technology for the creative

Metropolitan Police Video Training

Phil Crawley
@IsItBroke on Twitter

Video Measurement - Principals (4 days)

Course Aim

The aim of the course is to provide grounding in video fundamentals, compression and picture quality analysis for staff who work with video processing, detection and vision systems.

Course Structure

- Day 1 - TV Fundamentals; *Scanning and Sampling, Colour Systems, Analogue Composite Coding*
- Day 2 - TV Fundamentals; *Digital Component Coding, Conversion of Film to Television, High Definition*
- **Day 3 -** Compression; *DCT principles, Intra-Frame vs Inter-Frame Encoding, blocks and macroblocks etc.*
- **Video Tape Recording; *Magnetic recording principles, rotary recording, Simple VT maintenance.***
- Day 4 - Television Measurements; *Analogue, Digital*
- Picture Quality Analysis; *Analogue picture impairments, digital picture impairments, compression*
- TV Displays; *CRT, LCD and Plasma displays. Problems with LCD and Plasma, Projection systems.*

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Video Tape Recording

Magnetic recording principles – Since 1928 people have been recording audio signals onto magnetic tape;

- Plastic tape coated with Iron Oxide (Sellotape with rust!) is run past a recording head
- The head is an electromagnetic coil with an iron core
- If a signal is passed through the head the signal is recorded into a magnetic field on the tape
- If the tape is subsequently passed back over the head the magnetic field causes a (hopefully similar!) signal to be induced in the coil; this can be amplified and replayed.

As ever with physical processes nature works against us;

- An audio signal must be 'biased' with an additional voltage to get the tape to magnetise before it will take any of the signal into itself
- The mechanical process of the tape passing over the head, rumble in the motors, flutter of the tape etc. compromises the transfer
- The tape degrades over time as parts of the oxide coating fall off.

All these aside though it is reasonably easy to record an audio signal onto magnetic tape.

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Audio vs Video signals on magnetic tape

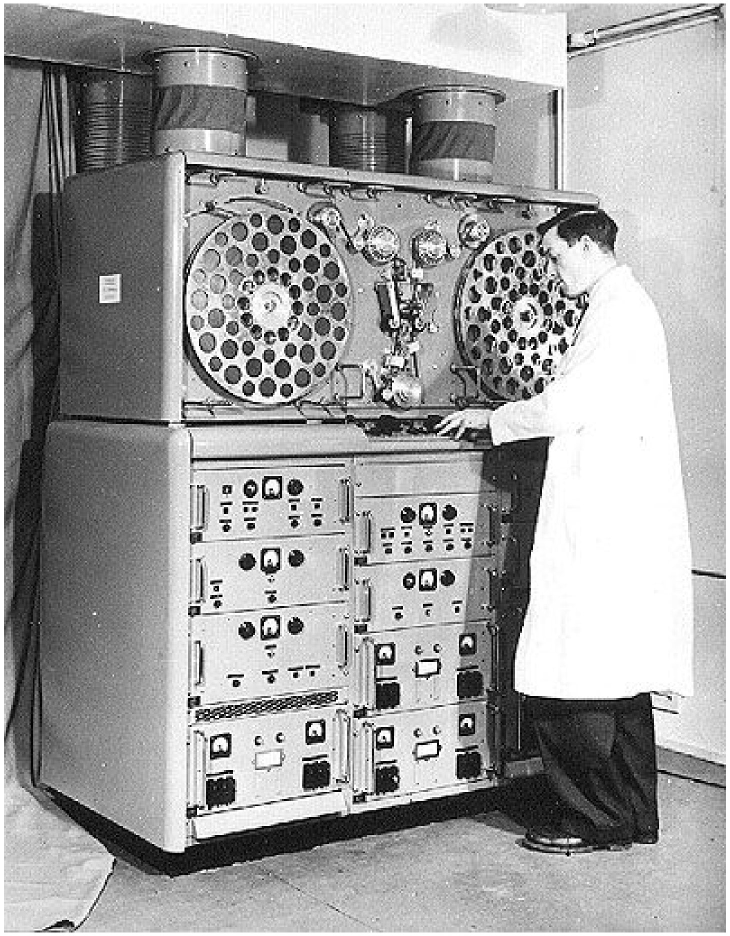
- Audio – 20hz to 20Khz with 78dBs of s/n
- Video – 15Khz to 5.5Mhz with 48dBs of s/n

So it turns out that video requires an awful lot more from magnetic tape. It is VERY hard to get the necessary bandwidth out of a linear tape recorder.

