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A BASIC GUIDE TO COLOUR TV & VCRs

BY DAVID BOTTO

**AN IN-DEPTH LOOK AT
THE OPERATION OF BOTH
COLOUR TV RECEIVERS
AND VIDEO RECORDERS**



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A Basic Guide to Colour

TV & VCRs

By David Botto

An Electronics Australia Publication

FOREWORD

This book is intended to help the reader to gain a sound basic knowledge of colour television and video cassette recorder principles.

The days are gone (if they ever existed) when electronic enthusiasts and service technicians could 'get by' using rule of thumb methods, intuition and guesswork. In today's world of advanced electronic technology a thorough grasp of basic principles is essential in order to properly understand and service colour television receivers and domestic video cassette recorders.

The book consists of 14 chapters, originally published as two series of articles in *Electronics Australia*. The first chapter opens by discussing the nature of light and colour, and then goes on to explain in detail how various colour TV systems work.

In the next seven chapters, the practical operation of the complete circuitry of a colour TV is thoroughly covered. The emphasis is on the PAL system.

The next six chapters explain the basic principles employed in domestic video cassette recorders.

The principles of magnetic recording are described. Then the apparently complex circuitry of a VCR is broken down, so that the reader can easily understand the operation of each component and circuit block.

Included is much essential information hard to find elsewhere. Also, an understanding of colour TV and VCR technical terms has not been assumed.

Explanations and meanings have been given in straightforward language. Plenty of schematics and diagrams are included to help you to quickly grasp essential technical principles.

The aim of this book is to impart a sound basic knowledge of colour television and domestic video cassette recorder principles to the reader — knowledge that will be invaluable during the coming years.

ABOUT THE AUTHOR

David Botto is a television, video and electronics service engineer with many years of practical 'on-the-bench' experience. He has also designed, constructed and maintained a wide range of test instruments.

As a boy of 12, he first became interested in radio and electronics when a relative presented him with an ancient crystal set. At age 17 he built his first valve-operated communication radio receiver. After attending Bournemouth School for Boys, he studied electronics at Bournemouth Municipal College.

At the age of 19 he started work in the service department of Bourne Radio. Since then he has worked in a variety of TV and Video Service Departments in England and Germany.

Over the years he has kept up his study at electronics by continuing study of such subjects as solid-state electronics, digital techniques, micro-processors and computer technology.

His articles dealing with such subjects as TV and VCR servicing, electronic speech and digital techniques, have appeared in *Television* magazine in England, *Radiorama* in Spain, and of course, in *Electronics Australia*.

He lives in Poole, England, with his wife Elsa.



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THE NATURE OF LIGHT AND COLOUR

Part 1

Before we try to understand the principles of colour television in general, or the specific details of the PAL colour TV system, we should refresh our concepts regarding the nature of light and colour.

In order to grasp the principles of colour television we first need an understanding of light and colour. We'll define light as the natural medium by which objects are made visible to our eyes, i.e., that section of the electromagnetic spectrum to which our eyes respond.

Much remains to be discovered concerning the nature of light, but it is generally accepted that light consists of electromagnetic waves which travel in straight lines and can be measured in terms of wavelength. This wave theory explains why light bends when passed through water or glass, the operation of lenses, and why solid objects cast sharply defined shadows.

However, it does not explain why light striking a metal plate causes the plate to emit a shower of electrons.

Further, the wave theory cannot explain the action of light in the case of solid-state optoelectronic devices. Here light behaves as if it consists of particles which can be absorbed into semiconductor materials. So light seems to travel as waves, yet appears to consist of tiny particles!

The present understanding, known as the quantum theory, is that light travels in waves consisting of a number of tiny particles or packets of energy called *photons*.

In a vacuum the velocity of all electromagnetic waves, including light, is 3×10^8 metres per second.

The electromagnetic spectrum covers a range from the cosmic, gamma and x-rays, through ultra-violet rays and the narrow band of visible light frequencies, down to the lower frequencies of infrared waves, television and radio waves (Fig.1).

White light can be split into a spectrum of colours by passing it through a glass prism (Fig.2). The wavelengths of the various colours, measured in nanometres (10^{-9} metres), are approximately -

purple/violet	380 to 450
blue	450 to 490
green	490 to 565
yellow	565 to 590
orange	590 to 630
red	630 to 760.

How our eyes see light and colour

Because a colour television picture is produced by mixing several colours in order to reproduce as accurately as possible the colours of the transmitted scene, it's helpful to know how our eyes see light and colour. When we view a scene, the curved surfaces of the cornea, eye fluids

and lens of the eye focus the image onto the retina, a light sensitive layer of cells at the back of the eye. This image is fed to the brain by the optic nerve which consists of about 800,000 nerve fibres.

The retina contains two kinds of light sensitive cells. These are named 'rods' and 'cones', according to their shape. The rods, which number approximately twelve million, are very sensitive and are able to detect small amounts of light and very fine detail.

The cones, which respond particularly to colour, consist of three groups, each group having peak sensitivity to a different colour.

Thus some cone-cells have a peak response to yellow light, some to red light and others to green light. The cone-cells total about seven million.

When the right balance of colours are detected by the three types of cone-cells, the optic nerve sends the sensation of white to the brain.

The rod-cells seem to be mainly concerned with monochrome vision and vision in low light intensities. Our understanding of both rod and cone cells remains incomplete for the present.

Although various colours possessing the same radiant energy may be present, the response of our eyes is not the same for all colours. Fig.3 shows the response curve of what is known as the 'standard' human eye possessing normal sight. Notice that green and yellow colours appear brighter to the eye than do red and violet shades.

When our eyes view a relatively large area in normal light, we easily distinguish between colours. However, as the size of the area decreases, the eye finds it harder to distinguish one colour from another. Blue and green become confused, and difficult to distinguish from grey. Blue and yellow appear grey.

Reds remain fairly distinct, but tend to merge with greys as the colour area

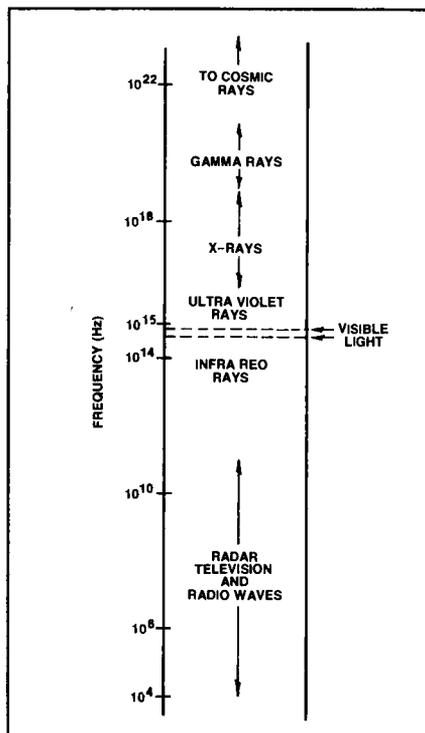


Fig.1: The electromagnetic spectrum.

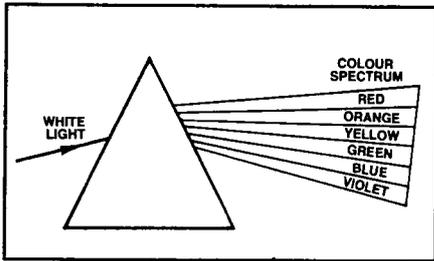


Fig.2: The colour spectrum can be obtained by passing white light through a glass prism.

becomes smaller. When the area is very small, all our eyes can distinguish are changes in brightness; colour cannot be seen at all.

Colour television systems use these properties of our eyes by transmitting the detail of the picture in high-definition monochrome ('black and white'), and the colour information at a relatively low definition. A rough comparison is that of a child's painting book where the picture is drawn in black and white, and the colour painted in the blank areas.

Sending the fine detail in monochrome has the further advantage that the colour transmission can be received in black and white on a monochrome receiver.

Why objects appear the colour they do

An object takes its colour from the colour of the light it reflects. When, in white light, an object appears green to us, it is because all other wavelengths of light are absorbed, and only green light is reflected. Similarly, a red object appears red because only red light is reflected, and the rest of the light absorbed.

If in a darkened room we shine a red light onto a green object, the object will appear to be black, because there is no green light available for the object to reflect.

Similarly, if the object is red, with only green light illuminating it, it will also appear to be black, as again there is no green light to be reflected.

A dull black object is black in any lighting conditions, because it reflects virtually no light of any colour. However, an unpolished pure white object reflects every colour and seems to the eye to be the colour of the light illuminating it.

Thus, if bathed in pure green light it will appear as a green object, while in pure red light it will appear as a red object. Hold your book in a coloured light in a darkened room, and the white page appears that colour, but the black print remains black.

Some basic terms used in colour television are hue, saturation, brightness and chromaticity.

Hue is the colour of the light as it appears to our eyes — the wave length of the light.

Saturation is the measure of how deep the colour is — the deeper the saturation, the less the amount of white light mixed with it. Thus deep red is highly saturated, but we say pink is less saturated because white light is mixed with the red colour.

Brightness is a term describing the intensity, or amount of light energy of a colour.

Chromaticity is the quality of colour and is dependent on both hue and saturation, but not on its brightness. Achromatic light is light without colour, ranging from white, through grey to black.

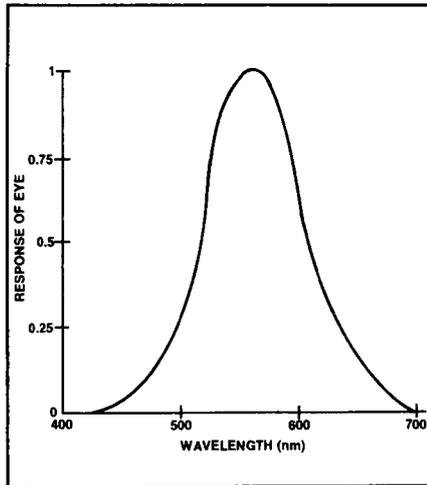


Fig.3: Response curve of the eye to various colours.

Colour mixing

Colour mixing, using three properly selected primary colours to obtain a wide range of colours, may be subtractive or additive.

Primary colours are those which mix together to produce a wide range of

colours, but no two of these colours will combine to yield the third colour.

Subtractive colour mixing uses the principle of mixing primary colours in such a way as to absorb some colours, leaving only the required colours. This method of colour mixing is generally employed in modern colour photography systems.

