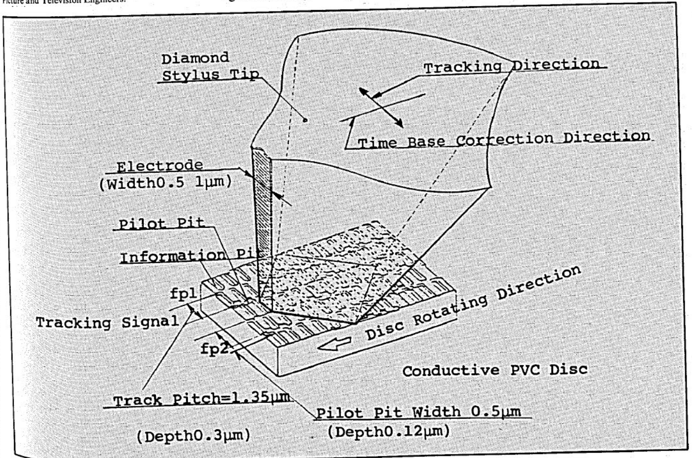

Figure 1. Relationship between information pit and stylus on disc surface.

This contribution was received from Toshiya Inoue, JVC, Japan, Tsuneyoshi Hidaka, JVC, Japan, and Vincent Roberts, VHD Disc Mfg, USA, on July 29, 1982.

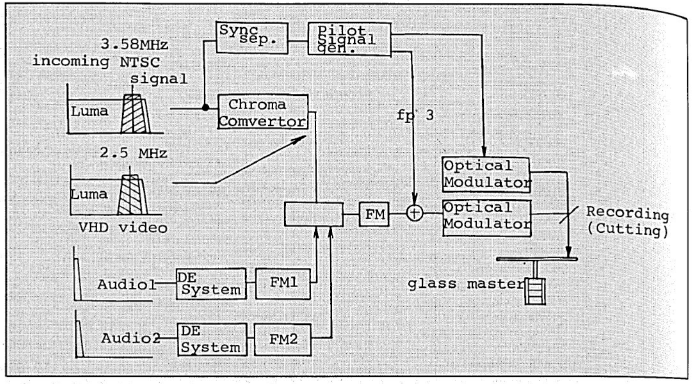

Figure 2. Signal processing encoding.

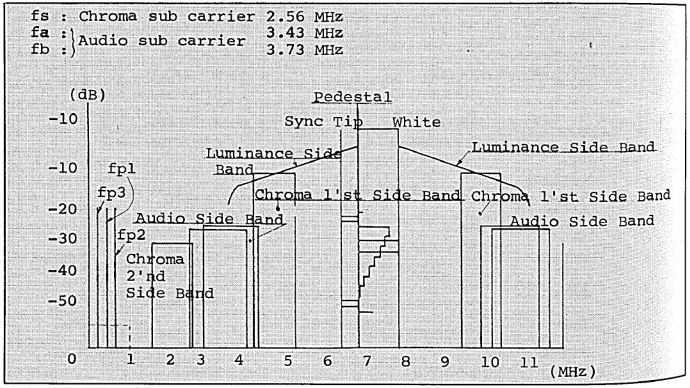

Figure 3. FM spectrum on the VHD disc.

a hard limiter. If the two carriers go through the non-linear portion, such as the limiter circuit, the spurious products will be produced as a beat frequency of the two carriers. Therefore, it is important to use a single-carrier system with a symmetrical side-band spectrum to minimize even-order spurious components.

Encoding

Figure 2 shows a simplified block diagram of the signal processing for encoding the video and audio signals. The chrominance signal, 3.58 MHz in NTSC, of the incoming composite video is converted down to 2.56 MHz. In the VHD system, the frequency of the subcarrier, 2.56 MHz, was chosen to be an odd multiple (162.5 × fH) of one-half the line frequency, to minimize its visibility in accordance with well-known frequency interleaving principles.

The two separate audio signals, after passing through the DE system,* are frequency modulated on carriers of 3.43 MHz and 3.73 MHz with a frequency deviation of ± 75 KHz.