The BBC 'VERA' project produced a machine that could record fifteen minutes of B&W 405-line video at modest quality.

Notice how quickly the spools spin in normal play mode. It takes eight minutes to rewind the fifteen minute recording!

Video – *VERA - Part Two*



Rotary recording

For a long time engineers understood the need for much greater bandwidth off tape and a slower use of tape – whole programmes would need to be recorded. The answer was rotary-scan recording. Initially the Quadruplex system;

- 2” wide tape
- Four heads mounted on a rotating drum spinning at 50 RPM (60 RPM for NTSC)
- Head 1 recorded the first half of field 1, then head 2 the lower half
- Heads 3 and 4 recorded field 2 as the tape was pulled past laterally
- Compressed air keeps the tape wrapped around the head assembly.

Video: *TR-70C 2 quadruplex video recorder in operation*

The other innovation with Quad was **FM recording**.

19 year-old Ray Dolby was the innovator.

Use of Frequency Modulation

A normal audio tape uses Amplitude Modulation – the louder the sound gets the bigger the magnetic field and so the strength of the field recorded on tape is proportional to the level of the sound recording. For old-school ¼" audio tape;

0dBu = 160nW/m^2 (line up level)
+8dBu = 400nW/m^2 (peak level for a TV show)

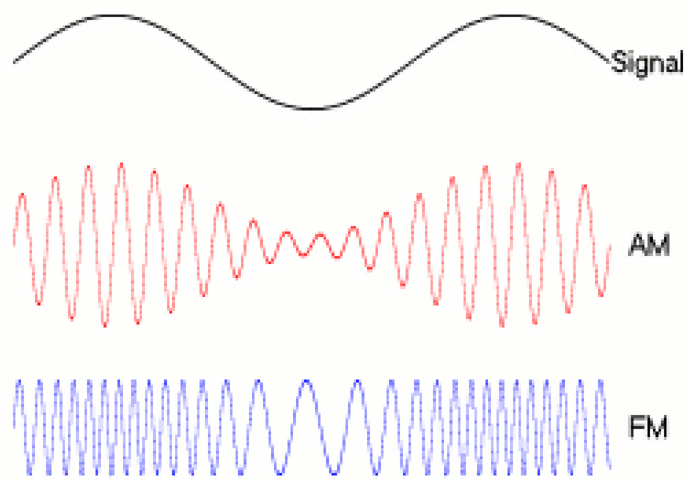
These levels are defined and so if a tape is moved between machines in different studios the sound will replay at the same level in both machines (assuming they are calibrated correctly).

However – As Ray Dolby discovered in 1956 AM doesn't work well for video!

Ampex VR1000 in the Science Museum

FM recording

If, instead of allowing the signal to just vary the recording current (and hence the magnetic flux on tape) we use the signal to drive a frequency modulator so the level of signal going onto tape would remain constant but the frequency would vary in proportion to that signal.



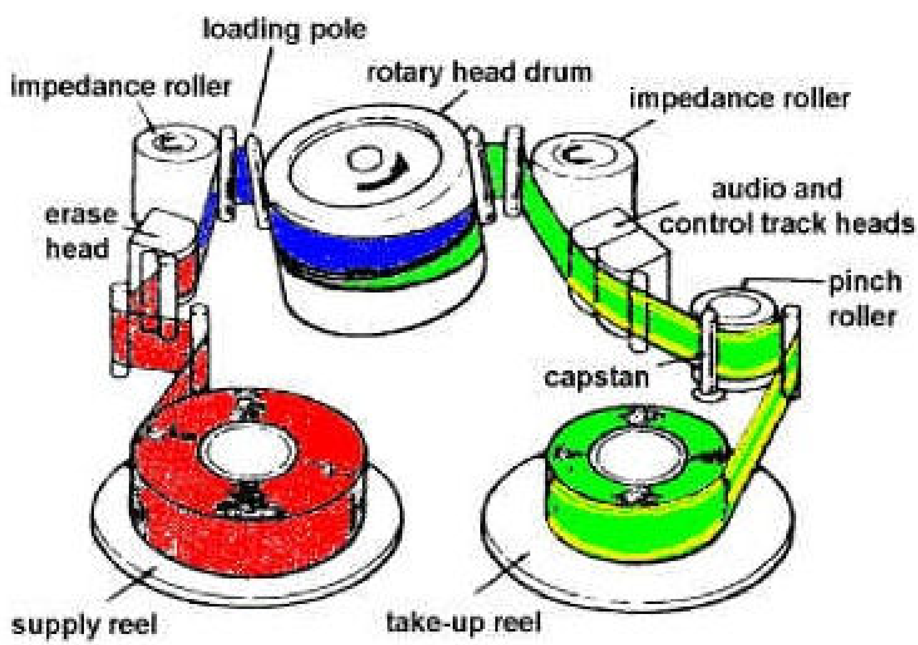
The advantages of FM recording are;

