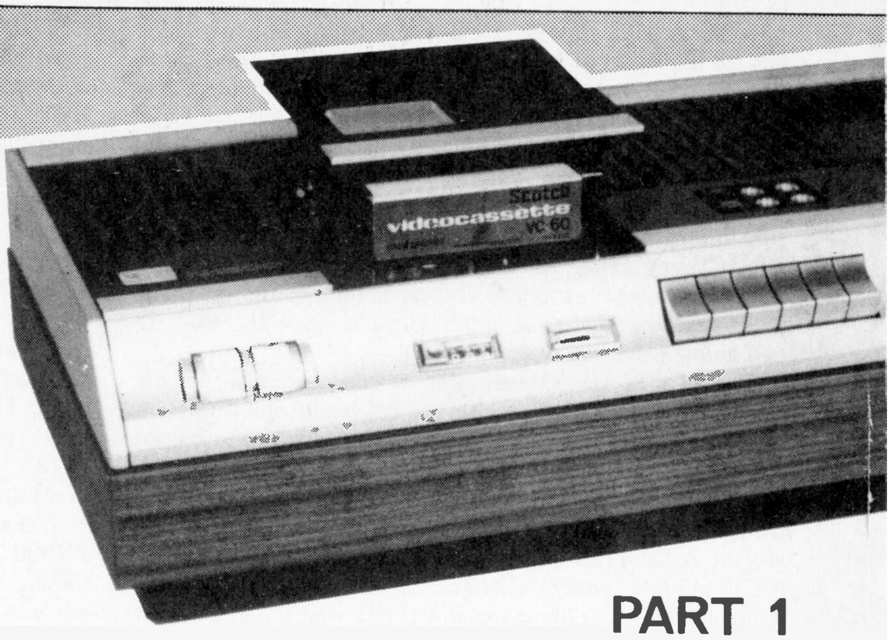
THE PHILIPS



M.P. RILEY

PART 1

IN the last two issues of *Television* the basic principles of helical scan videotape recorders have been outlined together with some of the more unusual techniques employed. In this and next month's articles we will concentrate on one machine; the Philips Video Cassette Recorder. This particular VTR has been chosen for several reasons, the most important being that it is the only video cassette recorder on the market at the time of writing that falls within the domestic price range. It should be noted at this point that with the introduction of VAT at 25%, the price of a VCR is over £500, and whether the consumer thinks that this is value for money remains to be seen.

Many other features of the machine make it an obvious choice for more detailed examination. A built-in tuner and i.f. strip enable 'off air' programmes to be recorded without the need for a separate colour receiver. A time switch is incorporated so that material can be recorded while the operator is away, and the cassette format makes the VCR very easy to use. In fact it has fewer controls than some audio cassette recorders.

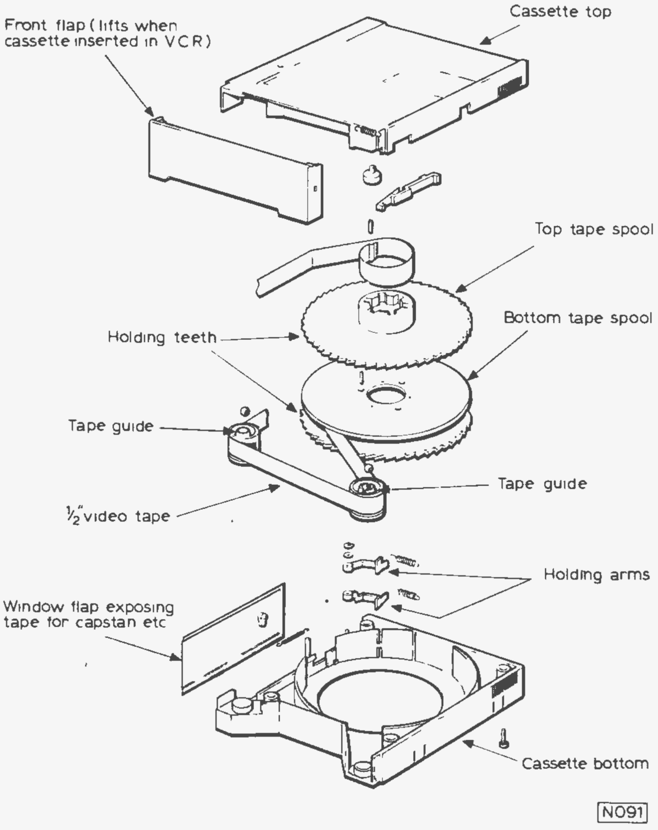


Fig. 1: Constructional details of the video cassette.

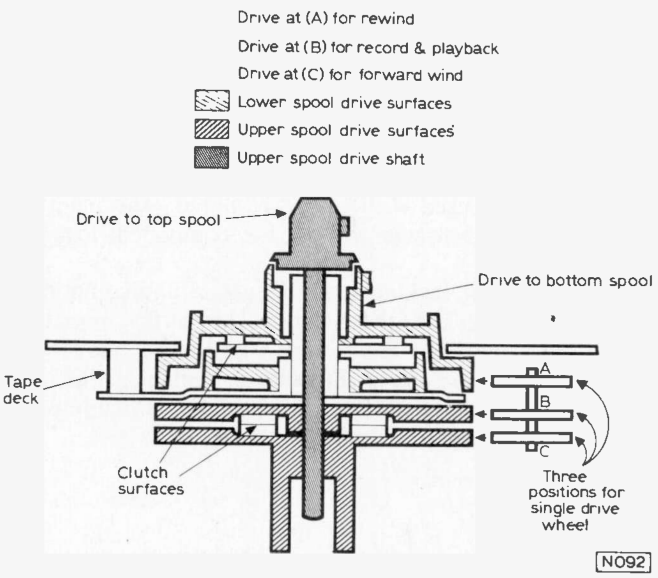
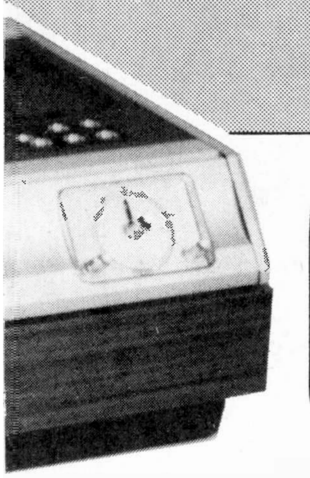


Fig. 2: Principle of the tape spool drive mechanism.



VIDEO CASSETTE RECORDER

The cassette format

The half inch video tape is housed in a cassette (Fig. 1) that stores the two spools of tape one on top of the other; the tape passing diagonally from the top spool to the bottom. This method of housing the tape in the cassette gives rise to a rather unusual method of providing drive to the two spools for forward and reverse winding of the tape, and the torque for record and playback. Simplified details of the drive system are shown in Fig. 2, where it can be seen that the two drive spindles are arranged in the same way as the control shafts on a dual concentric potentiometer, the centre spindle engaging in slots in the top spool of tape and the outer spindle driving the lower spool. Each spool has a large number of teeth cut into its outer rim which engage with small arms, preventing the spools from turning when the cassette is removed from the machine. This action stops the tape from spilling until the cassette is loaded in the VCR, whereupon the arms disengage enabling the spools to turn freely.

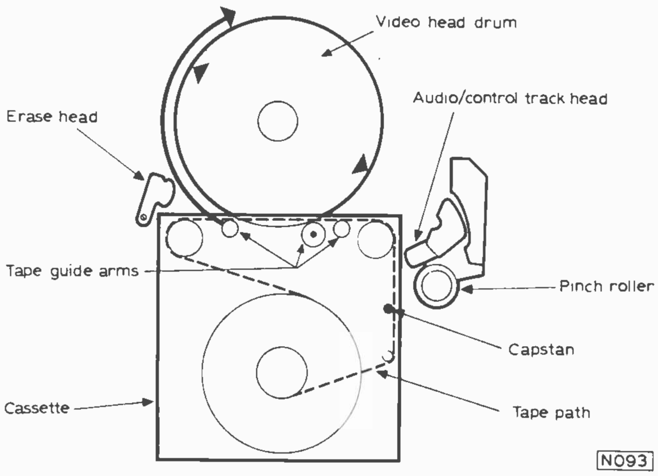


Fig. 3: Tape path with the machine turned off. The dashed line indicates the route of the tape.