The audio channel of the VHD videodisc system uses the DE system for both noise reduction and dynamic range expansion for better audio quality. The two frequency-modulated audio carriers are added to the converted video signal (luminance signal with 2.56 MHz chrominance signal). These three signals are frequency-modulated on a carrier at 6.6 MHz (6.1 MHz sync tip and 7.9 MHz for peak white), and the output FM carrier is used to modulate the intensity of a laser beam passing through the first electro-optical modulator in the master cutting machine.

Two pilot signals, f^{p1} = 511 KHz and f^{p2} = 716 KHz, will be made from the sync portion of the incoming video signal. There f^{p1} and f^{p2} are used to modulate the second electro-optical modulator. The index signal, f^{p3} = 275 KHz, is also made from sync and recorded once in every two frames in the vertical blanking period of the first field.

FM Spectrum

Since the main carrier is frequency-modulated by three signals, namely, 2.56 MHz chrominance, 3.43 MHz first audio carrier, and 3.73 MHz second audio carrier, the FM signal is in the following form:

$$fc(t) = Ac\, e^{j(\omega ct + \beta 1, \sin\omega/t + \beta 2z\sin\omega zt + \beta 3\sin\omega 3t)}$$

$$- Ac\left[\sum_{n=-\infty}^{\infty} Jn(\beta 1)e^{jn\omega/t}\right] \cdot \left[\sum_{n=-\infty}^{\infty} Jm(\beta 2)e^{jm\omega 2t}\right] \cdot \left[\sum_{n=-\infty}^{\infty} Jk(\beta 3)e^{jk\omega 3t}\right] e^{j\omega ct}$$

Where

$\beta 1$ = modulation index of first modulation signal such as a chrominance signal.

$\beta 2$ = modulation index of second modulation signal such as a first audio carrier.

$\beta 3$ = modulation index of third modulation signal such as a second audio carrier.

Then

$$fc(t) = Ac \sum_{n,m,}^{\infty} \sum_{k=-\infty} Cn,m,k e^{j(\omega c + n\omega/ + m\omega 2 + k\omega 3)t}$$

Therefore, the amplitude of the carrier and its sideband can be described as follows:

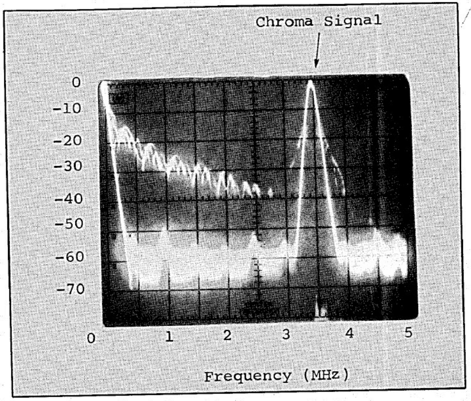

Figure 4. Spectrum at demod out.

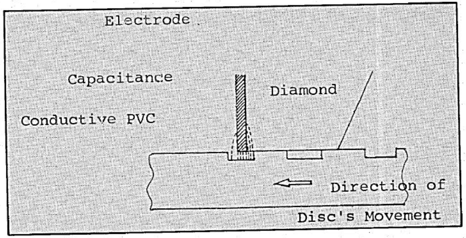

Figure 5. Stylus versus disc.

a. carrier: $Jo(\beta 1)Jo(\beta 2)Jo(\beta 3) Ace^{J\omega ct}$
b. Sideband due to $\omega 1$; $Jn(\beta 1)$-$Jo(\beta 2)Jo(\beta 3) \cdot Ace^{J(\omega c \pm n\omega 2)t}$
c. Sideband due to $\omega 2$; $Jm(\beta 2)$-$Jo(\beta 1)Jo(\beta 3) \cdot Ace^{J(\omega c \pm m\omega 2)t}$
d. Sideband due to ω^3; $Jk(\beta 3)$-$Jo(\beta 1)Jo(\beta 2) \cdot Ace^{J(\omega c \pm k\omega 3)t}$
e. Beat frequency at $\omega c \pm n\omega 1 \pm m\omega 2 \pm k\omega 3$; $Jn(\beta 1)Jm(\beta 2)$-$Jk(\beta 3) \cdot Ace^{J(\omega c \pm n\omega 1 \pm m\omega 2 \pm k\omega 3)t}$