If we subtract red light from white light we obtain the colour known as cyan. Subtract blue light from white light and the result is yellow. Removing green light from white leaves magenta. These three colours — cyan, yellow and magenta — together form three primary colours.

Fig.4 demonstrates the use of three coloured filters placed in front of a white light. The cyan filter absorbs all red light from the white light source, the yellow filter the blue light, and the magenta filter the green light.

This subtractive action results in the colour sensations of cyan, yellow and magenta. Thus a colour filter allows only the colour light of its name to pass through it. If we overlap the magenta and cyan filters (Fig.4a), the magenta filter removes the green light and the cyan filter the red light, so that our eyes see a blue colour.

Overlap all three filters as in Fig.4b, and the overlapping magenta and yellow filters remove green and blue light, leaving only red light. Similarly, the overlapping cyan and yellow filters stop the red and the blue light so that our eyes see a green colour. Where all three filters overlap, no light at all passes and our eyes register a black colour.

The primary colours used in subtractive colour mixing are known as complementary colours, because, as we have seen, to produce the primary colour another colour known as an additive primary was removed from white light to produce it. So the additive primaries of cyan, yellow and magenta are red, blue and green in that order.

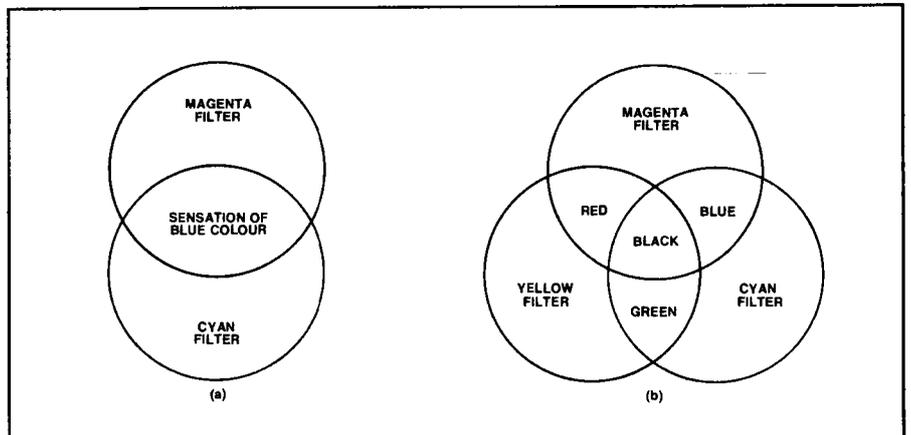


Fig.4: The cyan filter absorbs red light, the yellow filter blue light and the magenta filter green light.

Additive colour mixing

Colour television makes use of additive colour mixing. Although any three primary colours may be used for additive mixing, the three colours, red, green and blue, combined together in various proportions, provide the colour television viewer with the widest possible range of colours. Additive colour mixing may be demonstrated by the use of three projectors filtered with red, green and blue filters (Fig.5). When a single colour illuminates the white screen, that colour is reflected because a white screen reflects all colours.

When both red and green light are projected onto the screen, we see a yellow colour. This is because the cone-cells of our eyes are stimulated in the right proportions to make a yellow sensation, even though no pure yellow spectrum light is present.

Project green and blue and our eyes register a cyan colour. Red and blue projected together will appear magenta. If we now project all three colours, red, green and blue, at the correct intensities (by adjusting the brightness control of each projector), the result will appear as white.

Note that the six colours produced match those generated by the standard colour bar generator used for television servicing.

By using the three brightness controls to produce red, green and blue light at various levels of intensity, a large range of colour sensations may be obtained. The

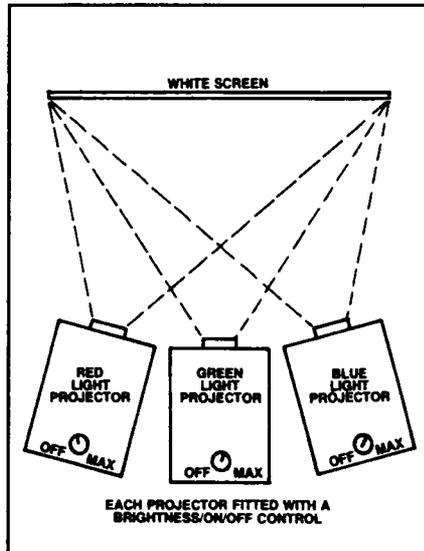


Fig.5: Basic additive colour mixing scheme.

proportions of the three primary colours used to form a wanted colour are known as *Tristimulus* values.

The colour picture reproduced by a television picture tube makes use of red, green and blue light-emitting phosphors. These produce a wider range of colours than a photographic colour print using subtractive colour mixing. However, the colour photograph is able to reproduce heavily saturated blues and greens outside the range of colour television.

Fig.6 shows the well known horseshoe shaped chromaticity diagram. Around the perimeter are figures that show the

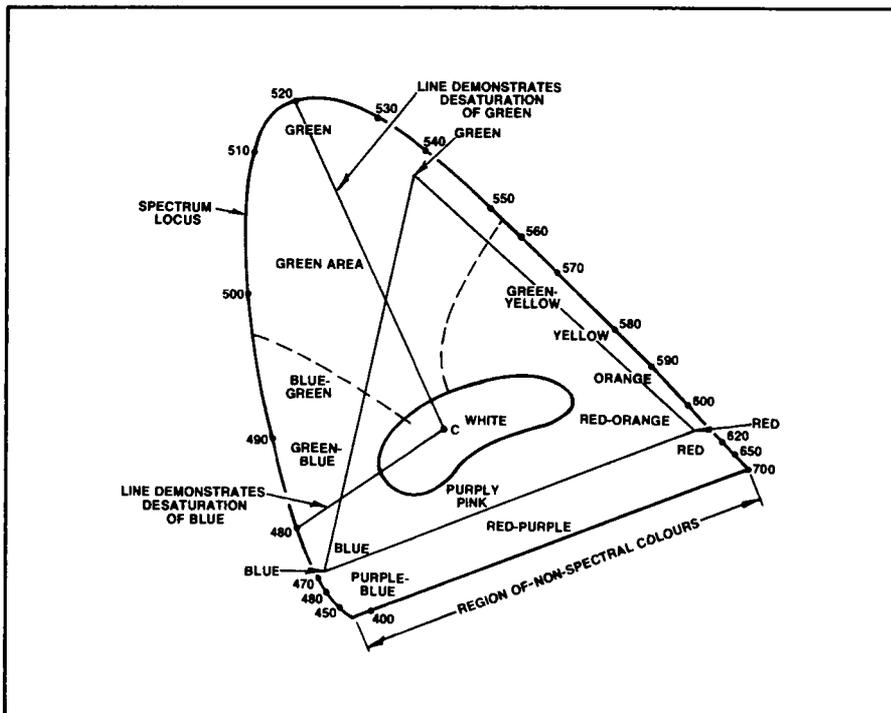


Fig.6: The horseshoe-shaped chromaticity diagram. The figures around the perimeter show the wavelengths of different hues of colours, in nanometres.

wavelengths of different basic hues of colours, in nanometres.

At the centre is a point labelled white. Sunlight at midday, daylight or light seen through a skylight are all white light, but with different energy levels over the entire colour spectrum of 400 to 700 nanometres.

Since there is no 'standard' white, various 'reference whites' are used, such as equal energy white light, Illuminant A, Illuminant B and Illuminant C.

The Australian standard is based on a warmer reference white known as Illuminant D 6500. This contains less blue and slightly more green light than the white of Illuminant C.

If we draw a line from the point numbered 520 at the perimeter of the chromaticity diagram to the point marked 'white', then at the edge of the diagram we have spectrum green at a wavelength of 520 nanometres.

As we move down the line towards the centre, more and more white light is added to the green, until at point C only white light remains.

Thus the spectrum green has been gradually diluted to produce graduations of colour from green to white. The mid-point of the line represents spectrum green saturated 50% with white light. Similarly, a line drawn from the point numbered 480 to point C begins at spectrum blue and is increasingly saturated with white light. The blue thus becomes paler in colour until only white light remains.

If you draw a straight line between any two points on the numbered perimeter of the chromaticity diagram, you will see the various colours that can be produced by combining two colours additively in various amounts.

The perimeter line at the bottom of the diagram is known as the region of non-spectral colours, because no pure colours are present here. In this area all colours are formed from different mixtures of red and blue.

The triangle within the diagram — called an RGB triangle — shows the range of colours that can be displayed by the colour television receiver using three colours. These are: red at a wavelength of about 610 nanometres; blue at 470 nanometres; and green at about 540 nanometres.

Colours outside the RGB triangle cannot be displayed, a fact that might appear to limit the reproduction of the colour picture. However, the more saturated colours outside the RGB triangle are not essential to good colour reproduction.

Since red, green and blue light in the right proportions stimulate the eyes to see white, the correct balance of the three colours can be used to transmit the

monochrome or brightness detail of the television picture. This is called the Y or *luminance* signal. The Y signal can be received by a monochrome receiver to provide a normal monochrome picture.

Because the eye is most sensitive to green, and more sensitive to red than to blue, the best balance of the three primary colours to form the Y signal is 59% green, plus 33% red, plus 11% blue. This is better expressed as:

$$EY = 0.59EG + 0.33ER + 0.11EB$$

where E represents the relative voltages of the different signals, and G, R and B the colours.

It might at first appear that to obtain a colour picture we need to transmit the EY signal, to form the high definition detail of the picture, and three colour signals carrying respectively red, green and blue colour information, in

order to reproduce the colours of the transmitted scene.

To do this would require excessive and unacceptable bandwidth in the transmitted television signal, and would result in unnecessary complexity of the colour television receiver, increasing the cost considerably.

Our study of additive colour mixing shows that it is not necessary to transmit three colour signals because all the colour information is contained in the Y signal and two of the three colour signals – recovering the third by subtracting the two colour signals transmitted from the Y signal. We could use any two of the three primary colour signals, and recover the third. The colour signals chosen are red and blue, sent in a form known as *colour difference signals*.

Green is not used to produce one of the two required colour difference signals because the maximum voltage of a green colour difference signal would be less than that of a red or blue colour difference signal, and would be more liable to distortion in transmission.

These colour difference signals are formed by inverting the Y signal (by means of an amplifier) to produce a -Y signal. By adding this -Y signal to the red signal (R), the red colour difference signal ER-EY is obtained (usually referred to as the R-Y signal).