Tape threading

A small window in the side of the cassette opens, exposing the tape, as the cassette is loaded into the machine. This length of tape is then presented to the audio and control track head stack, the capstan and the pinch roller, Fig. 3. The tape path is shown by the dotted line and it can be seen that the capstan and guide-arm assemblies are behind the backing of the tape. When the VCR is switched on the guide arm moves in the direction shown by the large arrow, pulling the tape out of the cassette and wrapping it around the head drum producing the familiar 180° half wrap. Fig. 4 shows the tape laced in the machine with the tape transport in the play or record modes. The pinch roller and audio/control track head assemblies have now moved forward to provide the required drive to the tape.

The video signal is recorded on the tape in the conventional diagonal manner. The main audio track is recorded along the lower edge of the tape and there is provision on some versions of the VCR to record a second audio track along the top edge. The control track is situated just below the second audio track with a guard band between the two. The complete tape format is shown in Fig. 5.

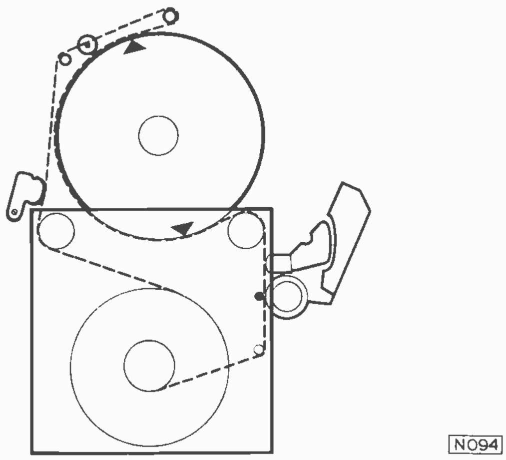


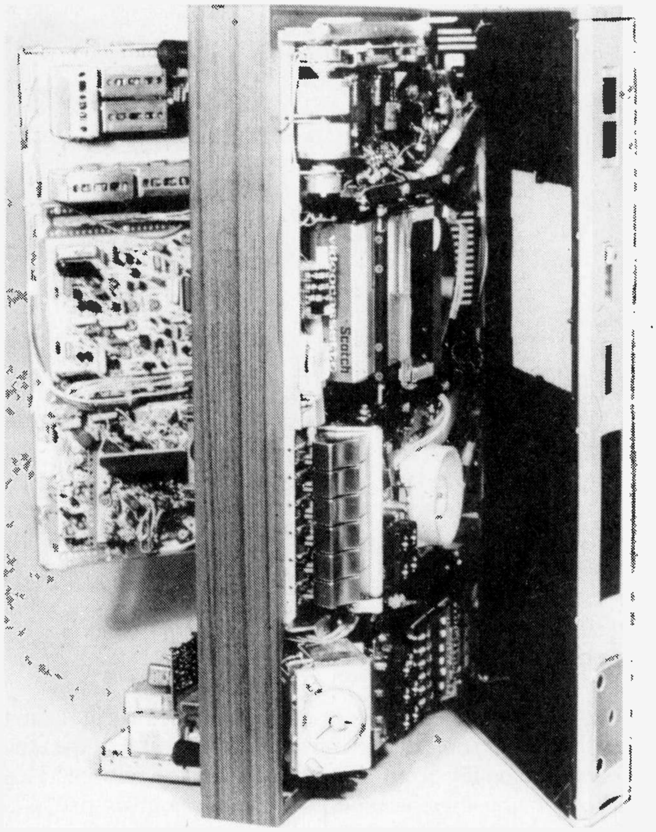
Fig. 4: Tape path with the machine turned on. A loop of tape has been drawn out of the cassette by the tape guide arms and wrapped around the video head drum.

The Record electronics

It is impossible to give a circuit description of a machine that uses 136 transistors, 67 diodes and 4 i.c.s in the limited space of two magazine articles; however a detailed examination of the techniques employed and the signal path through the VCR is possible. The reader will gather from the large number of transistors employed in relation to the very small number of integrated circuits that the production of videotape recorders for use in the home is very much in its infancy. The cost, size and electronic complexity of the VCR can only be reduced with the adoption of i.c. circuit techniques; but with the rather uncertain future of the market at this time manufacturers seem to be playing safe by using well-tried and easily available devices rather than invest in new custom-made i.c.s.

The VCR can be logically divided into sub-sections, but if this was attempted for our purposes life would become rather confusing! I feel the more conventional method of starting at the beginning and finishing at the end will be an easier way to tackle the problem. The accompanying photograph gives you an idea of what lies ahead. Are you sitting comfortably?

There are three main electronic modes in which the VCR operates: these are Record, Play and E to E modes. The E to E mode is used when the machine has been stopped but part of the video electronics is still in use, so as to provide an output to indicate that the VCR is receiving information. The E to E mode is the simplest of the three and uses familiar colour TV principles making a foundation on which we can build later.



This photograph of the VCR opened up for servicing gives some idea of the internal complexity.

The E to E mode

Tuner and a.f.c.

The u.h.f. aerial input applied to the VCR is first amplified in a wideband amplifier contained in module U504 (see Fig. 6). The output of this amplifier is fed to a splitter which in turn feeds the u.h.f./v.h.f. tuner unit and a second wideband amplifier. This second aerial amplifier then provides the main signal feed to the colour TV receiver via a second splitter which combines the output of the VCR with the amplified 'off air' signal feed. The v.h.f. (don't forget that the VCR is used throughout the European Economic Community which uses v.h.f. 625-line transmissions) and u.h.f. tuner units incorporate conventional electronic tuning with a rather interesting a.f.c. system known as PAFT. PAFT stands for Phase Dependent Automatic Fine Tuning, which adjusts the tuning control voltage to give maximum rejection at 33·5MHz instead of the widely used maximum gain at 39·5MHz. An a.f.c. system which tunes for maximum rejection at the sound carrier frequency provides a much more accurate control voltage for the tuner, and as the VCR is designed to operate unattended on a timer, tuning must be very accurate and stable if good quality recordings are to be made.

Two 6MHz sound i.f. signals are phase compared; one is from the sound i.f. amplifier and the other from the output of the luminance delay line. The latter signal has undergone a large amount of attenuation at 33·5MHz due to the rejectors in the i.f. amplifier, but the signal derived from the sound i.f. stage has had wideband amplification. Should the tuning frequency drift then the signal presented to the 33·5MHz rejector in the luminance i.f. amplifier will change, causing a phase shift in the signal leaving the rejector, and hence a change in phase of the 6MHz intercarrier sound produced at the luminance detector. The i.f. signal applied to the sound detector does not undergo any attenuation at 33·5MHz and therefore its phase will not be affected by the change in frequency of the signal.

The intercarrier signal from the sound i.f. amplifier is used as the chopping waveform for a synchronous phase detector U514, and the output of the luminance detector is used as the error signal. Any phase difference between these two signals is detected and the resulting error signal is smoothed and applied in series with the tuning voltage to correct for the drift in oscillator frequency. It is easy to see why this particular method of a.f.c. correction is not employed in the conventional colour receiver, and a comparison of accuracy between the two systems is very difficult to produce.

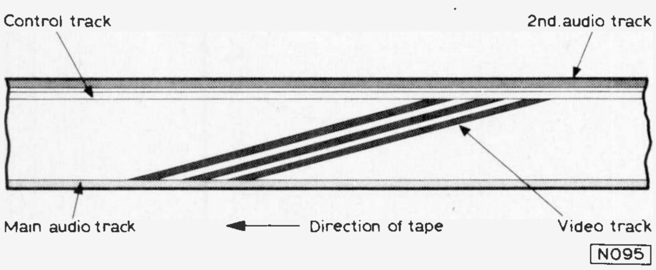


Fig. 5: The cassette tape format.