The FM spectrum on the VHD videodisc shown in Fig. 3 has an ideal symmetrical side-band distribution at both upper and lower sides of the main carrier.

fs: Chroma sub carrier 2.56 MHz

fa: } Audio sub carrier 3.43 MHz
fb: 3.73 MHz

The two pilot signals, f^{p1} and f^{p2}, at the low end of the spectrum are produced from the pilot signal track. Therefore, the f^{p1} and f^{p2} do not cause any even-order harmonic-distortion in the main carrier. Spurious components or moiré produced by the above FM spectrum will be so small that they can be ignored.

Figure 4 shows an oscillogram of a spectrum analyzer output of demodulated video for the "E-to-E" condition when a 100% saturated chrominance signal was used as the input signal. Note that the spurious components in the video passband are all below −50 dB, which produces a very clean, moiré-free picture.

Decoding at Player

When the stylus passes across an

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* The Dynamic range Expansion (DE) system is the noise-reduction system for the audio signal. The DE system not only improves the noise performance of the audio signal, but also expands its dynamic range.

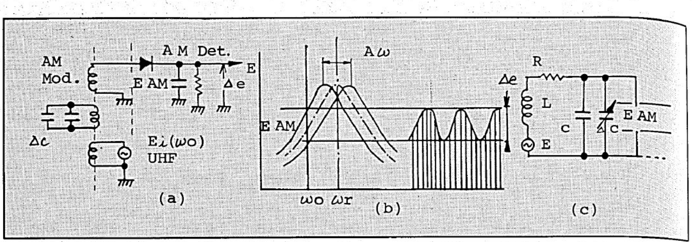

Figure 6. Capacitance variation to FM signal converter.

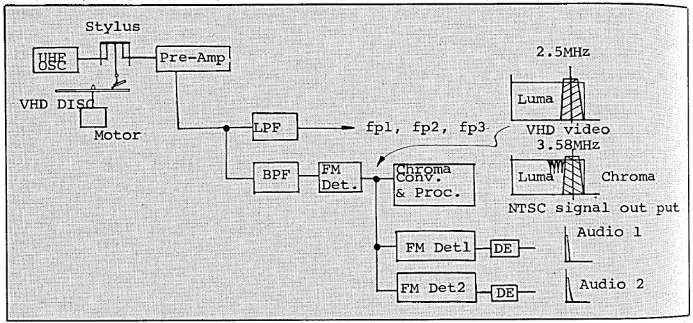

Figure 7. Decoding process.

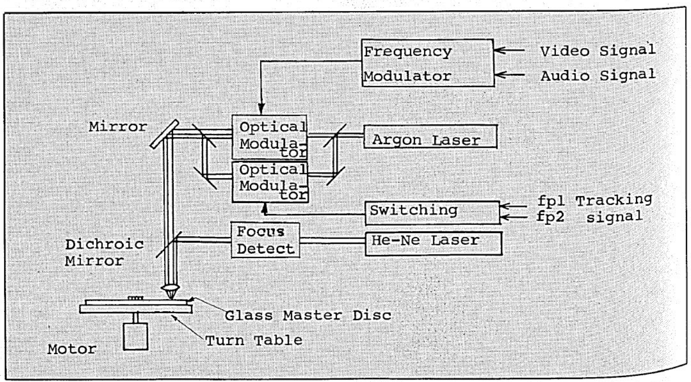

Figure 8. Optical path of the laser beam recorder.

information pit, the electrode on the stylus senses the capacitance variations (Fig. 5). The stylus is connected to a resonant circuit which is tuned to approximately 910 MHz. Figure 6 shows the equivalent circuit of the stylus and pre-amplifier which convert the capacitance variation between the stylus and the conductive disc to an electrical signal.

In Fig. 6a, the capacitance change (ΔC) between the stylus and the disc will vary the resonance frequency and cause amplitude modulation of the UHF, *Ei* (*ωo*), at the frequency modulation rate. The response curve of the resonance circuit and its amplitude modulation output are shown in Fig. 6b.