- The signal doesn't suffer so much from the tape's response
- The effect of the magnetic flux on the signal doesn't vary based of the frequency of the signal
- Signal level on tape doesn't now affect video level

All VTR formats use FM recording; 2", 1" (A, B, C and S-formats), ¾" Umatic (low, Hi, and SP), Betacam & SP, VHS, SVHS as well as the failed & obscure.

Helical Scan

Unlike Quadruplex all subsequent VTRs have used helical scan where the tape is wrapped around the drum at a shallow angle and the drum rotates within the loop of tape that is formed. Typically the head-drum completes a rotation for every frame of video meaning that the signal is written onto the tape as shallow diagonal stripes, each containing a field of video.

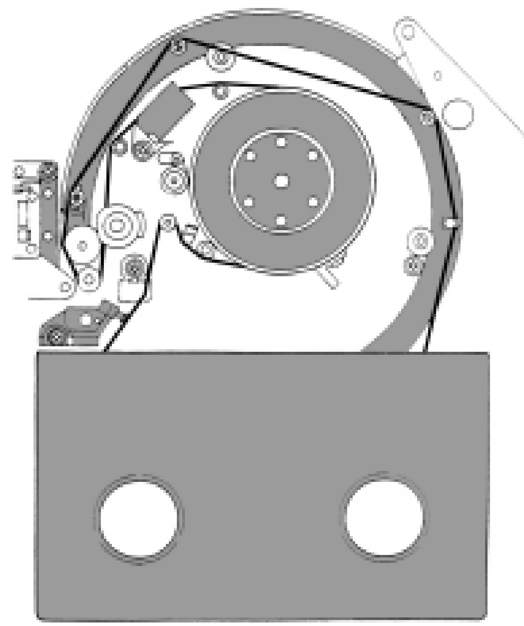


The rotation of the head-drum is locked using a linear control-track on the tape. This allows the rotating heads to always fly over the video track in the same way it was laid down.

Additionally, if the VTR is locked to external reference then the rotation of the head drum is locked to that video signal so that the signal recovered off tape will be synchronised to external reference.