Luminance and Sound circuits

Amplification of the i.f. signal at the output of the tuner is carried out in three stages by the amplifiers U506, U507, and

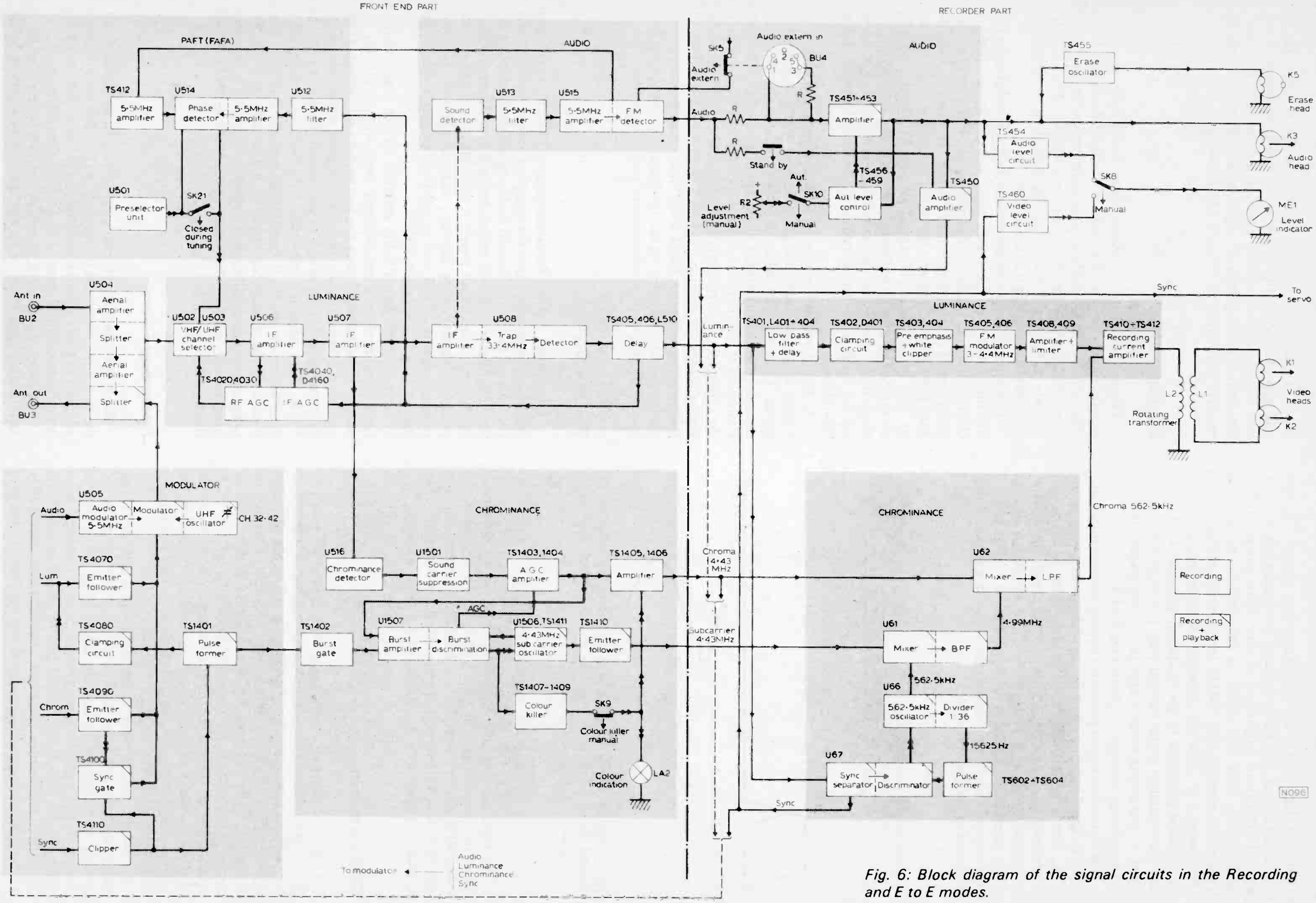


Fig. 6: Block diagram of the signal circuits in the Recording and E to E modes.

U508; module U508 also contains the sound rejector mentioned earlier, and the sound and luminance detectors. A take-off point is provided at the third stage of i.f. amplification, and this signal is fed directly to an a.m. detector to produce the 6MHz intercarrier sound signal. After passing through the bandpass filter in module U513 this signal is amplified by the sound i.f. amplifier U515 and then demodulated in the normal way to produce the audio signal. At the output of the sound i.f. amplifier a 6MHz take-off provides the reference signal for the PAFT.

The luminance signal produced by the detector in module U508 is amplified and then fed to three points within the VCR. The first is the luminance delay line (1μs) which compensates for the delay in the chroma processing stages, the second output is fed to module U512 which extracts the 6MHz intercarrier sound error signal for the PAFT, and the third output is used to produce a mean level a.g.c. voltage for the first i.f. amplifier and tuner.

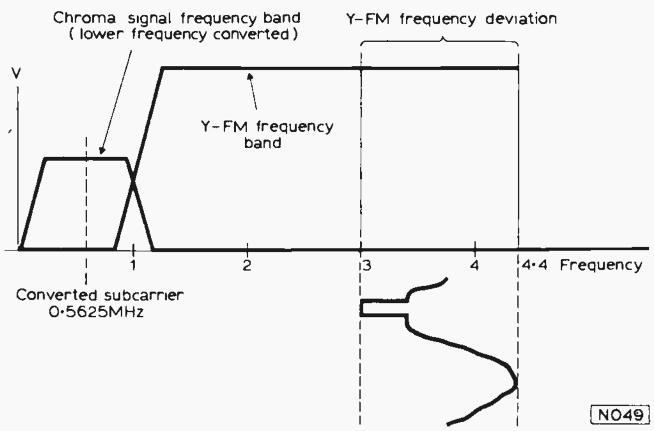


Fig. 7: Signal frequency spectrum of the VCR, showing the chroma information occupying the gap below the luminance f.m. signal.

We have now regained the luminance and sound signals from our transmission, we have yet to produce the 4·433MHz chroma signal and a mixed sync signal which is used to produce clamp pulses and servo drive waveforms. Let us look first of all at the production of the chroma signal.

Chroma circuits

Unlike the conventional decoder in a colour TV receiver, the VCR has only to produce the chrominance signal and need not go to the lengths of producing red, green and blue signals. This situation arises first because it would be impossible to fit the three wideband signals into the limited bandwidth available on the tape. Secondly, as the VCR produces a u.h.f. output to feed directly to the colour receiver's aerial socket, it would be pointless to decode the information and then have to recode it so that a domestic receiver could accept the signal from the VCR.

A 35MHz chrominance i.f. take-off point is provided at the output of the i.f. amplifier module U507, and this signal is fed directly to a detector in module U516. Any 6MHz sound present in the detected chrominance is then removed by a series rejector in module U1501 before amplification of the signal by transistors TS1403, 1404, 1405 and 1406. Automatic chrominance control is incorporated in the first stage of amplification using the conventional technique of half-wave rectifying the colour burst and using the resultant d.c. voltage to control the gain of the chroma amplifier. Production of the subcarrier signal again follows well-known receiver techniques and needs no explanation.

Sync pulse feeds

The output of the luminance delay line is split into three separate feeds, one of which goes to the sync separator U67. The output of this module is fed to a chroma processing stage (described later under the record mode), the tape servo to provide a reference for recording, and to a sync clipper module incorporating transistor TS4110.

This latter stage is a simple emitter-follower which clips the top and bottom of the mixed sync waveform providing a clean, noise-free signal of constant amplitude. The positive-going mixed sync output from TS4110 is then fed to the sync gate TS4100 which inverts the signal and adds it to the output of the luminance emitter-follower TS4070 and the chrominance emitter-follower TS4090. By combining all these three signals in the correct proportions a composite colour video waveform is produced which is then fed to the modulator.

A second output from the sync clipper feeds a pulse former circuit which provides pulses coincident with the line back porch. These are then fed to the burst gate in the chrominance decoder, and to the clamp at the input of module TS4070. Clamping at this point takes place during the line back porch, the clamp reference potential being black level. This clamping action biases the emitter-follower TS4070 so that cut-off of the transistor occurs at black level. Hence the line sync pulses are removed from the signal producing a non-composite luminance output to which new sync pulses are added.

The Modulator

The output signals from transistors TS4100, 4090 and 4070 are combined to form the complete colour signal. This is then added to the modulated audio signal derived from the f.m. modulator in U505 before being fed to the main u.h.f. modulator. The output frequency of this modulator can be preset to lie anywhere between channels 32 and 42, thus ensuring that the VCR can be used without interfering with the local u.h.f. TV transmissions.

Now that the signal being received by the machine has been processed and remodulated onto a new carrier, its output is recombined with the incoming u.h.f. signals from module U504 and fed to the colour receiver which has one of its channel selectors tuned to the output frequency of the VCR. The user is now able to select any incoming programme on the VCR tuner, transpose its frequency, and feed it to the colour receiver. He is also able to view the programme which is being recorded, or tune to a separate transmission without disturbing the recording operation of the machine.

Recording

When the machine is recording a selected programme all the functions described under the E to E mode take place in addition to those about to be explained. Let us just recap on what the machine is required to do during the record mode.

The audio signal must be processed in the same way as in an audio tape recorder, i.e. be equalised, added to an h.f. bias signal and then applied to the audio record head. The video signal must be passed through an h.f. filter, clamp, and then be frequency modulated before being applied to the video record head. The chrominance signal has to be processed and then added to the luminance f.m. signal.