The *AM* output, *E AM*, can be calculated as shown below, by using the equivalent circuit, Fig. 6c.

$$EAM = \frac{\dfrac{1}{j\omega o(c+\Delta c)}}{R + j\omega oL + \dfrac{1}{j\omega o(c+\Delta c)}}$$

$$\cdot Ei = 1/1 - \left(\frac{\omega o}{\omega r}\right)\cdot\left(1+\frac{\Delta c}{c}\right) + J\frac{1}{Q}\left(\frac{\omega o}{\omega r}\right)\left(1+\frac{\Delta c}{c}\right)$$

$$\text{Where } \omega r = \frac{1}{\sqrt{Lc}} \cdot Q = \frac{\omega rL}{R}$$

$$\frac{\Delta \mathrm{cop}}{c} = Aop \cos(\omega ct + \mathrm{B}\sin\omega mt)$$

The original FM-modulated signal on the disc will be reproduced by the AM-modulated UHF carrier.

Figure 7 shows the block diagram of the signal processing for decoding of the video and audio signals. The detected FM signals are fed to the preamplifier and then to the main FM detector through the band-pass filter (BPF). The main FM detector produces a video signal with 2.56 MHz and 3.43 MHz of the first audio carrier and 3.73 MHz of the second audio carrier.

The demodulated video signal is fed to the chroma processing circuit and converts the chroma frequency from 2.56 MHz to 3.58 MHz. The chroma processing circuit also stabilizes the chroma signal. The 2.56-MHz chroma signal is removed from the demodulated video by a comb filter in order to maintain wide luminance bandwidth. The two audio carriers are fed to the individual FM demodulator. The demodulated audio signal will be reconstructed by the DE demodulator circuit.

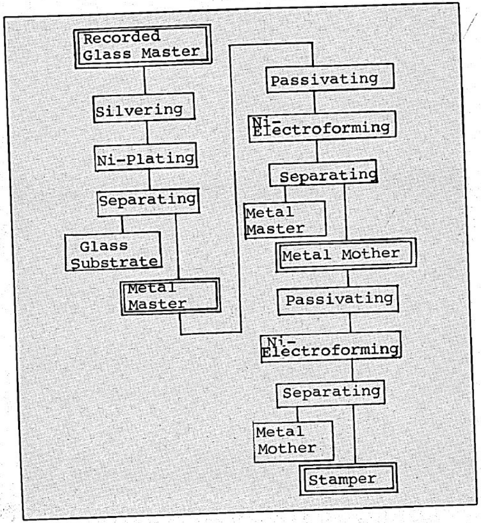

Figure 9. Matrix process flow-chart.

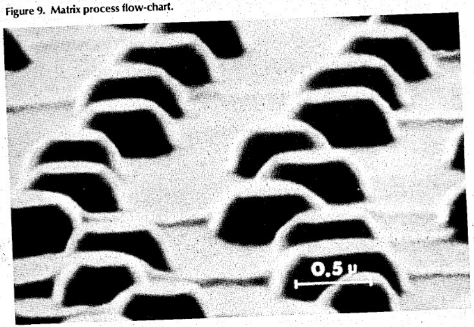

Figure 10. Metal master (slant view).

Disc Production

One of the big advantages of the VHD videodisc system is the ease of disc mass-production and its relatively low cost. The VHD videodisc uses in its production the technology and same facilities of the conventional LP record manufacturing process. Several steps occur in the VHD videodisc production process, from mastering to electroforming and pressing.

Mastering

Figure 8 shows the optical path of the laser beam recorder (cutter). Using a master disc made of glass, master recording is accomplished by using an optical cutting machine installed in a

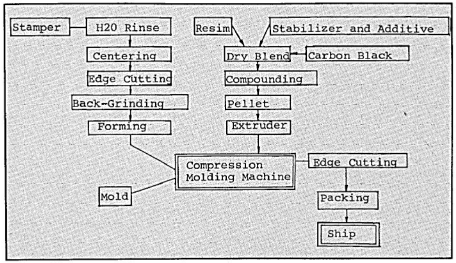

Figure 11. Videodisc replication process.