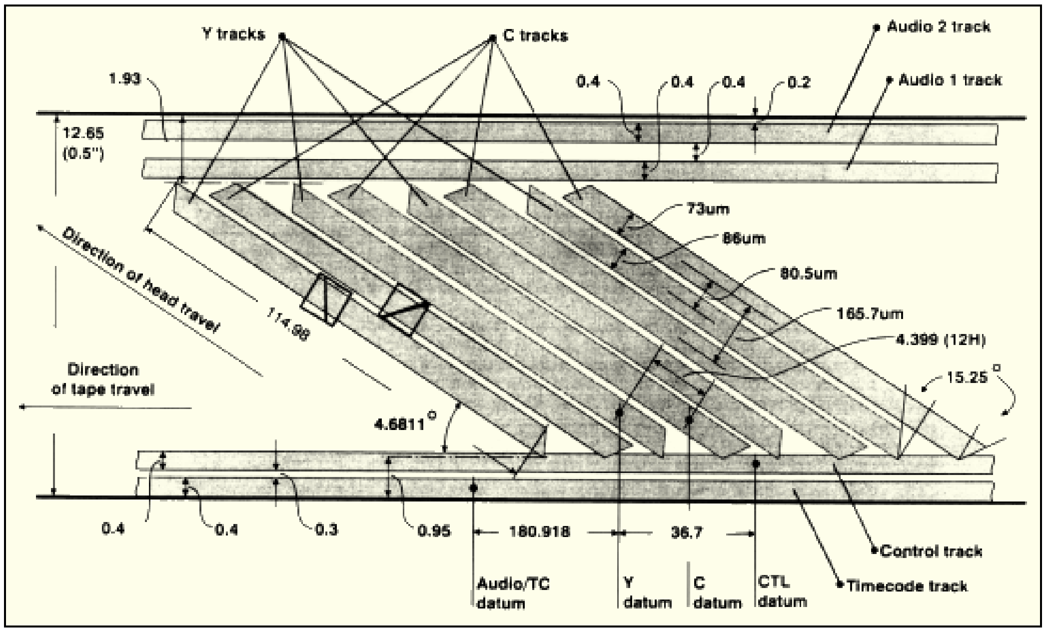
Betacam SP – signal format on tape

- Tape Width 1/2 inch
- Drum Diameter 2.9 inch
- Tape Speed (PAL) 101.5 mms^{-1}
- Head gap width Y: 85µm, C 73µm, Erase 160µm
- Y Track Width 86µm C Track Width 73µm Guard band width
- Maximum Recording Time (PAL) 90 mins approx
- Component S/N Ratio> 46dB
- Angle of Video Track 4.7°
- FM Deviation SP format Y: 6.8 - 8.8MHz   C:5.6 - 7.3MHz
- Control Track Width 0.4 mm
- Timecode Track Width 0.4 mm



YC separation

As we saw BetacamSP (unlike 2” and 1”) is a Component format (the Y-luminance signal is not combined with the C-Chrominance colour-difference signals) and so better quality is maintained so long as recordings are kept component. If you make a BetaSP->BetaSP copy using the single-wire composite input then all that advantage is lost.



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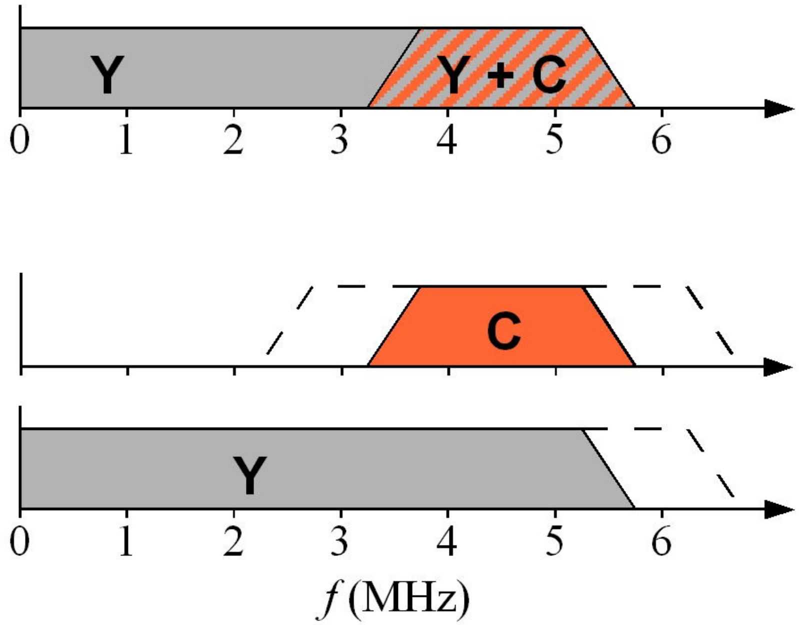
Colour-under recording



- Our composite video system has a mix of luminance and chrominance with the colour sub-carrier located at around 4.43Mhz (in PAL video).
- This means that to accurately record the colour portion of the signal a VTR has to accurately reproduce all frequencies up to 5.5Mhz
- For an expensive 1" or 2" machine this is not an issue.
- For a low-end cassette format like Umatic, VHS or BetaMax this is impossible!

The answer is to filter out the colour subcarrier and move the chrominance signal down the spectrum so that it is recordable on a low-band format. This is an example of 'hetrodyning'

Colour-under recording

- NTSC VHS recording system converts the colour subcarrier from the NTSC standard 3.58 MHz to ~629 kHz
- PAL VHS colour subcarrier is similarly downconverted from 4.43 MHz to 629Khz
- The 3/4" U-matic systems use a heterodyned ~688 kHz subcarrier for NTSC recordings
- PAL U-matic decks came in two mutually incompatible varieties, with different subcarrier frequencies, known as Hi-Band and Low-Band.
- Other videotape formats with heterodyne colour systems include Video-8 and Hi8.