Similarly, by adding the -Y signal to the blue (B) signal, the B-Y colour difference signal is formed.

We now have the Y signal, plus the R-Y and B-Y colour difference signals, and from these we can recover the G-Y signal.

EARLY COLOUR TELEVISION SYSTEMS

Part 2

Here we deal with the history of early colour TV systems, and look at how the need to maintain compatibility between colour and monochrome transmissions and receivers has been satisfied.

A modern colour television system must meet certain requirements. The signal transmitted by the colour television station must be *compatible*. In other words, the signal must be able to be received not only in colour on a suitable receiver, but also as a good quality black and white picture on an ordinary monochrome TV.

Also the colour television receiver ought to be able to receive monochrome transmissions — as, for example, for a film made in black and white. This is called reverse compatibility.

When the transmission is in colour, a high standard of both detail and colour is essential, without colour changes caused by signal distortion in the transmission path.

In addition, since channel space is limited, with perhaps several TV stations transmitting on nearby frequencies, it is important that there is no increase in the bandwidth of the transmitted signal over that required by the existing monochrome TV stations.

Usually, an existing monochrome TV transmitter must be converted to handle colour signals. Since expense is a big factor, it is desirable that the colour system chosen enables an existing monochrome transmitter to be converted to the new colour system by the addition of extra components. The alternative, of building a complete new colour transmitter, is unacceptable.

The final points to consider when choosing a system of colour TV transmission and reception, are the probable cost and reliability of the proposed colour TV receiver. If the receivers are overly complex, they will be unreliable and expensive to service.

Let us accept for the moment that every country which now has television has either gone through the above process of selection, either via costly research and

development or by the decision to adopt one of the now proven and refined colour TV systems, such as PAL, NTSC or SECAM.

Colour television as we know it is a refinement of the principles used in black and white television. Therefore, before studying colour TV principles, we will briefly revise those used in black and white television.

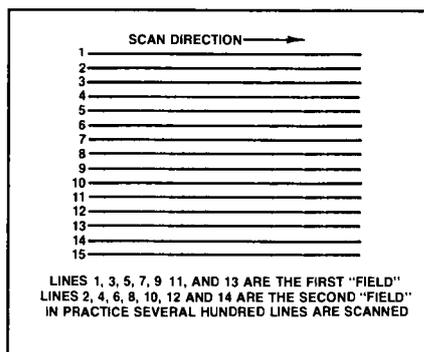


Fig.1: This diagram shows how the electron beam of the TV camera scans a scene. The flyback lines are not shown as the TV receiver blanks them out.

Scanning

You will remember that at the TV station, the monochrome TV camera scans the scene at a fixed rate, beginning at the top and moving from left to right. At each point of this scan a signal voltage proportional to the brightness of the scene appears at the output of the camera (see Fig.1).

The first line completed, the camera beam scan returns to the top left of the scene at high speed, and scans again — but just slightly below the first 'trace'. The process is then repeated until the whole scene has been scanned.

To reduce flicker, the camera again

scans the scene in a series of lines spaced (interlaced) between the first set. The section of the scene traced by each set of lines is called a 'field', and the complete picture from these two fields is referred to as a 'frame'.

In a monochrome television system using 625 lines, fifty fields each second are traced, so that each complete frame of the transmitted scene is repeated 25 times per second.

The viewer's TV receiver builds up a matching series of lines by the movement of the electron beam of the cathode ray tube across the tube face.

The beam is synchronised with the scanning of the TV camera, and its intensity is controlled by the received signal, reproducing the same light intensity as the transmitted scene at each point of the scan.

Our eyes retain an impression of what we see for a brief moment — a quality we call *persistence of vision*.

Because of this quality, helped by the brief afterglow properties of the picture tube phosphors, a complete black and white picture, composed of a series of fine closely spaced lines is seen, despite the fact that only a single fast moving spot of light of changing brightness is actually present on the screen.

Colour television systems

As explained in the first chapter, colour television employs additive colour mixing by using three primary colours: red, green and blue.

This, you will recall, enables a wide range of colours to be reproduced by the colour television receiver.

A simple system to accomplish this is to send three colour pictures simultaneously, each picture containing only the separate red, green or blue components of the transmitted scene. To do this, three TV cameras are used. Camera 1 has a red

filter fitted, Camera 2 a blue filter and Camera 3 a green filter (Fig.2).

From our study of colour we know that only the radiant energy of the red light in the scene will be registered by Camera 1, the blue light energy by Camera 2 and the green light energy by Camera 3.

A separate transmission path carries each of the three colour components of the studio scene to the viewer. At the receiving end each camera colour picture signal is detected, amplified and then displayed by one of three separate cathode ray tubes.

Cathode ray tube 1 displays the red component of the received picture, cathode ray tube 2 the blue component, and cathode ray tube 3 the green component. The three CRTs are simply monochrome tubes fitted with individual red, green and blue colour filters.

Alternatively, each tube could use a different coloured phosphor screen to produce the three primary colours. The separate red, green and blue received pictures are then optically combined to reproduce the colour picture.

Quite a good colour picture could be obtained using this system, although there would be problems in combining and synchronising the three pictures. The unacceptable drawback is that the transmitted signal needs a total channel bandwidth of *three times* that of a monochrome television signal!

To overcome the bandwidth problem the idea of transmitting the three colours in sequence, switching from one camera to another in turn at high speed was tried. At the receiver end, another switch, synchronised with the camera signals, diverted the received signal to each picture tube in turn.

Since the change from one colour to the next is very fast the eye sees the scene as a complete colour picture (Fig.3).

By using this sequential system, the station bandwidth of the transmitted colour signal is no greater than that of a monochrome transmission. The main drawback was that the picture suffered from a nasty flicker effect.

CBS sequential system

To eliminate this defect, a version of the sequential system was further developed by the Columbia Broadcasting System in the USA from 1946 onwards.

A monochrome television camera was used, in front of which was a rotating filter disc made up of colour filter sections — red, blue and green. At the viewer's end, a similar filter disc, synchronised to run at the same speed as the disc at the TV camera, rotated in front of the

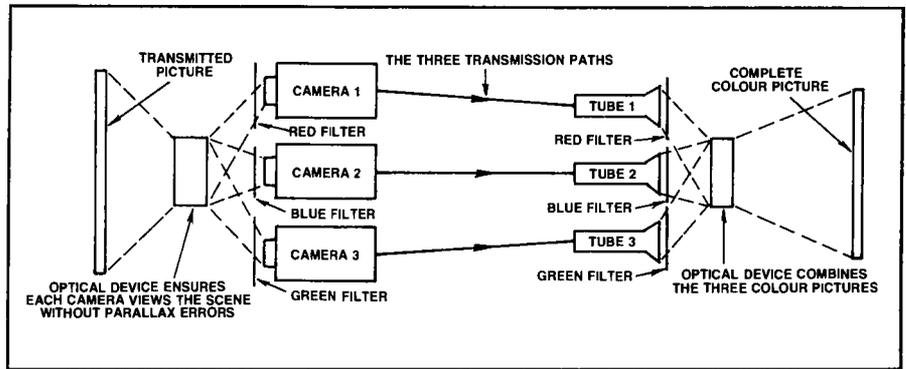


Fig.2: It would be possible to transmit and receive a colour picture by using three separate transmission paths for the red, blue and green information but the required bandwidth would be prohibitive.

receiver's monochrome cathode ray tube. Because of the high rotation speed, persistence of vision caused the viewer to see a complete colour picture.

Once again, excessive bandwidth proved to be a problem. In fact, one early version of the CBS sequential system needed a channel bandwidth of 12MHz.

To keep the station bandwidth within the normal 6MHz channel allocation, the scanning lines in the picture were decreased from the standard 525 (for USA) to 405 lines. Each of the 144 fields per second consisted of 202.5 lines, with a horizontal scanning rate of 29,160Hz (202.5 x 144).

The colour disc rotated at 1440rpm and contained six filters coloured red, green, blue, red green, blue, in that order. Six fields were scanned in sequence for each disc rotation, so that each field of the picture was scanned in turn by all three primary colours.

A TV receiver with a monochrome picture tube of some 30cm in diameter or less was used so that the viewer's spinning synchronised colour disc was not excessive in size. The viewer could increase the picture size by fitting a large magnifying glass to the face of the picture tube.

This CBS field sequential system was

not compatible, although the system was 'convertible'. The television receiver contained scanning circuitry that could be switched from 144 fields to 60 fields per second, the colour disc being removed for reception of monochrome transmissions.

RCA sequential system

Colour television broadcasts using the CBS system began in the USA in mid 1951 in New York. However, Radio Corporation of America continued to develop their Dot-Sequential Colour TV system.

This system was based on the standard USA monochrome television which employed 525 horizontal lines for each frame. Each frame therefore consisted of two fields of 262.5 lines scanned at 60 per second. This gave a frame rate of 30 per second.

Use was made of the principle of 'mixed highs'. This simply means that the fine detail of the picture is sent in monochrome at high definition, and the colour information at a considerably lower definition.

In the RCA system, the monochrome signal occupied a bandwidth of 2 to 4MHz and the colour information a bandwidth of 0 to 2MHz. The three colour signals were electronically

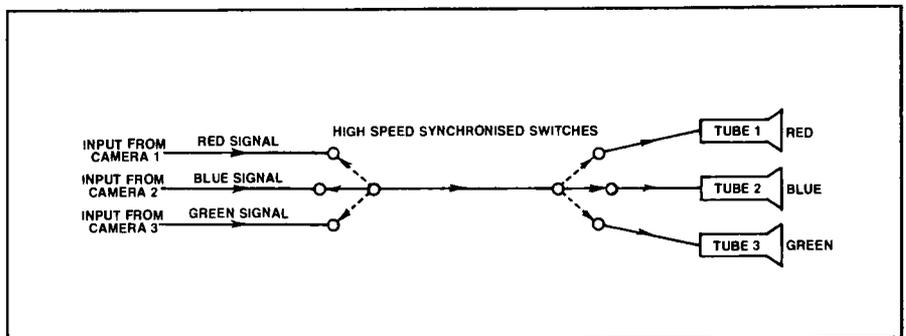


Fig.3: An alternative to using three transmission paths would be to send the red, blue and green picture information sequentially. Again, bandwidth would be a problem.