The Chroma signal

As the VCR has a bandwidth of only 2·7MHz the chrominance information must be processed in such a way as to lie in the passband of the machine. It can be seen from Fig. 7 that this is achieved by transposing its frequency from 4·433MHz down to 562·5kHz, fitting below the spectrum of the luminance f.m. signal. During the playback of the signal the chroma is converted up in frequency, back to its original 4·433MHz. Incorporated in this system of transposing the chrominance frequency is a method of automatically compensating for changes in chroma phase caused by variations in head to tape speed during recording and playback. The system works as follows.

Line sync pulses from the sync separator module U67 are derived from the signal to be recorded, and used as a reference signal for the phase comparator also in module U67. The output from the comparator is used to lock an oscillator running at 562·5kHz (36 times line frequency). To complete the phase-locked loop the oscillator output is divided by 36 to produce a line frequency feedback signal for the phase comparator.

We now have an oscillator running at 562·5kHz which is directly locked to the line sync information contained in the signal to be recorded. The output of the oscillator is mixed with subcarrier derived from a crystal oscillator situated in the chroma decoder and locked to the colour burst of the incoming signal. A band-pass filter incorporated in U61 with the mixer passes the additive products of the mixed signal to produce a 4·99MHz sine wave. This second frequency is now directly locked to (a) the line sync information and (b) the subcarrier frequency of the video signal to be recorded. Any change in frequency or phase of (a) or (b) will produce a change in the frequency or phase of the 4·99MHz signal from U61.

A second mixer in U62 takes the output of the chroma decoder previously described and the 4·99MHz signal from U61 and mixes the two signals together. A low-pass filter at the output of the mixer passes the subtractive products to produce the final 562·5kHz. This transposed chrominance signal is derived directly from (1) line sync (2) subcarrier and (3) the chrominance signal. Any change in phase of these three signals will result in a phase change of the transposed chroma frequency. The table below shows the mathematical sequence used to produce the 562·5kHz chrominance.

Line Sync = 15·625kHz
36 × line sync = 562·5kHz
Subcarrier = 4·43361875MHz
Subcarrier + 36 times line frequency = 4·9961187MHz
4·9961187MHz − Chrominance frequency = 562·5kHz

The Luminance signal

The luminance signal is processed in almost exactly the same way as that of the Sony VTR described in last month's article. The signal from the luminance delay line in the receiver section of the VCR is fed directly to a low-pass filter TS401 where all the frequencies above the passband of the machine are removed. The signal is then black-level clamped to set the carrier frequency of the modulator, and white clipped to prevent over-deviation. After the signal has been pre-emphasised it is modulated on to a 3MHz carrier which is deviated up to 4·4MHz at peak white. The modulated signal is then limited by a simple two-stage clipper and amplified before being applied via a rotary transformer to the record heads. In the record current amplifier the transposed chrominance signal is added to the f.m. luminance signal. Fig. 8 shows the way in which the f.m. signal acts as the h.f. bias for the lower frequency chroma information, thus enabling both signals to be recorded at the same time with minimum mutual interference.

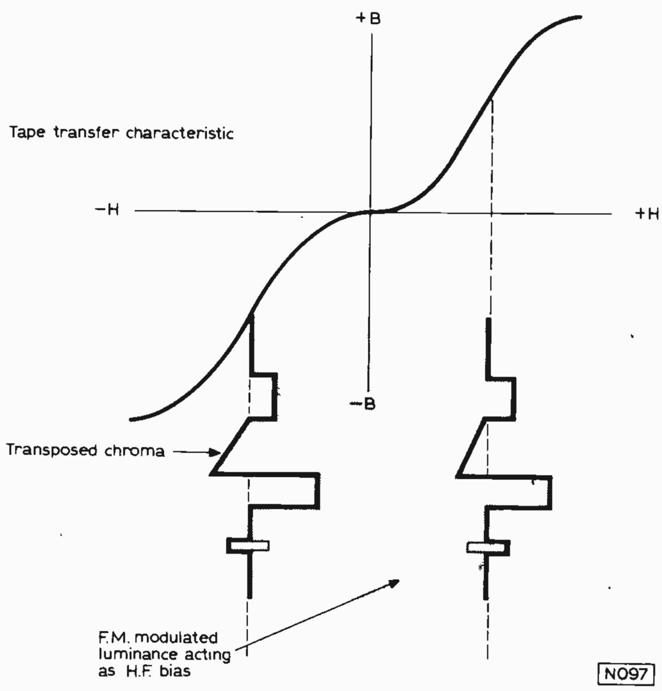


Fig. 8: The f.m. luminance signal acts as h.f. bias for the lower frequency chrominance signal on recording.

The Audio signal

Audio recording techniques are very simple when compared to the electronics of the rest of the machine. The output from the f.m. detector U515 is fed directly to an amplifier providing pre-emphasis and audio record level control. The operator has a choice of manual or automatic control of the audio signal, but the video signal record level is preset by the a.g.c. system in the luminance i.f. amplifier and therefore is completely automatic.

A 60kHz bias signal derived from the erase oscillator TS455 is added to the audio before it is applied to the record head K3. A separate audio amplifier TS450 provides the signal for the 6MHz f.m. modulator in U505. The output of two simple level circuits TS454 and TS460 can be switched to a meter to enable the operator to measure the level of either signal being recorded.

Next month

In next month's issue, we will examine the playback system of the VCR together with the operation of the servo system in the Record and Playback modes.

THE PHILIPS VIDEO CASSETTE RECORDER

M. P. RILEY PART 2

THIS is the fourth and final article in this series on videotape recorders, in which the playback path and the servo system of the Philips VCR will be explained. In last month's issue the tape path of the machine and the functions of the E to E and Record electronics were outlined.

As with the record mode, the playback path can be logically subdivided into three sections, these being for the audio, luminance and chrominance signals. As the first of these is the easiest to understand and contains the least amount of electronics, it will be dealt with first.

The audio signal

The block diagram shown in Fig. 12 covers the complete playback system of the VCR together with the modulator section which was described in last month's issue. The signal from the audio record/playback head K3 is fed directly to a series of transistor amplifiers TS451 to TS453, where it is amplified and l.f. equalised to produce a reasonably flat audio response. From here it is fed to the output sockets provided for CCTV use, and also to a final single-stage amplifier TS450 which drives the 6 MHz f.m. modulator in module U505.

The luminance signal

The path of the luminance signal in the VCR is very similar to systems already described in this series, but there are a few major differences in the operation of the head amplifier and the dropout compensator. The two video heads mounted on the circumference of the drum are wired in series, and therefore only one head amplifier is required in the playback path between the heads and the limiter. Coupling between the heads and the amplifier is through a rotary transformer.

The head amplifier does not use the cascode circuit described earlier but utilises an n-channel field effect transistor (BFW11) in the common-source mode of operation. This is followed by a common-emitter amplifier with negative feedback and then an emitter-follower. Further amplification and equalisation of the f.m. signal is provided by transistors TS423 to TS425. The amplified and corrected f.m. signal is now fed to three separate sections of the machine, these being the luminance limiter, dropout compensator and chrominance processor.

The luminance section contains a high-pass filter which removes the 562·5kHz chrominance information before feeding the signal to the limiter. If this were not done then the a.m. chrominance signal would still remain, and the clipping action of the limiter on the chrominance would produce a large number of harmonics falling inside the luminance passband. These harmonics would beat with the luminance f.m. signal resulting in herring-bone patterning.

The limiter in the VCR is contained in a TAA350 integrated circuit which is in common use in many TV receivers; the i.c. contains four single-stage amplifiers connected in cascade. The output of the i.c. is fed to a pulse-counting f.m. detector. This type of detector is seldom used in TV receivers and so may be new to many readers; a brief explanation of this simplest of f.m. detectors will therefore be given.

Pulse-counting detector

An f.m. detector is required to give a change in output voltage when fed with a signal of constant amplitude and varying frequency. If the f.m. signal is fed across a capacitor (see Fig. 9) whose value is fixed, the reactance of the capacitor will change with the frequency of the applied signal. If the capacitor acts as a load to an amplifier being fed with the f.m. signal, then as the load impedance changes with changing frequency so will the output of the amplifier. Fig. 10 shows a simple pulse-counting detector. If

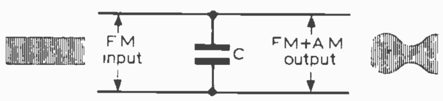


Fig. 9: Principle of the pulse-counting detector.