On playback, the recorded colour information is heterodyned back to the standard subcarrier frequencies for display on televisions and for interchange with other standard video equipment.

This causes lots of potential picture distortions but in the early '70s these were worthwhile for a format that could be used for offline/review/approval.

The heterodyne process also messes up the strict line-colour relationship (referred to as *ScH*) and so the signal is unusable in a studio, for example.

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VHS signal system

Launched in 1974 VHS became the predominant home/CCTV/industrial system for three decades. Variations are;

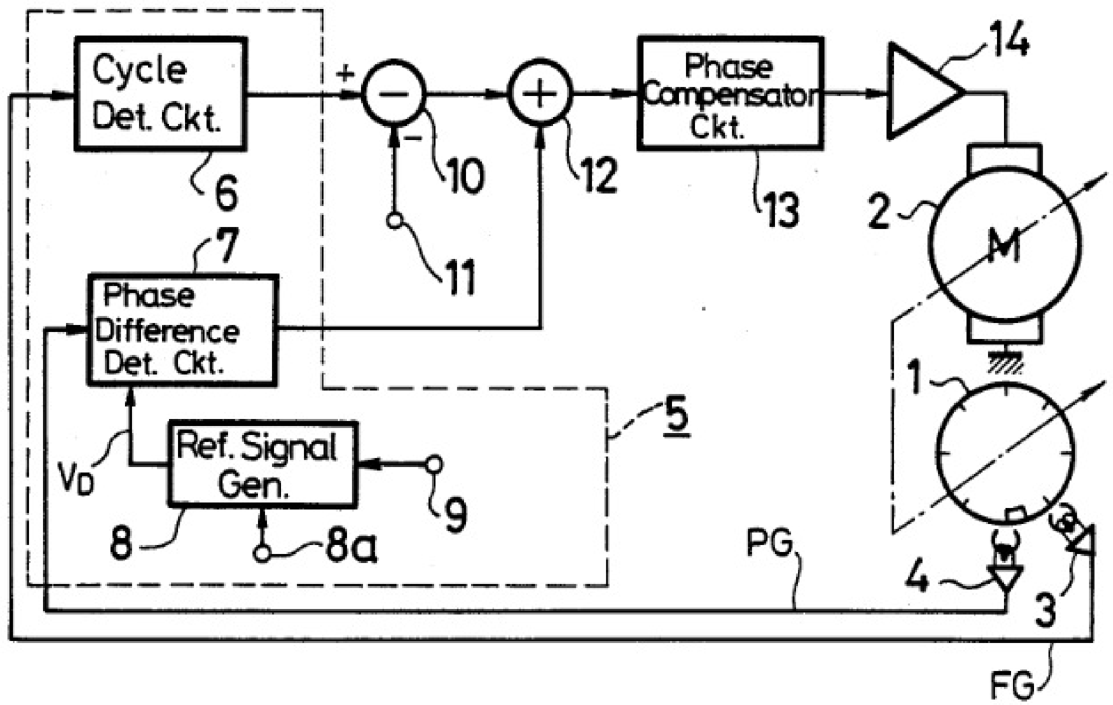
- HiFi audio – extra stereo audio recorded on an FM carrier deeper into the tape than the video at around 1.6Mhz; there was a semi-pro longitudinal stereo audio system as well
- Long-play where a four hour tape could be eight or even twelve hours, timelapse, P-as-B
- SVHS – metal particle tape for better luma and chrominance response; those machines also included SVideo in/out to avoid mixing the signal before record
- VHS-C was a smaller cassette shell for camcorders that would go into an adaptor.

VHS is a very poor system for SD recordings by today's standards, but all of the principles of VTR maintenance we shall deal with later are equally applicable for cleaning etc.

Servo objectives & example simplified schematics

A servo circuit controls a physical feature of the machine – typically a motor that needs regulating.