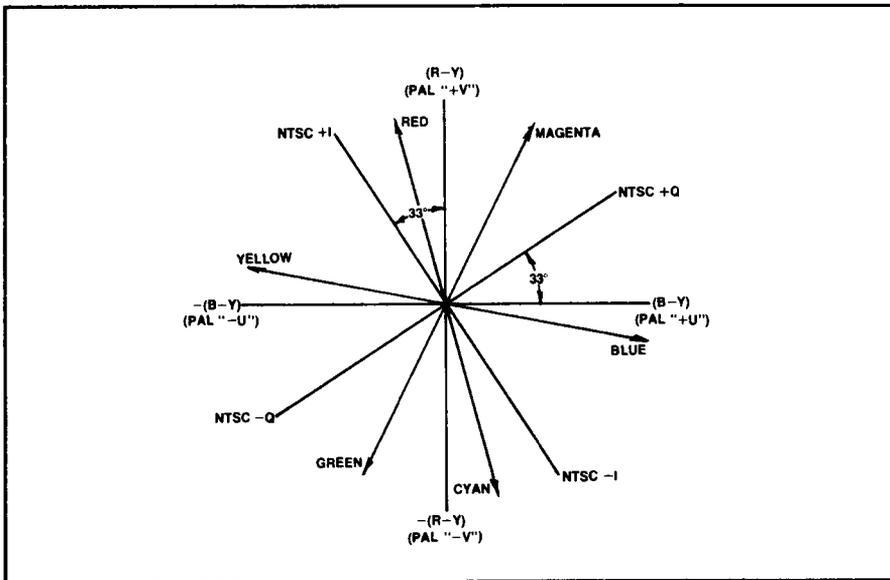


Fig.4: This diagram shows the relative phase angles of the 'I' and 'Q' signals and the respective colours for NTSC and PAL systems.

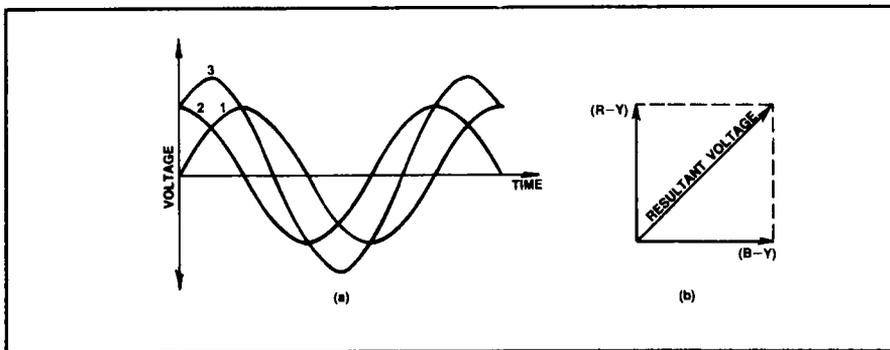


Fig.5: The result of combining two sine waves of the same frequency and amplitude but 90 degrees out of phase. (1) and (2) are sine waves while (3) is the resultant waveform. This is depicted at right in vector form.

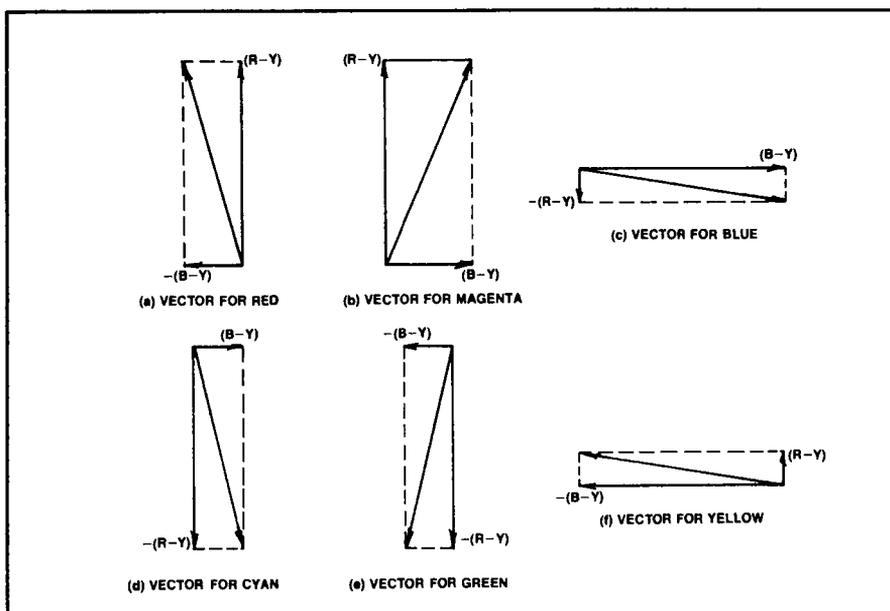


Fig.6: These vector diagrams show the colours produced by relative R-Y and B-Y voltages.

switched at 3.58MHz. This high speed sampling of the three colour signals caused the colour picture to be formed by a series of differently coloured dots.

Early versions used three cathode ray tubes and combined the three pictures using a system of colour-selective mirrors to produce a complete colour picture. This arrangement needed a lot of space, and was difficult to set up correctly both optically and electronically.

For this reason, later versions used a single picture tube, known as 'Tricolour' tube, on which the viewer could see the complete colour picture.

When a monochrome picture was received the dots combined to produce a black and white picture, so that the RCA dot sequential system was truly compatible. Picture flicker was the main drawback of this system.

A mechanical system

Long before the development of any other system, John Logie Baird demonstrated the world's first colour television pictures in 1928. Mechanical scanning of the picture was used, being developed from his earlier monochrome system.

The 'Scanning Disc' as it was called included three spirals with colour filters instead of a single spiral, the transmitted picture being scanned by the three primary colours in turn. Thus, it was a sequential system.

The NTSC system

Since both the PAL and SECAM colour TV systems are a result of work originally based on the NTSC system, we'll consider the operation of this system first.

The design of the NTSC system was directed by a committee in the USA known as the National Television System Committee. Commercial colour TV broadcasting using the NTSC system received the approval of the Federal Communications Commission (FCC) on January 2nd, 1954 and the CBS system then became obsolete.

The NTSC picture is made up of 525 lines and 30 frames per second (60 fields). The bandwidth is the same as for a monochrome signal (6MHz) which includes the sound carrier, and the colour information is cleverly interleaved with the monochrome information during picture transmission.

Again the use of the principle of 'mixed highs' is used, the picture detail being transmitted in monochrome at high definition. A transmission made using the NTSC system can be received as a good quality black and white picture using a monochrome receiver.

The monochrome or brightness signal for the NTSC system is referred to as the luminance of 'Y' signal. What is transmitted is the monochrome signal with a frequency bandwidth of 0 to 4MHz, and only two of the three colour signals, the third colour signal being recovered by subtracting the two transmitted colour signals from the Y signal.

The two colour signals transmitted in the NTSC system are referred to as the I signal, which has a frequency range of 0 to 1.5MHz, and the Q signal with a range of 0 to 0.5MHz.

These signals are sent as amplitude modulated colour subcarriers, both at 3.579545MHz but 90 degrees out of phase with each other. The frequency of 3.579545MHz was selected to avoid interference with the luminance signal.

In chapter 1 we saw that the Y (monochrome brightness) signal consists of a combination of the three primary colours expressed as:

$$EY = 0.59 EG + 0.30 ER + 0.11 EB$$

with E standing for the relative voltages, and G, R and B for the colours green, red and blue.

Inverting the Y signal to produce -Y and adding -Y in turn to the red signal R, and the blue signal B, we obtain the $ER - EY$ and $EB - EY$ signals, which we'll now call the R-Y and B-Y signals.

Fig.4 shows the relative phase angles of the I and Q signals. Notice that the +I signal is displaced 33 degrees to the left of the R-Y signal, and the +Q signal is 33 degrees left of the B-Y signal. This produces better results than if the I and Q signals were made to correspond exactly with the R-Y and B-Y signals.

Once the R-Y and B-Y signals are obtained, the G-Y colour difference signal can be recovered in the receiver's matrix circuitry, knowing that

$$(G-Y) = 0.41G - 0.30G - 0.11B.$$

How this is done will be discussed in a later chapter, because the method G-Y recovery from the matrix in an NTSC receiver is similar to that used in a PAL receiver.

Thus the amplitude-modulated 3.58MHz colour subcarrier needs to be modulated by two colour signals only, the I and Q signals.

Fig.5a shows the result of combining two signals of the same frequency and same peak voltage, but out of step with each other by 90 degrees. Because these signals rise and fall evenly against a time scale they are sine waves.

According to the relative voltage of each colour signal, a resultant carrier will be produced (Fig.5b). The greater the depth or saturation of a transmitted colour, the higher this resultant voltage

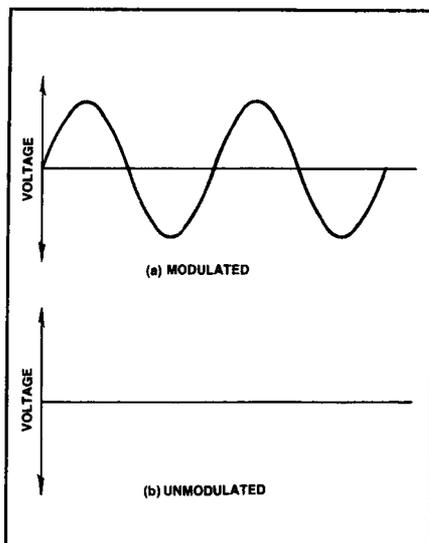


Fig.7: In suppressed carrier modulation, the waveform is present (a) when modulated by signal but absent when modulation is zero (b).

will be. The hue of the colour transmitted will determine the phase angle of the resultant (Fig.6).

As you may know, the resultant arrows shown in the diagrams are vectors. If you look again at Fig.5 you will see the phase angles of various colours.