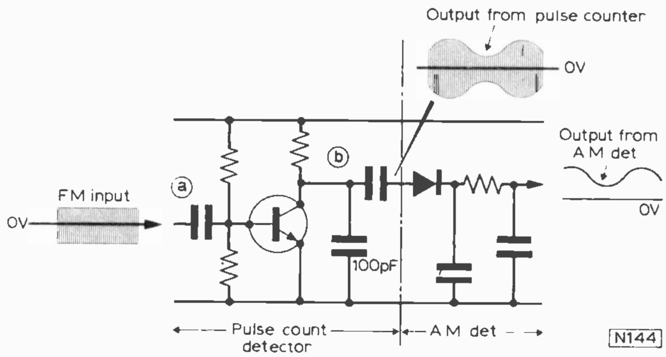


Fig. 10: A simple pulse-counting detector circuit.

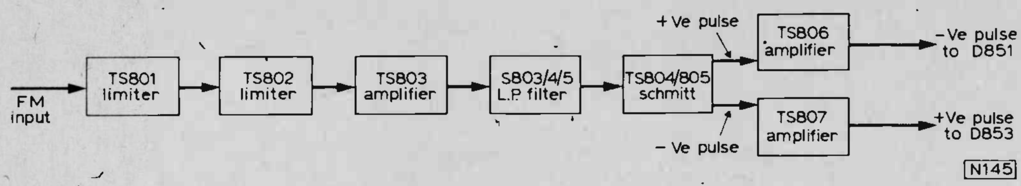


Fig. 11: Block diagram of the dropout detector circuit.

the f.m. input at point (a) is varying in frequency from 3 to 4·4MHz then the output at point (b) will be developed across a load whose impedance will change from 530Ω at 3MHz to 361Ω at 4·4MHz.

As the load impedance of the amplifier goes down with an increase in the frequency of the input signal, the output of the detector will always be negative-going. The output signal of the detector will still be an f.m. signal, but the amplitude of the signal will also be changing as shown in Fig. 10. If the signal is then fed to a conventional a.m. detector and filter, the f.m. content will be removed leaving only the amplitude variations. One major advantage with this type of detector is that, providing it is working over the straight part of the capacitor's reactance range, the output is very linear. Returning to Fig. 12, the pulse-counting detector is represented by TS427 and the following low-pass filter by L416/417 and TS853. The demodulated luminance signal is now fed to the electronic switch in the dropout compensator.

Dropout compensator

The delayed signal path to the dropout compensator differs from the system described in the September issue in that it is the f.m. signal that is delayed and then fed to a second limiter and demodulator. TS808 is a single-stage common-emitter amplifier which feeds the f.m. signal to a conventional 64μs glass delay line and also to the dropout detector. The output from the delay line TD801 is fed to a limiter, demodulator and low-pass filter, all of which are virtually identical to the modules used in the luminance signal path. The delayed luminance signal is then fed to the second input of the electronic switch. You will note that dropout compensation is applied to the luminance signal only and not to the chrominance signal.

Transistors TS801 to TS807 form the dropout detector which has been further subdivided for our purposes in Fig. 11. The amplified signal from TS808 is fed directly to two limiter stages TS801 and TS802 to remove any small amplitude variations that may be present. The limited signal is then coupled to a low-pass filter which removes the f.m. content of the signal, leaving a smooth d.c. voltage.

When a dropout occurs, the f.m. signal will disappear causing a change in d.c. level at the output of the low-pass filter. This voltage change is coupled to the Schmitt trigger TS804 and TS805. Two push-pull switching pulses are produced and these are fed to the amplifiers TS806 and TS807. The inverted outputs of these amplifiers are then used to switch diodes D851 and D853 in the video switch.

The dropout-compensated signal from the video switch is de-emphasised and then delayed to compensate for the inherent delay of the chrominance processor. Signal processing from this point onwards is identical in all respects to the record mode of the machine.

The chrominance signal

Chrominance processing of the signal from the video head is the most complex of the three signal paths because it entails the conversion of the chrominance from 562·5kHz up to 4·433MHz. Not only does this up-conversion of frequency have to take place, but correction of the final chrominance frequency against head and tape speed variations has also to be effected if they are not to cause changes in picture hue or saturation. Both of these requirements are in fact built into the chrominance processor and are effected simultaneously.

Modules U66 and U67 operate together with U61 in exactly the same way as in the record mode, only the signal feeds are changed. Off-tape luminance is fed to the sync separator in U67 and the resulting line sync is used to lock the 562·5kHz oscillator. The oscillator output is divided by 36 and used as the feedback signal to the discriminator. The output of the oscillator is now locked to the off-tape video signal, and should the speed of the tape vary over the period of several lines the output frequency of the 562·5kHz oscillator will also vary with the change in timing of the line sync.

This oscillator frequency is mixed with a 4·433MHz subcarrier signal produced by the now free-running subcarrier oscillator in the decoder. A 4·99MHz sinewave is obtained from the additive products of these two signals whose frequency is again directly locked to the off-tape line sync pulses. The 562·5kHz off-tape chrominance signal is mixed with the 4·99MHz sinewave in module U64, the subtractive products of the mixing being filtered to produce the regenerated 4·433MHz chroma signal.

Phase-shift correction

Correction of the chrominance phase-shift caused by changes in tape speed can only be explained if a small amount of mathematics is applied. Let us examine a case where the tape speed increases by 1%. The off-tape chrominance, if not corrected for this increase in tape speed, would rise in frequency by 1%, i.e. 4·43361875MHz plus 0·0443361MHz = 4·4779548MHz. This new chrominance frequency would of course throw the subcarrier oscillator in the receiver completely out of sync and cause the operation of the colour killer in the decoder.

A 1% rise in tape speed would produce a new line frequency of 15·78125kHz. This signal when used to lock the 36 times line frequency oscillator in U66 would in turn produce a frequency of 568·125kHz at the output of U66 (i.e. 562·5kHz +1%). This new frequency is now added to the 4·43361875MHz signal from the subcarrier oscillator in the decoder of the VCR to produce a frequency of 5·0017437MHz at the output of U61. The off-tape chrominance frequency will also rise by a factor of 1% from 562·5kHz to 568·125kHz. The mixer in U64 takes the new off-tape chroma frequency of 0·568125MHz and the regenerated 5·0017437MHz sinewave from U61 and mixes the two signals. The subtractive products are selected by the band-pass filter (i.e. 5·0017437 −0·568125MHz) producing 4·43361875MHz, the required chrominance frequency.

The reader will realise that this correction will only be effective over a period of several lines, and any speed

