We have acquired digital transfer capability for the original Philips VCR and VCR Long Play recordings. Our primary playback decks (N1501, N1702) are modified to provide optimal video signal acquisition for analog-to-digital conversions.

In this document, we take a look at the physical, magnetic and video signal parameters pertinent to VCR format, as well as describe the modifications made on our VCR playback decks.

Evolutionary format
The original VCR format is based on the helical scan recording, employing the so-called guard-band video track layout. The video track pitch is 187 µm, but the actual track width only 130 µm. The tracks are separated by a 57-µm guard bands to prevent inter-track signal leakage. Since 50 video tracks, slanted at a shallow angle of 3° 45’ are needed for every second of recorded CCIR (625/50) video signal, the required longitudinal tape speed is 14.29 cm/s. This, in comparison, amounts to over six times the tape area consumption of the VCR’s successor formats like Beta and VHS.

Figure 1. The original Philips VCR magnetic track layout. Video track width is 130 µm separated by 57 µm unrecorded guard bands.
In 1977, Philips launched the N1700-series, that also uses a half-inch tape, wound on coaxial or 'stacked' reels, and a cartridge identical to the original VCR. However, the VCR LP's (Long Play) other physical parameters were considerably revised. The tape speed is reduced by over 50 %, to 6.56 cm/s, affording more than twice the recording time. Such a radical speed reduction was possible due to the use of an ingenious azimuth recording that made guard bands redundant. The air gaps of the video head pair are tilted by ±15 degrees. On replay, the 30-degree azimuth difference sufficiently attenuates the inter-track signal leakage or 'cross-talk', even though the adjacent tracks are written without guard bands. Also, the use of advanced high-output tape formulations allowed to reduce the video track width to 85 µm.

![Figure 2. Generalized magnetic track patterns (not to scale) showing the main parameters of the original VCR format.](image)

In 1978, Grundig came up with yet another version of the VCR cassette by introducing their SVR (Super Video Recording) format. High-output chromium dioxide magnetic tapes permit to use of even narrower video tracks, at 50µm. Since other parameters such as video head cylinder size (105 mm) remain the same, the SVR linear tape speed was halved once more, to 3.95 cm/s. Thus, the SVR format provides recording times up to more than four hours.

Philips wanted to keep the VCR format alive by introducing a two-track (stereo sound) version, the N1520. Meanwhile, Grundig went on to demonstrate their prototype of dual-format VCR/SVR machine. It is compatible with Philips LP and Grundig SVR recordings. However, the emergence of Beta and VHS formats in 1975-1976, made the somewhat bulky VCR format obsolete. As a result of these developments, a video restorationist may come across with three incompatible VCR-type tape recordings – all encased in basically identical cartridges.
Figure 3. VCR Long Play format is based on the azimuth recording; video tracks are laid side by side with no guard bands. The track width is also reduced to 85 µm.

Video signal system in brief
The standard PAL composite video signal consists of two components: luminance (Y) and chrominance (C). Ideally, the Y signal spectrum extends to about 5 MHz, while the C component, representing color image information is a QAM (amplitude/quadrature-modulated) subcarrier, centered at 4.43 MHz, (±500kHz).

Figure 4. VCR and VCR LP video signal spectra.
Recording process

On recording, the input Y and C signals are separated, the former being routed via a 3-MHz low-pass filter. This sets the upper Y signal resolution of the VCR format at about 325 vertical lines. A filtered Y signal is fed into a frequency modulator to create an FM carrier. The Y signal sync pulse tips correspond to the carrier deviation of 3 MHz, the black-level to 3.42 MHz and the mid-grey to about 3.7 MHz. Peak white amplitudes swing up to 4.4 MHz. The primary carrier spectrum width is 1.4 MHz. However, before the FM process, the Y signal is routed via a high-frequency emphasis circuit, making the reduced FM sidebands to extend beyond 1.4 MHz. This FM Y signal is amplitude limited before being supplied to a recording amplifier, thence to the rotary transformer and eventually the rotating video heads.

In consumer-grade VCRs, video signals over 3 MHz are difficult to replay with reasonable stability as such. This is why the original 4.43-MHz chroma signal is down-converted to the 0.56-MHz range thus being shifted to below the Y signal carrier. At recording, the C carrier is summed to the Y signal only at the video head recording amplifier. Since the C carrier is an AM signal, it has to be linearized during the recording process. This is accomplished conveniently as the constant-amplitude Y carrier signal makes up a high-frequency bias current to the C signal.