The 3.579545MHz or '3.58MHz' colour signal is transmitted with its carrier suppressed, only the sidebands being sent. This carrier suppression (see Fig.7) prevents the generation of a beat note be-

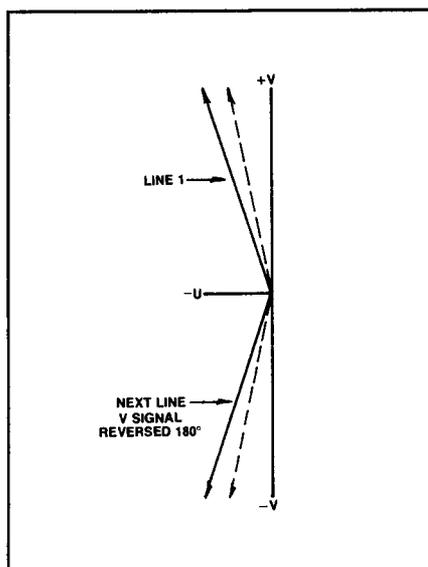


Fig.8: In the PAL system, phase distortion is corrected. The dotted lines show how phase distortion has delayed the red vector, taking it towards magenta. Averaging the phase errors restores the colour to red.

tween the colour subcarrier and the sound carrier of the colour TV receiver, which could produce interference lines on the picture. Another advantage is that during a monochrome transmission no colour signal is present.

To recover the colour difference signals in the receiver so that the I and Q signals may be demodulated, the missing subcarrier is re-inserted.

A local 3.58MHz oscillator, contained in the receiver circuitry and synchronised by a transmitted *colour burst signal*, is generally used to do this.

The receiver circuitry can now recover the three basic colours (red, blue and green) which, together with the black and white picture information, are applied to the picture tube to display a colour picture.

Before adopting the PAL colour television system, the British Broadcasting Corporation experimented with its own version of NTSC using a 405-line version, this being the number of lines used by the existing monochrome TV system in England. The colour subcarrier chosen was 2.6578125MHz. This figure is an odd multiple of half the line scan frequency of 10,125Hz (5062.5 times 525).

At the time of its introduction the NTSC system made all other colour systems obsolete. However, if the NTSC TV signal is distorted for any reason in its transmission path the phase of the colour signal becomes incorrect, and the colour hues on the screen will be wrong.

To compensate for this failing, an NTSC receiver usually has a phase control for the viewer to adjust when changing stations, or if the colours appear incorrect.

To overcome this failing, further efforts were made to develop new colour systems.

The SECAM system

In the SECAM system, only one colour difference signal for each line of the picture is used. The TV receiver 'stores' each line (by means of a delay line) just long enough to use it again on the next line. For one line only, the B-Y signal is used plus the 'stored' R-Y signal from the previous line.

The next line uses the R-Y signal only plus the 'stored' B-Y signal of the line before. The following line uses the B-Y signal again plus the 'stored' R-Y signals of the previous line, and so on.

The subcarrier is frequency modulated, with each of the two colour difference signals having its own subcarrier. Phase distortion is no longer a problem and the colour hues remain constant.

In this book the emphasis will be on the PAL colour television system, considered

by many engineers to be the best. (However, recently when visiting France, the writer viewed both PAL and SECAM TV and could see little difference in the received pictures!)

The PAL system

The PAL system owes much to the NTSC system. Dr W. Bruch, of the Telefunken TV Laboratories in Germany, who devised the PAL system, described it as a variant of NTSC. Again two colour difference signals are used.

These are known as the V signal and the U signal (refer again to Fig.4). The

PAL system renders unnecessary the displacement of the V and U colour difference signals by 33 degrees from the R-Y and B-Y axes, and both have equal bandwidths.

With the BBC 625 line PAL transmissions, the suppressed subcarrier frequency is 4.43361876MHz. To cancel out colour phase errors due to transmission path distortion, the phase of the R-Y (the V signal) is reversed by 180 degrees as alternate lines of the picture are transmitted. So, if one line of picture phase distortion takes the colour away from red, the next takes it toward the red, the

average of the two lines producing the correct hue (Fig.8). Hence the term 'PAL' standing for Phase Alternation Line.

As in the NTSC system, circuitry in the colour TV generates the missing subcarrier in order that the U and V signals can be demodulated and recovered. The phase of the subcarrier regenerator output must be switched by 180 degrees for each line when modulated by the R-Y signal. The main advantage of PAL when compared to NTSC is that phase distortion has practically no effect on the picture, resulting in excellent colour reproduction.

THE PAL COLOUR SIGNAL

Part 3

Here the author discusses colour television cameras and the makeup of the PAL colour signal.

A colour television camera scans the scene to be transmitted, producing video signal outputs proportional to the black and white light, and of the colour present in the scene. Fig.1 shows the principle of the three-tube camera. Three dichroic mirrors are used to split the light into its red, green and blue components.

Dichroic mirrors do this by reflecting only one primary colour and allowing light of all other wavelengths to pass through. These are so arranged that only red light falls on camera tube (a), blue light on tube (b), and green light on tube (c).

Camera beam current

Each of the camera tubes has a target of photoconductive material which is scanned by an electron beam which scans from left to right. As light strikes each element of the target, it produces an electric charge which is then removed as the electron beam scans across the element. The net effect is that the electron beam current varies as the scene is scanned, according to the variations in brightness.

In effect then, each camera tube can be considered to be a capacitor with a high value of parallel resistance which varies according to the brightness of the scene at any point (Fig.2). The electron beam through the tube circuit then becomes the video output signal.

In a 625 line system, the electron beam scans horizontally at a rate of 15,625 lines each second, the vertical scan rate being 50Hz. Field and line scan coils are used to deflect the beam and the scanning of the three colour tubes must be accurately synchronised.

Some colour TV cameras have used four pick-up tubes, one for each of the three primary additive colours, and a separate tube for the monochrome or Y signal. Most colour cameras, however, use three pick-up tubes.

If for a scene consisting of pure white and correctly illuminated with white light, each camera tube supplies one volt of signal, then the outputs must be adjusted to combine 0.30 volts from camera tube A, 0.11 volts from tube C and 0.59 volts from tube B.

These proportions combine to make up the luminance, or Y signal, as defined previously.

$(Y = 0.59E_G + 0.30E_R + 0.11E_B)$
where E represents the signal voltage, and G, R and B the colours).

In a three tube colour camera, the three colour output signals are added in this way to obtain the Y signal. When the camera scans a pure green scene, the green and the Y outputs will both be 0.59 volts, because E_Y consists of the green signal voltage only. The figures below show the camera outputs for various colour backgrounds. Because additive colour mixing is used in colour television, yellow is produced by mixing red and green light, cyan by mixing green and blue, and magenta by mixing red and blue (see Table 1).

When a normal scene is scanned by

the camera the output signals from the three tubes will vary continuously as the colour and brightness content of the scene changes. The three combined signals produce the Y signal which (as explained last month) contains the high definition detail of the picture.

Since only two colour signals will be transmitted, together with the luminance signal, all three colour signals, together with the Y signal are fed into a matrix circuit to obtain the desired signals. However, before being matrixed, the signals must be *gamma corrected* (see Fig.3)

Gamma correction

When the input signal to the television receiver cathode ray tube increases, the light from the screen does not increase in direct proportion. As an example, if the signal voltage input to the picture tube doubles, the light output from the screen phosphors increases by approximately four times. So the picture tube is not linear and the camera output needs to be modified to compensate for it.

Gamma correction circuitry in the form of a non-linear amplifier is used to over-

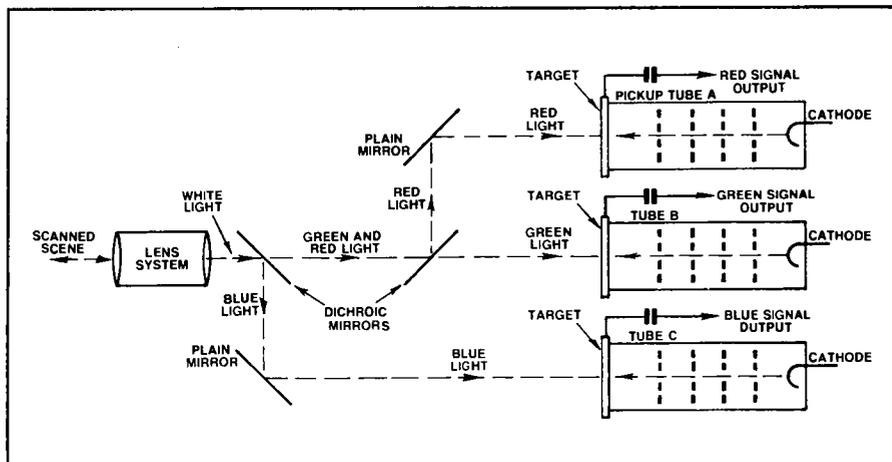
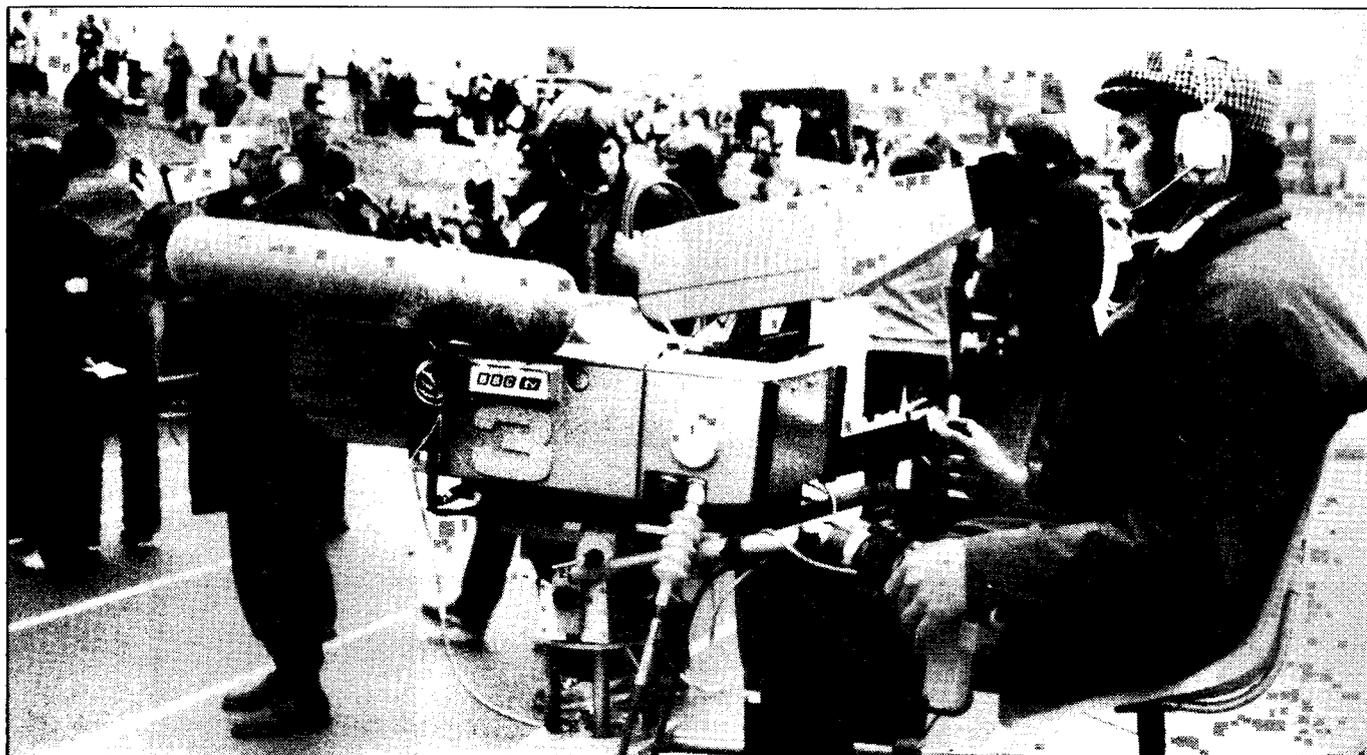


Fig.1: Basic principle of the three tube colour TV camera. Red light falls on pickup tube A, green on pickup tube B, and blue on pickup tube C.