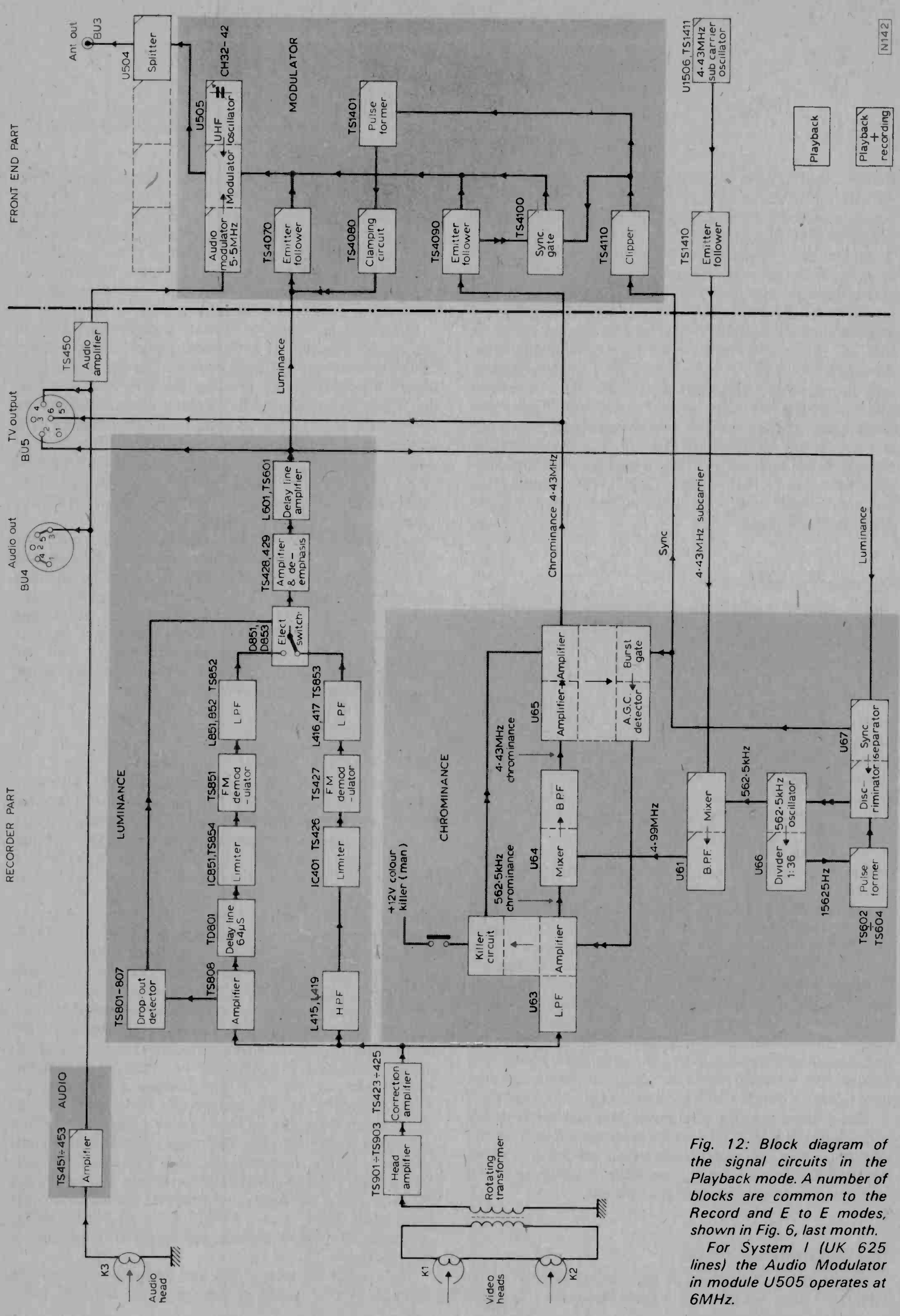


Fig. 12: Block diagram of the signal circuits in the Playback mode. A number of blocks are common to the Record and E to E modes, shown in Fig. 6, last month.
For System I (UK 625 lines) the Audio Modulator in module U505 operates at 6MHz.

variations that take place during a single line will not be compensated. It should also be noted that as the drum revolves at 25 r.p.s. (picture frequency) any speed change of the drum will take place over several fields. The error used in this example is quite realistic as it represents an increase of head drum speed of a quarter of a revolution per second.

The circuitry between the chrominance processor and the head amplifier follows standard colour receiver techniques and is quite simple. Module U63 contains a low-pass filter which separates the off-tape chrominance signal from the luminance f.m. signal and passes it to a variable gain amplifier. The automatic chrominance control voltage fed to this amplifier is produced in module U65 by gating out the colour burst and passing it through a gated half-wave rectifier and smoothing circuit.

A colour killer is incorporated in U63 which produces a second d.c. control voltage biasing the chroma amplifier in U65 into conduction during the presence of a colour signal. A manual colour killer facility is provided which removes the supply voltage to all the chrominance circuits in modules U63, 64 and 65. The fully processed chrominance signal at the output of U65 is fed to the TV output socket for CCTV applications, and also to the emitter-follower TS4090 which in turn drives the u.h.f. modulator described last month.

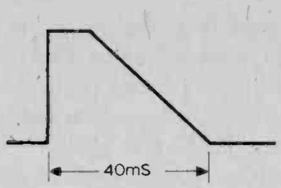
I hope that this description of the video processing sections of the VCR has given the reader an insight to the principles involved in the field of video tape recording. In the following section the servo system of the machine is described in a little more detail because very few people who have been involved with television servicing will have come across this particular type of electronics. Being in my middle twenties, I have only vague memories of the last time electric motors were commonly used in connection with the television trade. I am, of course, referring to the original type of electronic tuning where motors were employed to turn the biscuits in a mechanical tuner, and from what I can remember the inside of the receiver resembled the gearbox of an Austin Twelve rather than the publicised 'modern TV receiver'. Things have certainly changed!

The servo

The principles of the servo were explained earlier in the series to give the reader a foundation on which we are about to build. Before any explanation of the VCR servo can be given, a closer examination of some of its functions must be made.

Two types of correction to the speed of either the tape capstan or head drum can take place. The first of these will correct for long-term fluctuations in the speed of rotation, such as may be caused by the changing amounts of tape on the two spools in the cassette producing a slow but gradual fluctuation in the tape tension around the head drum. The second type of correction will take place during a short period of time, for example to correct sync disturbances of the programme material, or very large servo errors which develop when either the record or playback modes are entered. Splices, creases and dropouts can also cause the servo to compensate for an error very quickly.

Long-term errors are normally caused by changes in the mechanical conditions of the transport system itself, while short-term disturbances are nearly always caused by electronic fluctuations of either the material being recorded or replayed, or the electronics of the machine. One must always bear in mind that the prime function of the VCR servo is to reproduce during the playback mode the exact conditions that were present in the record mode.



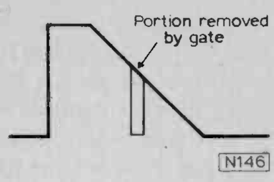


Fig. 13(left): The servo reference ramp.

Fig. 14 (right): Application of the feedback signal.

Error voltage generation

The method used in the VCR (and in many other VTRs) to produce the error voltage, which is fed via a power amplifier to the eddy current brake, is rather unusual and warrants a closer look. To generate the error voltage two signals are required. One is a reference which is known to be correct, and the second is the feedback voltage which is to be compared with the reference. The reference voltage takes the form of a sawtooth ramp falling in a linear manner from a high potential to a low potential, see Fig. 13. This ramp is of course generated at the reference frequency, 25Hz. The feedback signal which is to be compared with the reference consists of a pulse of constant amplitude and width, but whose frequency will change with a change in speed of the head drum or capstan motors. The feedback pulse is used to gate out part of the reference ramp as shown in Fig. 14.

When the servo has locked, the gate position will appear in the centre of the ramp, but should the phase of the motor change then the gate position will travel either up or down the slope depending whether the speed of the motor has decreased or increased. The sampling gate conducts during the period occupied by the feedback pulse, and the coincident portion of the ramp is removed. This is amplified and then fed to a smoothing or storage stage. A basic block diagram is shown in Fig. 15. As the phase of the feedback pulse changes then so does the gating position on the reference ramp causing the gated signal to rise or fall in potential. See Fig. 16.

Servo record mode

The block diagram of the VCR servo in the record mode is shown in Fig. 17. As we have seen, during the record mode the servo reference is the field sync information

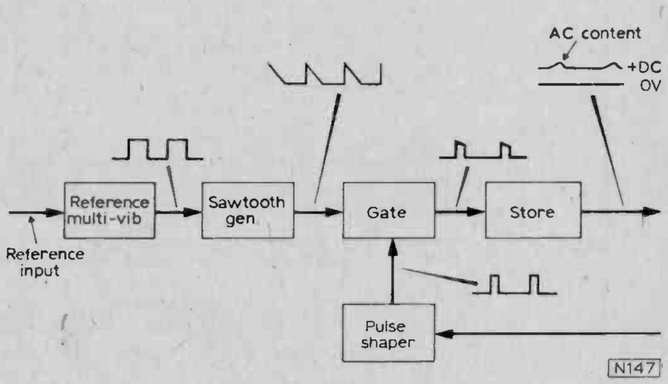


Fig. 15: Block diagram of the error-voltage generator.

contained in the video signal to be recorded. The separated mixed sync pulses are fed to a field pulse separator TS461 and then clipped by TS462 to produce a clean positive-going field sync pulse. These field sync pulses are then used to lock the master reference oscillator TS228 and TS229.

It can be seen from the block diagram that the method of controlling the frequency of this oscillator is very similar to the correction system just explained. The squarewave output from the oscillator TS228, TS229 is fed to a sawtooth generator TS230. The output of this stage is a waveform similar to that shown in Fig. 13 and this is gated by the shaped field pulse which is applied to the sampling gate TS231. The output of the sampling gate consists of the gated portion of the ramp applied to its input, the amplitude of this gated signal being dependent on the phase of the master oscillator when compared with the reference field pulses. This error voltage is then applied across a capacitor to store the signal and convert it to the d.c. control voltage. From here the signal is d.c. coupled to an impedance matching emitter-follower and then applied to the master oscillator.