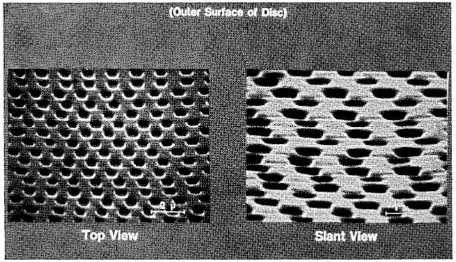

Figure 12. Relativity between signal and pilot.

cleanroom. The smooth, flat glass disc is coated with ordinary photosensitive material.

While the disc is rotated at a speed of 900 rpm for NTSC (750 rpm, PAL/SECAM), it is irradiated by minute laser beams. Since the VHD videodisc system employs a constant angular velocity system, the track velocity changes from outside to inside. Therefore, the signal element at the innermost position becomes shorter, relative to the outside. If the spot size of the laser beam is constant through the entire disc, from outside to inside, the duty cycle of the pits becomes asymmetrical, causing an even order of harmonic distortion of the playback FM signal. In order to compensate for this, the mastering machine during recording varies the spot size of the laser beam to correspond with the diameter of the disc.

In Fig. 8 the argon laser beam is split, one half for the information signals, the other for the tracking signals. The recorded glass disc is then developed with interferometer thickness at a developing station.

Matrix (Electroforming)

The matrix or electroforming process on the VHD videodisc system is identical to the electroforming of the conventional phonograph record. The overall matrix-process flow chart used for the VHD disc is shown in Fig. 9.

A recorded glass master is silver-coated with an extremely thin layer (≈ 800 Å) that is sprayed onto the surface of the glass. The silvered-glass master is pre-plated at a low temperature and current density before being transferred to a tank for deposition at the normal speed. After plating, the metal master is separated from the glass master.

The metal master is then nickel-plated for "mother" forming. The stamper is produced from the mother in the same manner. Figure 10 shows the scanning electron microscope picture of the metal master.

Videodisc Pressing

The videodisc material is a PVC-based compound which should have extremely fine particles, no degradation by the cycle of high and low temperature, and good melt-flow properties. Figure 11 shows a flow-chart of the videodisc replication process.

Physical process: The back of the videodisc stamper is ground before it is mounted to the molding machine to prevent any back-roughness from penetrating the surface of the disc.

Compound process: The videodisc materials (resin, stabilizer additive, and carbon black) are mixed together in a "dry blending" machine. The carbon black is added to make the disc electrically conductive.

Compression Molding: The thermoplastic molding is produced by heat, pressure, and subsequent cooling from a pair of stampers in a suitable disc press. The VHD videodisc compression molding machine was converted from the conventional phonograph audio-record pressing machine. It uses a fully automated pressing process and is installed in the cleanroom. Figure 12 shows the scanning electron microscope picture of the pressed videodisc. No additional processing, such as rinsing, lubrication, or metal coating, is required after the pressing is made.

Conclusion

A most important consideration is to establish a standard for consumer products — a standard that results in high product performance — a product that can build and grow with today's technology. By understanding the capabilities and limitations of this process, in both software and hardware, the videodisc medium can be utilized to the fullest. The VHD family consists of many manufacturing elements from all over the world. Player and disc manufacturing companies are working together to produce a disc system with good interchangeability, and production processes with low material usage, low production cost, and above all, high quality.

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Quantization Effects on Differential Phase and Gain Measurements

By Frederick A. Williams and Richard K. Olsen

This article discusses absolute standards of performance as a means of characterizing television systems. Absolute standards are based on the best theoretically obtainable performance as defined by DP and DG limits. Until now, however, there has been no published means of the best way to arrive at these limits. This article provides a set of equations used to provide theoretically obtainable DP and DG limits for use in the evaluation and diagnosis of television equipment.