A Philips LDK5 colour TV camera in use by a BBC London Outside Broadcast crew. (Photo courtesy BBC, London).

come this problem. This is interposed between the television camera, and what is known as the matrix circuitry. The non-linear amplifier compresses the signals non-linearly to compensate for the non-linear television receiver picture

tube characteristics. Gamma corrected signals are indicated with an apostrophe, so that for example, E'_Y gamma corrected is shown as E'_Y .

Matrixing the signals

Fig.3 shows a simplified diagram of a matrix network. The E'_R , E'_G and E'_B signals all go via resistors R1, R2 and R3, to form the E'_Y signal. Amplifier A inverts the E'_Y signal to produce a $-E'_Y$ signal. The E'_R and E'_B signals then have the $-E'_Y$ signal subtracted from them to produce two different signals, $(E'_R - E'_Y)$ and $(E'_B - E'_Y)$, which are usually referred to as the (R-Y) and (B-Y) colour difference signals.

Notice that the signal at output (1) is 0.877 multiplied by the (R-Y) signal, and the signal at output (2) is 0.493 multiplied by (B-Y). This 'weighting' of the colour signals is necessary to prevent overloading the transmitter. Without weighting, the peak colour signals would exceed 100% modulation and cause distortion (Fig.8).

The weighted (R-Y) signal now be-

comes the PAL V signal, and the (B-Y) the U signal. Because the (G-Y) colour difference signal is recovered at the television receiver, only the U and the V colour difference signals, together with the Y signal are transmitted.

The PAL transmitter

The U and V signals feed through low pass filter stages A and B to the modulator stages (see Fig.4). The subcarrier generator has a precise frequency of 4.43361875MHz.

This 4.43MHz signal must be modulated by both the U and V signals to produce a single modulated carrier. Furthermore, the colour information must not interfere with the monochrome signal.

The output signal from the 4.43MHz oscillator is taken directly to modulator B to be modulated by the U colour difference signal. However, the 4.43-MHz signal is not taken directly to modulator A, but passes through circuitry which changes the phase by 90 degrees. This 90 degree phase-shift 4.43MHz signal goes via a PAL switch inverter circuit which switches the 4.43MHz signal 180 degrees to coincide with every alternate scanned line of the picture.

Ring modulator

To prevent the colour subcarrier interfering with the monochrome signal, and producing objectionable patterning on

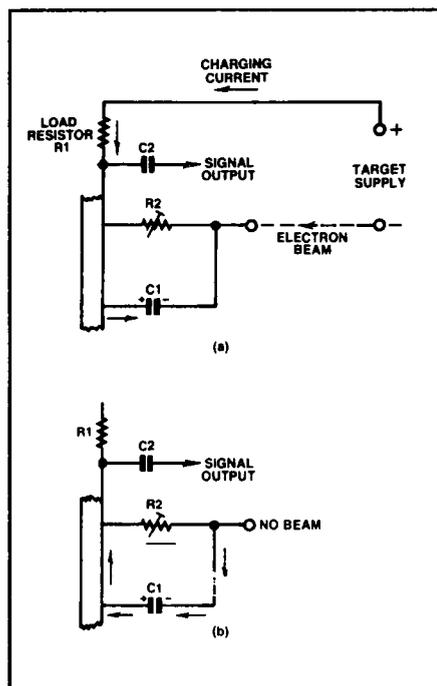


Fig.2: The camera tube can be considered as a capacitor with a high value parallel resistance.

	E_Y	E_R	E_B	E_G
Red	0.30	0.30	0.00	0.00
Blue	0.11	0.00	0.11	0.00
Green	0.59	0.00	0.00	0.59
Yellow	0.89	0.30	0.00	0.59
Cyan	0.70	0.00	0.11	0.59
Magenta	0.41	0.30	0.11	0.00

the received colour picture, *suppressed carrier* modulation is used.

One way to accomplish this is by use of a ring modulator circuit (Fig.5). The circuit is assumed to be perfectly balanced although in practice, preset adjustments are included.

When the 4.43MHz signal is positive-going at connection 'C' of transformer T1, the signal at connection 'E' will be negative going.

This means that only diodes D2 and D1 will conduct, D1 to produce a positive output and D2 a negative output, which exactly cancel each other out. Diodes D3 and D4 will not conduct, therefore no signal appears across connection 'D' and 'Y' or at connections 'X' and 'Z' of transformer T2, and so there will be no subcarrier output.

Similarly, when connection 'C' is negative-going and connection 'E' is positive-going only diodes D3 and D4 produce outputs, again producing opposing voltages at connection 'Z' on transformer T2. As before, no signal appears across 'D' and 'Y', or at connections 'X' and 'Z', and the subcarrier output is zero.

The output remains zero until a 'V' signal input appears at the input terminals. Signal current now flows between connections 'X' and 'Y' and then, in turn, between 'Y' and 'Z' during successive half cycles of the V signal, because the diode outputs no longer cancel each other out. As the current through the primary of T2 changes, suppressed subcarrier output is generated in the secondary winding of T2.

A similar ring modulator handles the U signal. The suppressed carrier outputs from the two ring modulators are combined to form the chrominance signal. Fig.6 compares amplitude modulation with suppressed carrier modulation.

The suppressed carrier outputs of the two ring modulators are combined in the adder circuitry, producing a composite subcarrier containing all the colour information needed for the transmitter.

The voltage amplitude and phase of this composite signal will depend on the relative amplitude voltage of the V and U signals (which always remain 90 degrees out of phase with each other) see Fig.7. This method of modulation is known as quadrature modulation.

You will remember that the phase of the transmitted colour signal determines the hue, and the amplitude of the signal its saturation.

Should the TV signal be distorted for any reason in its transmission path to the receiver, the phase of the colour signal will be changed, and incorrect colours will be displayed.

This occurs in the NTSC system (Fig.7a). This is the reason why, in the PAL system, the 4.43MHz oscillator signal supplied to the modulator handling the V signal is switched 180 degrees on alternate lines of picture signal.

Now if the colour signal received by the viewer suffers phase distortion, the next line with the V signal 180 degrees in opposite phase will correct the error, producing the correct colour (Fig.7b).

The colour burst signal

The colour television receiver must 'decode' the transmitted colour information. To do this the colour subcarrier must be re-inserted, by means of a local 4.43MHz oscillator in the receiver.

This re-inserted 4.43MHz carrier must be exactly locked in phase with the 4.43MHz oscillator at the TV transmitter. To enable the TV's local oscillator to

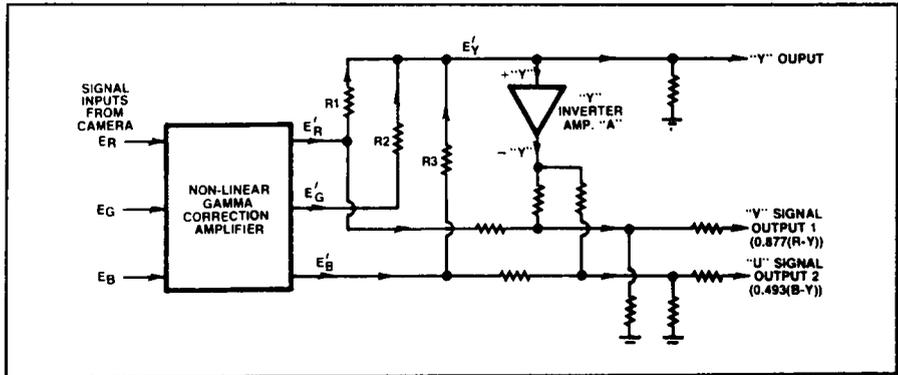


Fig.3: Basic scheme for a matrix network. This is used to produce the weighted (R-Y) and (B-Y) colour difference signals (referred to as the PAL 'V' and 'U')

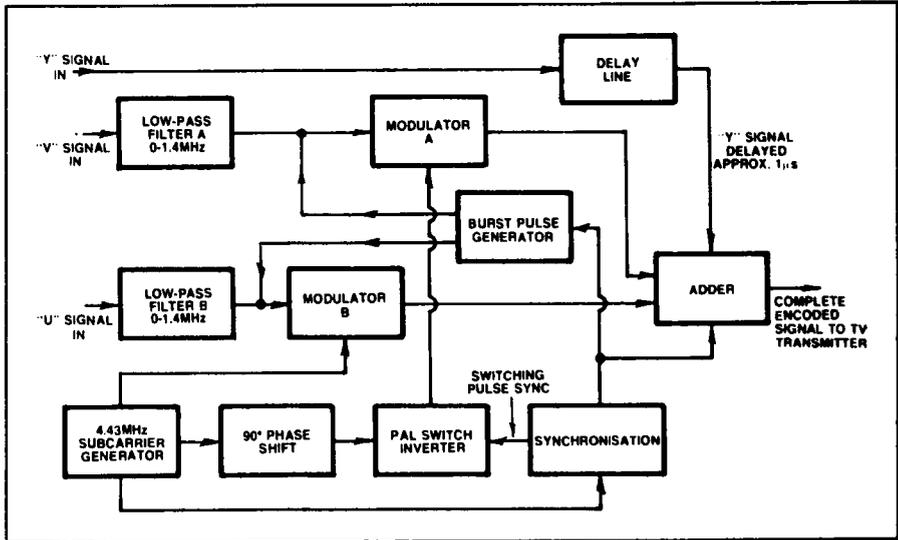


Fig.4: Basic schematic of a PAL modulator.