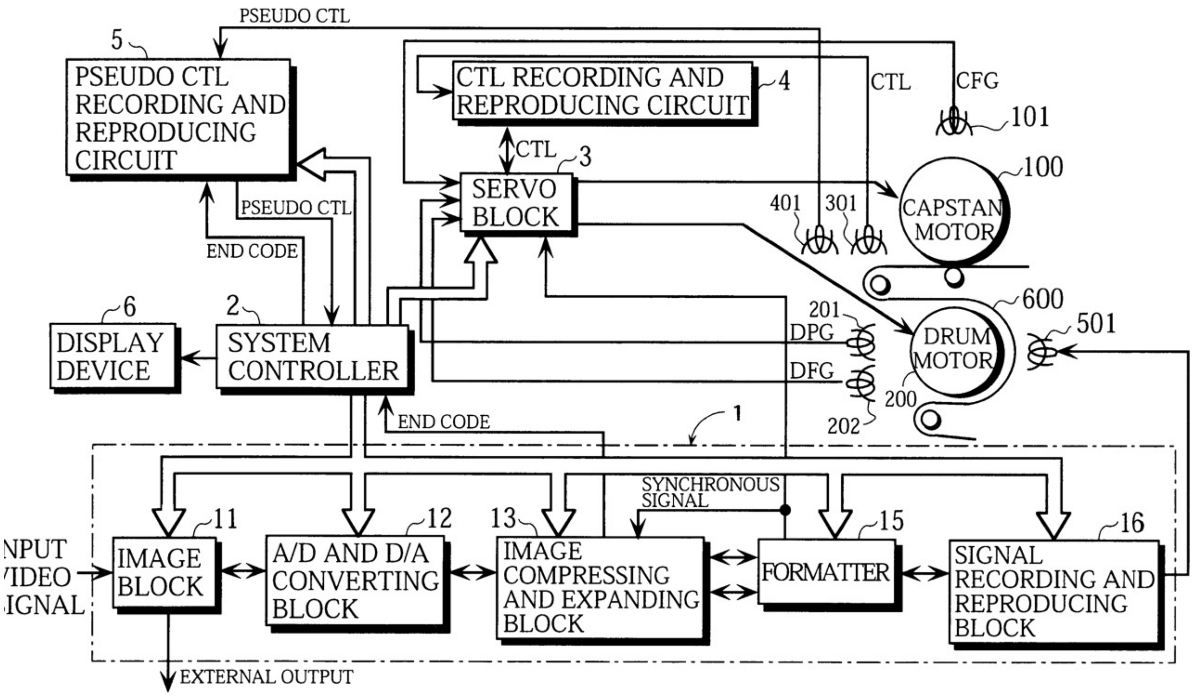
Head-drum servo



- Motor that drives the head-drum
- Sensors on the head-drum so that the servo knows phase
- Reference signal circuit to correct the phase of the drum WRT incoming video reference

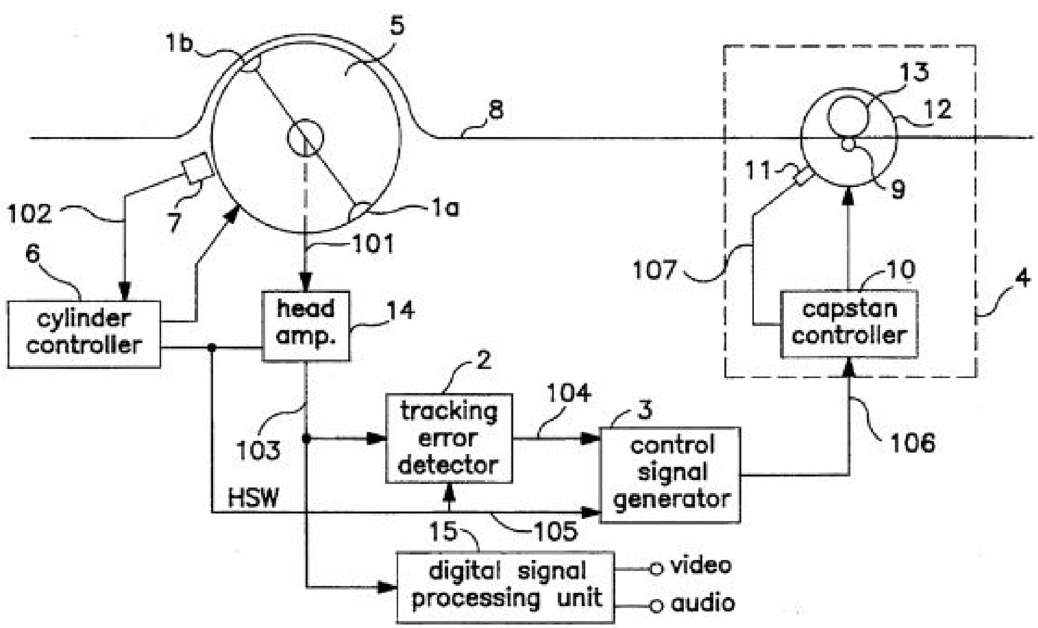
Servo objectives & example simplified schematics