Playback process

On playback, the FM Y signal is amplified, demodulated, low-pass filtered and de-emphasized to reconstruct the 3-MHz 'baseband' luminance signal. Momentary FM carrier losses due to tape defects, are concealed by a dropout compensator circuit. The DOC is built around fast-acting switch logic and a 64-µsec quartz-glass delay line. Dropouts are concealed by inserting segments of the delayed FM-carrier back into the 'real-time' carrier signal.

Figure 5. VCR video playback signal process.

The down-converted 0.56-MHz chroma carrier from the tape is first low-pass filtered to remove the residual FM Y signal; then level-controlled with reference to the color burst signals that were inserted in the C signal in recording. Next, the chroma signal is taken to a balanced modulator. It is essentially a mixer that produces sum and difference signals, or upper and lower sidebands of the two input signals.
In VCR chroma demodulator, two balanced modulators are needed. The main modulator is supplied with the down-converted C signal (0.56 MHz) from the tape, and another 4.99-MHz signal generated by the frequency-/phase-controlled 'local' oscillators. The difference from these two signals (4.99 - 0.56 MHz) is 4.33 MHz, which constitutes a standard PAL chroma subcarrier, ideally, at 4.43361875MHz. However, tape stretches and running speed variations prevent such frequency precision, or stability, despite of capstan and head cylinder motor servo systems.

Still, at VCR playback, time-base errors, or video jitter can be tolerated up to 0.5 % (of the 15.625kHz). However, that is far too much to attain a chroma signal synchronism, or phase stability required by stable PAL signal demodulation. To provide the necessary stability, another balanced modulator is used. It is also fed with two signals; one is derived from a phase-locked, crystal-controlled 4.43-MHz oscillator. The other is generated by a frequency-controlled oscillator, running nominally at 562.5-kHz, which is exactly 36 times the nominal PAL signal line sync frequency (15.625 kHz). The FCO is controlled by a frequency discriminator synchronized to the line sync pulses, extracted from the Y signal. When the FCO is down-converted to 15.625 kHz by means of a digital 1:36 divider, an AFC (automatic frequency control) 'loop' is formed. The AFC, running at 562.5-kHz, corrects its frequency at 64-μs intervals, derived from the playback Y signal line sync pulses.

The AFC loop is capable of bringing the synchronism to within about 0.1 % of the 15.625 kHz. That is sufficient to reduce the Y signal video jitter to tolerable levels, but not enough to provide the required C signal frequency/phase stability at 4.43361875MHz. To reduce the C signal phase fluctuations, another control circuit is needed. For this, a 4.43-MHz VXO (voltage-controlled crystal oscillator) signal is phase-locked to the burst signals of the up-converted (4.43MHz) playback C signal, then supplied to the balanced modulator 2. The other input is the AFC-stabilized FCO (562.5 kHz) described above. These two signals create a sum signal of 4.99 MHz (0.5625+4.43 MHz) which is phase-stabilized by the APC circuit around the 4.43-MHz VXO, together with the Y signal line-sync controlled 562.5-kHz FCO. In short, the tasks of the chroma demodulator circuit are to up-convert the 562.5-kHz C signal according to 4.43 MHz standard PAL format, and correct the frequency and phase errors from the tape signal.
Modified video head preamp
As always, when reconditioning old VCRs for digital transfer work, we looked into their video playback circuits to see whether there are ways of enhancing or stabilising the playback signals. The video tape signal is in the microvolt range, and always vulnerable to local tape defects, storage maltreatment, stickiness or self-demagnetization.

Bad or weakened tape signal, be it audio, control or video, are likely to cause noise, dropouts or occasional image instabilities. In worst cases, it may even become impossible for a regular VCR to render demodulate a stable monochrome and color image from the aged video tapes. We modified the video output so that the signal is taken out in an Y/C component format in order to minimize errors and noise due to chrominance/luminance mixing.

![Figure 7. Tuning up the N1501 video head preamplifier circuit.](image)

We also made some circuit changes using modern low-noise semiconductors that provide considerably more gain from the video heads to achieve optimal video signal transfers particularly from low-output tapes.

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