Video test signals are used to characterize television systems for two different purposes: the comparative evaluation of properly functioning equipment, and the diagnosis of malfunctioning equipment. For NTSC color television equipment, color fidelity is in part characterized by differential phase (DP) and differential gain (DG) measurements. These measurements are only meaningful in comparison with a standard of performance, since they are not direct (optical) measurements of color fidelity. Two kinds of performance standards exist: relative and absolute. Since the state of the television art is not constant, relative standards can and must change. Absolute standards, based on theoretical limitations, provide both a goal and a restriction on performance. As a result, it is desirable to know what is the best theoretically obtainable performance. This is true for either the evaluation or diagnosis of equipment. It is therefore surprising that the theoretically obtainable DP and DG limits have not been derived and published for digital video systems operating at a sampling rate of four times the color subcarrier. This paper is intended to provide those limits.

Test Signals

Michael Felix, in his groundbreaking paper on digital phase and gain measurements,[1] concludes his discussion of the effects of digitization on DP and DG measurement with the recommendation of the use of a 40 IRE peak-to-peak modulated ramp, unlocked to either line or frame rate. This results in a smoother and more intelligible vectorscope display. The measurements so taken correspond more closely to actual color fidelity than a locked, 20 IRE (p-p) ramp. We will follow his recommendations (and some of his procedures) in this paper.

Quantization Errors

The test signals used for testing video equipment are analog. To handle video signals digitally, two processes are necessary. First, the signal must be sampled. A common practice in the television industry is to sample the television signal at a rate which is four times the subcarrier frequency. Note that the operation of sampling a band-limited signal does not inherently degrade the signal.

In addition to sampling, quantization must also be performed. A digital processor of any variety (time base corrector, special effects generator, VTR, or any other kind) handles a very limited number ("b") of signal values (usually two: either a one or a zero) on a limited number ("n") of signal lines (usually eight or nine). As a result, there is a limited number (bn) of possible signal combinations at any given time to represent the input analog signal. Quantization is thus merely the act of selecting the digital representation (out of bn possible representations) which is closest to the actual value.

Calculations

We'll perform our calculations for a signal at the subcarrier frequency of amplitude A, added to a DC level C

$$V(t) = A \sin 2\pi f_s t + C \qquad (1)$$

Sampling will occur at four times color subcarrier, at some angle θ relative to the phase of the test signal. For each cycle, therefore, four sample vectors are taken. We'll call these w, x, y, and z.

$$w = A \sin \theta + C \qquad (2)$$

$$x = A \sin (\theta + \pi/2) + C = A \cos \theta + C \qquad (3)$$

$$y = A \sin (\theta + \pi) + C = -A \sin \theta + C \qquad (4)$$

$$z = A \sin (\theta + 3\pi/2) + C = -A \cos \theta + C \qquad (5)$$

What we need now is a set of equations which take the sample values and give us luminance, chrominance amplitude, and chrominance phase. Put mathematically, give w, x, y, and z, then solve for C, A, and θ. First we'll derive the luminance. Remember that the average value of a sine wave is zero (there is no DC component). So, if we average a single cycle (in other words, four samples) we'll get the luminance.

$$C = \frac{w + x + y + z}{4} \qquad (6)$$

To solve for the amplitude A, we first need to remove the effects of the DC offset C (to look at the sine wave only). To do this, we'll subtract the equations which are 180° out of phase.

$$w - y = A \sin \theta + C - (-A \sin \theta + C) = 2A \sin \theta \qquad (7)$$

$$x - z = A \cos \theta + C - (-A \cos \theta + C) = 2A \cos \theta \qquad (8)$$

Next, we need to remove the effect of phase. We'll use the relationship $\sin^2 \theta + \cos^2 \theta = 1$. Squaring (7) and (8) gives:

$$(w - y)^2 = 4A^2 \sin^2 \theta \qquad (9)$$

$$(x - z)^2 = 4A^2 \cos^2 \theta \qquad (10)$$

Adding (9) and (10) gives:

$$(w - y)^2 + (x - z)^2 = 4A^2 (\sin^2\theta + \cos^2\theta) = 4A^2 \qquad (11)$$

This contribution was received on January 12, 1982, from Frederic A. Williams, Senior Applications Engineer, TRW LSI Products, and Richard K. Olsen, Manager, Field Applications Engineering, TRW LSI Products.