The squarewave output of the master oscillator is fed to a binary divider TS226, 227 and from here the true reference signal is fed to three separate sections of the servo. The first of these feeds is to a pulse amplifier which drives the control track record head. It will be noted that the signal recorded does not have h.f. bias as one might expect but is simply recorded directly onto the tape. All that is required of the control track signal is that it gives an accurate reference of the moment that a new picture is recorded. The shape, or any distortion is not important. Even broadcast machines costing many tens of thousands of pounds do not go to the expense of biasing the control track signal.

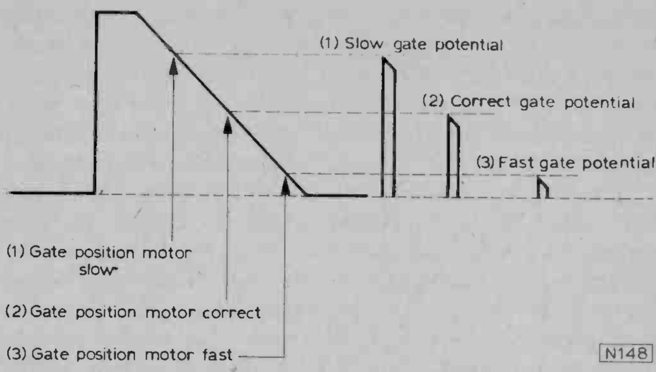


Fig. 16: Variation of gate position with changes in motor speed.

The second output of the binary divider is applied to the head drum servo as the reference signal and the third output is fed to the capstan servo, again as a reference.

Head drum servo

Comparison between the reference and the feedback signal needs no detailed explanation, apart from mentioning that the feedback signal is produced by passing a magnet that is attached to the head drum over a pick-up coil once every revolution of the head drum. The resulting pulse from the pick-up coil is shaped by TS201 before being used to gate the ramp. The error voltage from the storage circuit is applied to one input of a differential amplifier, the second input to this amplifier is produced by half-wave rectifying and smoothing the error voltage (D205 and C209).

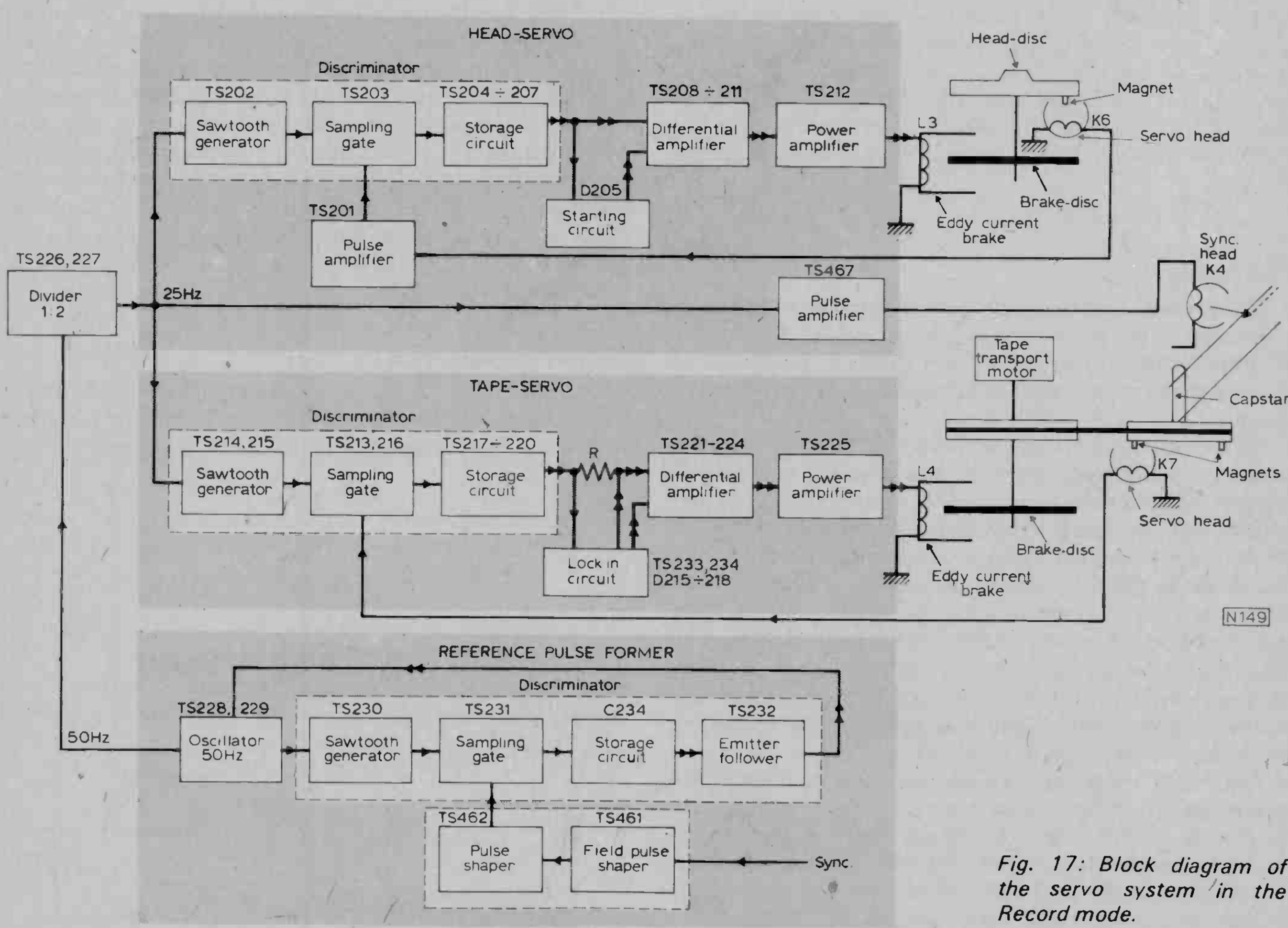


Fig. 17: Block diagram of the servo system in the Record mode.

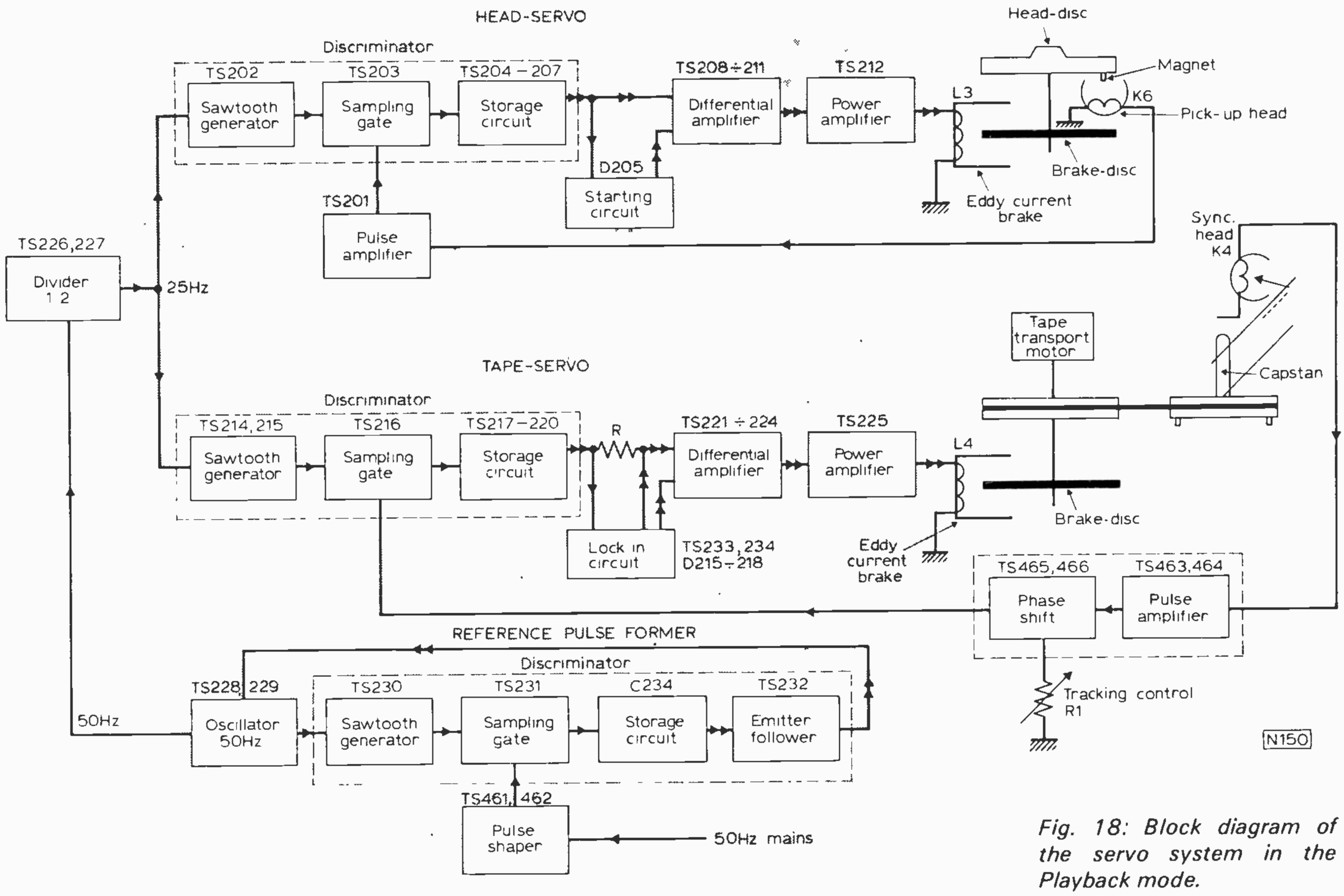


Fig. 18: Block diagram of the servo system in the Playback mode.