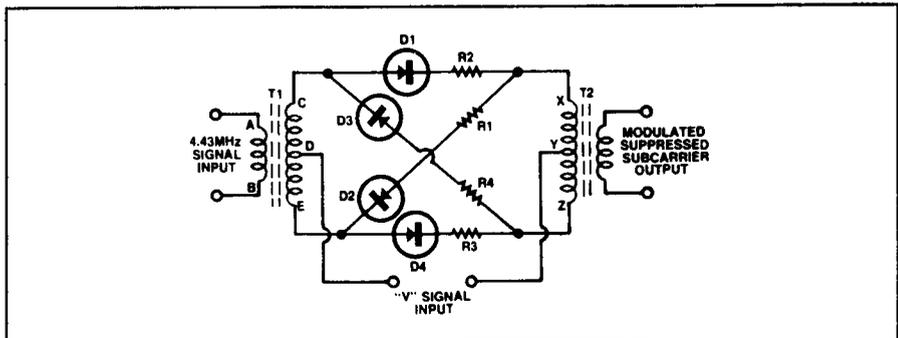


Fig.5: The ring modulator is used to produce suppressed carrier modulation.

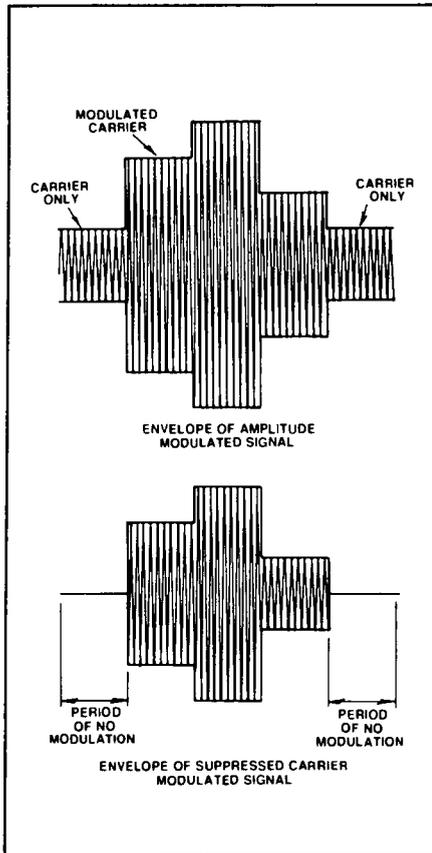


Fig.6: Comparison of amplitude modulation (top) with suppressed carrier modulation (bottom).

do this, 10 cycles of 4.43MHz colour 'burst' information are sent with each line of signal information. This burst sits on the backporch of the line synchronisation pulse. Fig.8 shows one complete line of signal as the camera scans a standard colour bar chart.

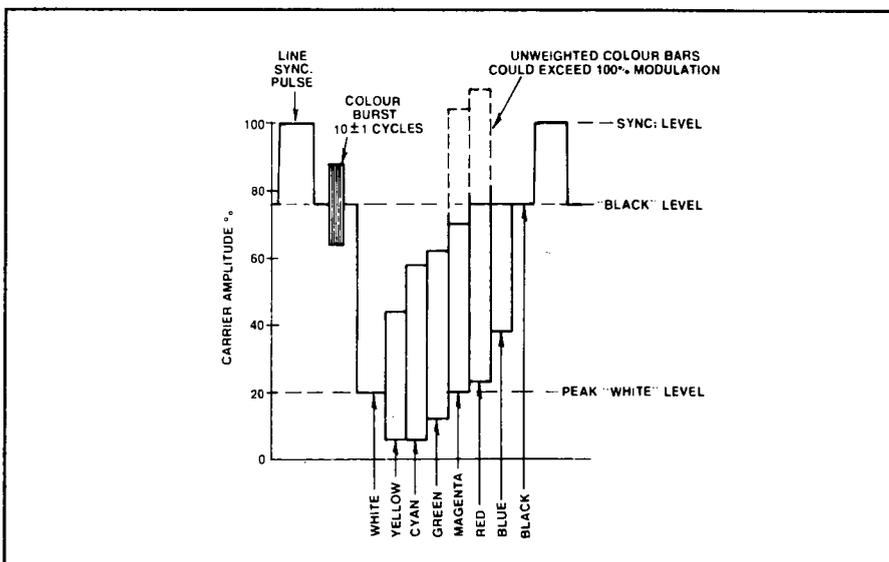


Fig.8: The video signal waveform generated by a standard colour bar chart. Note the colour burst signal on the back porch of the line sync pulse.

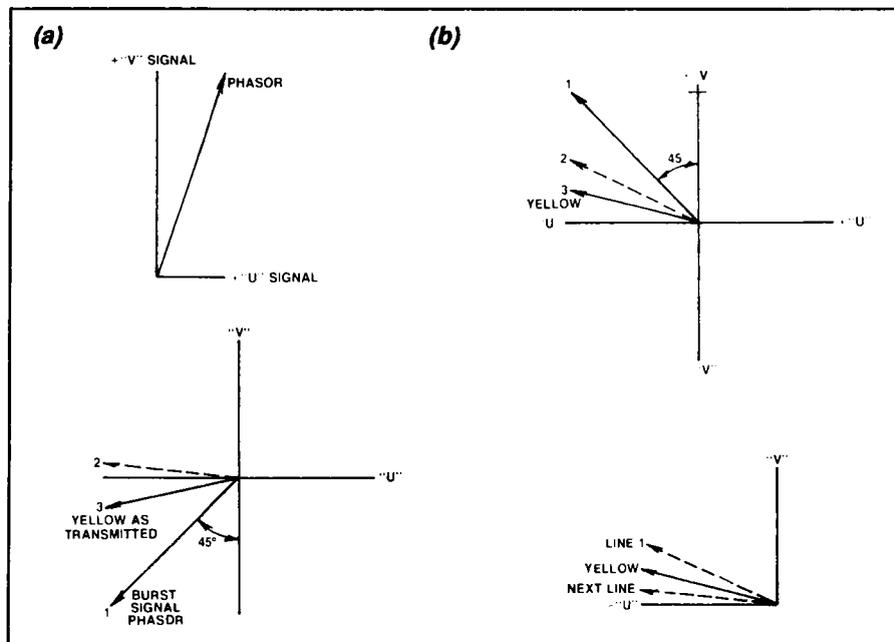


Fig.7a: (Top) The hue of the colour is determined by the relative signal voltages of the 'V' and 'U' signals. The resultant arrow is called a 'phasor'. (Bottom) The arrow (3) indicates a yellow colour while arrow (2) shows the result of phase distortion at the TV receiver due to transmission path problems. Arrow (1) is the burst signal phasor.

Fig.7b: (Top) For the next line, the 'V' signal has been switched by 180 degrees. Compare the received phase distorted signal (2) with (2) in Fig.7a and note that the averaged resultant gives the correct colour. (Bottom) The dotted lines represent the alternate phase distorted signals while the solid line shows the resultant average signal.

The burst signal is referred to as the 'PAL swinging burst' because its phase changes with each transmitted line of picture information by 90 degrees, keeping it in step with the transmitted V signal (Fig.7a and 7b). Notice that the burst vector on the first line is shown 45 degrees

above the -U axis line, and on the next line 45 degrees below the -U axis.

Looking again at the block diagram of the colour section of a PAL transmitter (Fig.4), you will see that the 4.43MHz subcarrier generator signal output also feeds into the sync generator. Sync pulses are supplied from this generator to the adder circuitry and also to the burst pulse generator, which feeds burst signals into the two modulators. A further pulse from the sync generator synchronises the PAL inverter switch.

The Y signal from the matrix circuitry goes via a delay line to the adder circuitry, and arrives at the correct time and phase to fit in with the chroma signals. The complete signal waveform now goes to the transmitter.

Interleaving the signals

One of the requirements of a colour television system is that there be no increase in the station bandwidth of the transmitted signal over that required by the existing monochrome TV stations.

The total bandwidth used by the Australian 625-line transmitters is 7MHz, which includes the sound signal carrier. The high definition Y signal, which you'll recall conveys the black and white detail

of the picture, occupies 5MHz of the signal bandwidth. How then, can we add the colour subcarrier signal without increasing the station bandwidth?

And how do we ensure that viewers with black and white TV receivers can still receive the programs in monochrome?

Fortunately, monochrome signals do not occupy the entire bandwidth of the signal, but occur in clusters of energy at multiples (harmonics) of the line frequency. This is because the monochrome picture is scanned one line at a time, building up the complete picture.

This means that the transmitted colour information can be interleaved between peaks of monochrome energy (Fig.9). The 'distance' between each peak of colour signal energy and the last and next cluster of monochrome signal energy is half the line frequency.

To ensure that the colour signal energy clusters are properly spaced between the monochrome clusters, the frequency of the colour subcarrier must be carefully chosen. For a 625-line system, the line frequency is 15,625Hz and the field rate 50Hz.

The exact value of the colour subcarrier frequency chosen to do this is 4.43361875MHz. This is calculated using the formula:

$$\text{Subcarrier frequency} = 0.5 \times \text{field frequency} + (283.5 + 0.25) \times 15,625\text{Hz.}$$

The complete PAL signal

Our study of the PAL system has shown us that the complete PAL signal includes the Y signal containing the fine detail of the picture.

Then the U and PAL switched V suppressed carrier colour signals, together



RCA's first colour TV receiver, the Victor Model CT100, was produced in 1954. (Photo courtesy RCA Corporation, USA).

with the colour burst signals, are quadrature modulated and combined together with the Y signal in the adding circuitry (Fig.4).

Line and field synchronising signals to 'lock' the transmitted picture, whether in monochrome or colour, plus the neces-

sary blanking pulses are also supplied to the adder circuitry.

The result is a complete video signal, known as an encoded signal, which is sent to the transmitter, and via the transmitter path to the TV viewer's receiver where the received signal is decoded.

The 7MHz TV station bandwidth used in Australia has the frequency modulated sound carrier separated from the vision carrier by 5.5MHz (known as PAL system 'B').