Capstan Motor Servo



- Unlike the head-drum servo the capstan speed varies with tape speed
- Even in normal play the capstan needs to be regulated by the RS422 control system
- In modern VTRs this is a digital servo
- As you can see there is interaction between the head-drum servo and the capstan servo

DT servo



AKA "Auto Scan Tracking" in Ampex machine the Dynamic Tracking system allows the DT head to follow the video track on tape when the machine is in non-standard speed playback.

- From -1 to +2 speed (and still frame) noise-free pictures are possible.
- In record mode the DT heads are used for 'confidence' playback during records.
- In Digital VTRs this allows "pre-read" operation.

The DT servo looks at the strength of the signal off tape and dithers the head position to maximise (hence the head flies down the middle of the RF track).

Reliability and longevity issues

Several things affect the reliability of mechanical VTRs

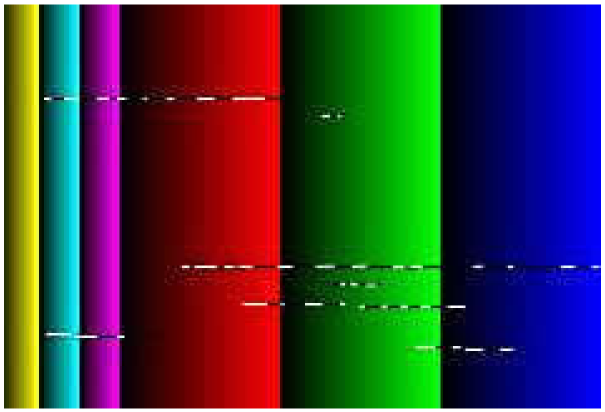
- Dust – the head-gap of a BetacamSP deck is 85µm so even a single particle of brick dust (for example) can spoil the record track
- Smoke – particles are typ. 50µm & the residue clogs up the mechanics
- Moisture – mechanical parts can be affected
- Shock – the precision of the tape path is important

Proper and regular maintenance will ensure best life from the transport. In the case of BVW-series BetacamSP Sony recommend;

- Replacing the upper drum assembly at 1000 tape hours
- Replacing the complete drum assembly and tape path at 3000 tape hours
- Complete mechanical re-build at 9000 tape hours

With proper cleaning and inspection these figures can be safely ignored!

Analogue VTR misalignment problems



Dropouts

- Oxide wearing off the tape
- Particles on tape when recording made
- Good example of the Test Card F tape 00:01:22:20
- VTR uses TBC to compensate

Head-switch

- Machine incorrectly starts/stops field 1 / 2
- May be mechanical or electrical
- Position of the control track head

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Introduction to DV

Introduced in 1995 initially as mini-DV the format is a whole family of 25 megabit/sec compressed VTRs that use 8mm tapes.

- Mini-DV – Sony VX1000, PD-150, etc
- DVCam – Sony pro-variant; bigger tapes, DSR-series cameras
- DVCPro – Panasonic's pro version – 4:1:1 rather than 4:2:0 of Sony's DVCam

The system has even been extended to HD

- DCVProHD/100 – Panasonic's 100 megabit/sec 1920x1080
- HDV – Sony's "thin raster" 1440x1080 version – only 18 megabits/sec long-GOP

All DV-format camcorders and VTRs have a FireWire connector to allow direct digital transfer into a computer. All editing packages understand basic DV *at least* – it has become the province of wedding videographers and guerrilla film-makers.

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Simple VT maintenance

Using a BVW-75P (which has seen some action!) we will perform the kind of maintenance that doesn't require a fully-equipped workshop.

- Wet-clean the rotating heads using lint-free cloth & Isopropynol
- Inspect/clean/replace the pinch roller
- Inspect/clean the capstan
- Inspect/clean the control-track head
- Inspect/clean the fixed head stack
- Inspect the brakes
- Inspect/clean the DT brush/slip-ring system
- Remove/inspect the cassette carriage
- Diagnose faults with the lacing ring/motor system
- Diagnose faults with the T-Drawer arm assembly
- Diagnose faults with the tape guides by inspecting the RF-envelope.

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