The direct feed to the differential amplifier will be a d.c. voltage plus a ripple a.c. caused by the sample rate in the discriminator. The second input contains just the d.c. component of the error. Once the servo has locked the ripple voltage will fall because a constant-rate sample of the same potential is being made and then smoothed by the storage circuit. If the servo loses lock then the gate position will travel up or down the ramp producing the varying ripple voltage which is then used to produce an output from the differential amplifier.

The big advantage if producing both inputs of the differential amplifier from the error voltage is that the difference between the two will always be comparatively small. Hence the servo is always inside its normal lock-in range, and is able to lock from the start of a mode with maximum speed. The output of the differential amplifier is amplified by TS212 and fed to the eddy current brake to control the speed of the head drum. The video head is now locked directly to the picture information being recorded and phased so that the field sync is being recorded at the beginning of a new scan of the tape.

Capstan servo

The techniques used in the tape-capstan servo are very similar indeed to those used with the head drum, the only differences being the introduction of a lock-in circuit between the storage stage and the differential amplifier, and the absence of a pulse amplifier in the feedback path. The discriminator is the same, in principle, as before; only the feedback signal has changed and this takes the form of a 25Hz pulse derived from a sync head on the capstan flywheel.

The error signal from the storage stage TS217/220 has its d.c. component directly coupled to the differential amplifier, while the a.c. component is fed to a lock-in circuit which amplifies the a.c. error and stores it on a 10μF capacitor, producing a smoothed d.c. voltage. A portion of this voltage is added to the original error and applied to one input of the differential amplifier. The remainder of the d.c. voltage is fed via a diode limiting circuit (to prevent the servo from going outside its correction range) to the second input.

The reader will notice that up to now all the correction on the speed of the capstan servo has been long-term d.c. correction because of the slow tape speed changes required. Remember that the guard band between video tracks on the tape is very small indeed, and any rapid correction could cause the servo to overshoot the information on the tape. A small amount of a.c. correction is however applied in the form of feedback from the output to the input of the differential amplifier. The error output of the differential amplifier is now fed via a power amplifier to the eddy current brake on the tape transport capstan motor.

During the record mode the capstan and the head drum are synchronised directly to the incoming picture information. The head drum is locked in such a way that the field sync information is recorded at the beginning of each new video track, and the capstan produces a synchronised and continuous tape speed. Should the frequency of the reference field pulse shift, then both servos will compensate for the change simultaneously.

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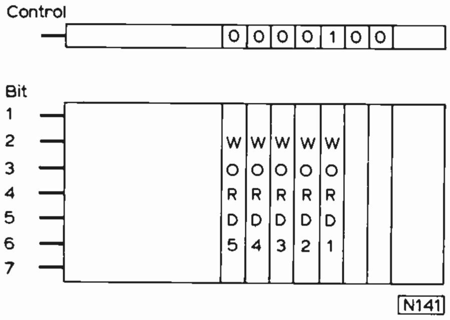

Fig. 31: Use of a control track to identify the position of Word 1 in a shift register.

1103A which is a direct replacement but does not require a Precharge signal. The price of 1103 devices is about £7 each.

The second industry standard type, popular with the computer equipment makers, is the Intel 2102 which is a 1024-bit static RAM contained in a 16-pin DIL package. It has the advantage of requiring a single +5 volt supply and matches directly into 74 series TTL circuits. National, Fairchild and ITT also produce the 2102 whilst the Signetics 2602 and Texas TMS4033 are direct equivalent types. Because of its popularity the 2102 is relatively cheap at some £3·00 to £3·50 each for the standard version in a plastic package. There are high speed versions also available but the standard 1μs version is adequate for use in a teletext memory.

Shift registers

For shift register memories the most convenient device is likely to be the Signetics 2533 or one of its equivalent types such as the Texas TMS3133 or the faster Fairchild 3355. These are 1024-bit static shift registers with recirculate logic built into the chip. They come in 8-lead DIL cases and need +5V and −12V supplies. Once again the output can be coupled directly to TTL devices. The cost varies between about £4·00 and £7·00 depending upon the particular type.

All of the devices described use MOS (Metal-Oxide-Silicon) type technology which employs field effect transistors on the chip instead of the bipolar types used for TTL type logic devices. In general MOS devices are slower than the TTL types but require much less power which is a great advantage when there may be 2000 to 3000 transistors on the chip. The inputs on MOS devices can exhibit very high impedance and are sometimes prone to damage by static electric charges. Most current devices like the 2102 have built-in protection against static but it is still a wise precaution to handle the devices with some care.

There are many other types of RAM and shift register devices which could be used but most are faster than is needed for teletext and hence more expensive.

Suppliers

Intel type devices can be obtained from Rapid Recall Ltd., 9 Betterton St., London WC2H 9BS. Signetics and Texas Instruments devices are obtainable from S. D. S. Components Ltd., Hilsea Industrial Estate, Portsmouth, Hants and National Semiconductor types are available from Jermyn Industries, Vestry Estate, Sevenoaks, Kent.

Now that the data has been stored in the page memory the next stage is to produce the display on the television screen. Next month we shall see how the characters are generated for the display.

THE PHILIPS VCR

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Playback mode

As we have seen earlier in the series, the servo reference in the playback mode is mains frequency, and the head drum servo locks directly to this reference once it has been processed and divided by two. Fig. 18 shows the block diagram of the machine in the playback mode; the head drum servo should need no explanation.

The capstan servo is again very similar to the arrangement used in the record mode apart from the fact that the feedback signal is delayed by TS465 and TS466. This provides a method of accurately phasing the position of the tape so that the video head is scanning through the centre of the recorded information. The capstan servo feedback signal is of course the picture frequency control track.

When both of the servos are locked in the playback mode the feedback pulse from the head drum is coincident with the mains reference, causing the video head to start its scan of the tape. The capstan has positioned the tape so that the control track pulse from the tape is again coincident with the mains reference, and hence the control track pulse is also coincident with the beginning of the head scan across the tape. In the record mode this was the point at which the field sync information was recorded, so it can be seen that the servo has in fact reproduced the exact conditions that were present during the recording of the material.

Conclusion

The purpose behind this series of articles has been to give the reader a basic idea of the problems and techniques used in the low-cost range of video tape recorders. Special attention has been paid to the VCR because it combines all the basic theory, together with some of the more unusual techniques, in one machine; and as the reader is more likely to meet this particular machine than any of the others, it seemed the most logical choice for a more detailed examination.

Videotape recording is at the moment a large and rapidly expanding field of electronics which is just beginning to make an impact on the domestic market. In the future it is going to make an even bigger impression. Digital techniques have many applications in the VTR, and it must surely be just a matter of time before the domestic machine makes use of these. One aspect has to be sorted out before very long however, and that is the tape format and recording standards that are going to be used. Personally I think this is going to be a much bigger problem than any other in the future development of the domestic videotape recorder.

SAFETY NOTE

In a recent service bulletin issued by Combined Electronic Services Ltd., the Philips service organisation, warning was given of a possible fault condition on early N1500 VCRs.

Routine tests have shown that there is a danger of the right-hand timer spindle (Set Recording Time) becoming live, due to a fault in the timer motor.

All recorders with serial numbers below 76,000 should be checked for this fault, using a flash tester with an output of greater than 2000V a.c. Multimeters or "Megger" type insulation testers are not adequate to carry out this test.

Each C.E.S. service depot is equipped with a suitable flash tester and can carry out the necessary tests.