Britain uses a station bandwidth of 8MHz, with the FM sound carrier being separated from the vision carrier by 6MHz (System I). PAL systems 'B' and 'I' both use 625 lines and 50 frames per second.

We have referred to the fact that the 'Y' signal used in colour television is made up of the proportions $Y = 0.59G + 0.30R + 0.11B$.

You will remember these proportions are used because the eye is most sensitive to green light, and more sensitive to red light than blue light. As we will be referring again to this formula you will find it helpful to commit it to memory.

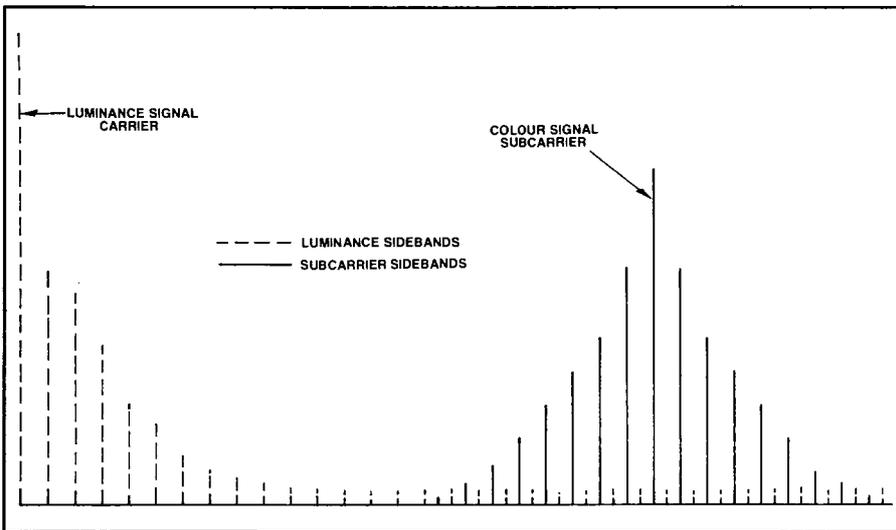


Fig.9: The colour signal's subcarrier sidebands are interleaved with the monochrome signal sidebands.

VIEWING THE RECEIVED PICTURE

Part 4

The shadow-mask picture tube forms the heart of the modern colour TV receiver. Here we examine the basic principles of the shadow mask tube and discuss the problems of purity and convergence adjustment.

Modern colour TV systems make use of the principle of 'mixed highs'. This, you will remember, simply means that the fine detail of the picture is transmitted as a high definition monochrome signal, together with the accompanying colour information at lower frequencies.

The television receiver circuitry then presents the colour display device with a monochrome or Y signal, proportional to the brightness of each point of the scanned scene, plus colour information in the form of varying proportions of red, green and blue colour signals. These signals must then be combined by the display device to produce a colour picture which faithfully reproduces the scene at the TV studio.

The display device must be reasonably compact and not prohibitive in cost. It must also be capable of producing a picture which is free from objectionable flicker and with colours of correct hue and saturation.

In addition, the picture should be easy for a family to view in the lighting conditions of the average home. Finally, it must not demand unacceptably complex circuitry in the television receiver, or require continuous adjustment and setting up for satisfactory results.

Display development

During the development of colour television, many display device ideas were researched and built. Some of these were described in the second article in this series, including the world's first colour television receiver demonstrated by John Logie Baird in 1928. Fig.1 shows his earlier monochrome receiver from which this colour system was developed.

When the British Broadcasting Corporation began to transmit regular colour television programs in 1967, the only

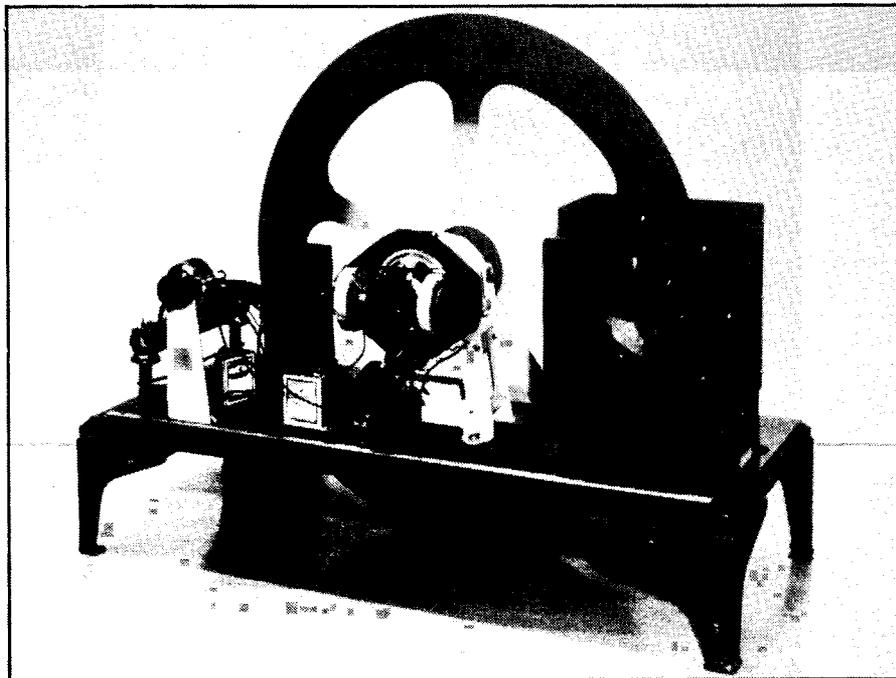


Fig.1: This photograph shows John Logie Baird's scanning disc 'televisor', from which his colour 'televisor' was developed. (Photo courtesy of the Baird Museum and Radio Rentals Limited, Relay House, Swindon).

practical display device for home use was the tri-gun shadow mask cathode ray tube.

The shadow mask tube was invented and developed by Radio Corporation of America, and first demonstrated by that company in 1950. It had the advantage that it could be used with almost any colour television system.

The shadow mask picture tube uses a delta-gun arrangement; so-called because the grouping of the electron guns resembled the Greek letter delta (Fig.2).

Delta-gun tubes are no longer fitted in the latest television receivers, although you'll find them still in use in many older colour TVs. Also, some high-definition computer displays use an advanced

type of delta-formation tube. Almost all modern colour tubes are a development of the delta-gun shadow mask tube developed by RCA. Because of this, we need to understand its basic operating principles.

If you consider Fig.3, the shadow mask tube appears as three tubes in one. Deposited inside the faceplate of the tube are dots of phosphors in triangular groups of three, the whole being coated with a thin film of aluminium which reflects light towards the phosphor material to increase brightness.

Three different kinds of phosphors make up each triangular group, deposited and spaced with precise accuracy. When struck by a beam of electrons, one of the

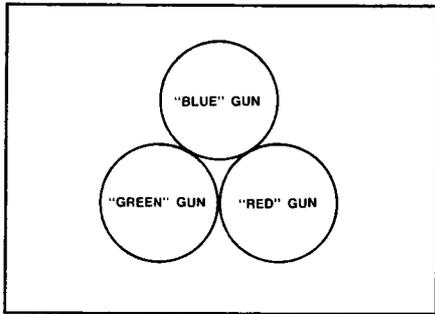


Fig.2: The delta-gun arrangement.

phosphors emits red light, another green light, and the third blue light.

Notice that in Fig.3, the electron guns are labelled Red, Green and Blue.

If we can ensure that the electron beam from the 'red' gun hits the correct phosphor dot in each triangular group, red light will be emitted. The brightness of the emitted light from each phosphor dot will depend on the intensity of the stream of electrons striking it.

In practice, the three electron beams are deflected together, line by line, by the receiver's scanning circuitry. In this manner, they build up a set of horizontal lines known as a raster.

A single visible raster really consists of three separate rasters, one red, one green and one blue. Thus, if switches 'G' and 'B' in Fig.3 were opened, a red raster would be seen. Similarly, if switches 'R' and 'B' were opened and switch 'G' closed, a green raster would be visible. And if 'R' and 'G' were opened and 'B' closed, a blue raster would be visible.

When switches 'R', 'G' and 'B' are all closed, and the intensity of the electron beams from the three guns correctly balanced, a white raster will be seen. This is because the phosphor dots are grouped so closely together that, by additive colour mixing of the red, green and blue primary colours, the eye registers the sensation of white.

To ensure that each electron beam falls on its correct colour emitting phosphor dots, the three gun assemblies are slightly angled towards each other. This means that, with the receiver scanning circuitry disconnected, and the beams stationary, the three electron beams meet (or converge) at a single spot at the middle of the screen.

As each electron beam curves through the scanning coils, it is suddenly deflected at a point called the 'apparent deflection centre' (Fig.4).

The scan coils can be moved up and down the neck of the tube, changing the position of the apparent deflection centre and the position where the beams

meet. In the delta-gun shadow mask tube this is an essential adjustment.

The shadow mask

Just behind the tube face is the shadow mask, a fixed steel plate perforated with tiny holes spaced so that each is exactly in line with the centre of one of the triangular phosphor groups.

The shadow mask fitted in a 63cm tube has about 400,000 of these perforations. As the three electron beams are deflected by the scanning circuitry, they converge together at the shadow mask holes (Fig.5a).

Fig.5b shows how the electron beams are reduced in size by the shadow mask. The phosphor dots are placed very close to each other, each individual dot having a diameter of 0.25mm. There are three of these dots (one red, one green and one blue), for each individual hole in the shadow mask, giving a total of over one million dots.

The function of the shadow mask is to prevent each separate beam of electrons from 'spilling over' and energising more than one dot. The other two dots in the triangle lie in the shadow of the mask, hence the term 'shadow mask'.

Colour purity

Various adjustments are needed in the television receiver so that the red, green and blue rasters of the delta-gun tube will be in proper registration with each other, appearing to the eye as a single raster. To achieve this it is essential that the red

raster is pure red, the blue raster pure blue, and the green raster, pure green.

This means that the three electron beams must be deflected at their correct apparent deflection centres and pass through the holes in the shadow mask perforations to strike the proper 'colour' phosphor dots.

Due to small manufacturing production differences in individual picture tubes, compensating adjustments are needed. These colour correction adjustments are usually referred to as *purity* adjustments.

If you look again at Fig.4 you'll notice on the neck of the tube the purity magnet assembly, which consists of two magnetised rings which can be independently rotated. These produce a weak magnetic field that can be altered in strength and direction to bend the three electron beams together so that they pass through the correct perforations in the metal shadow mask.

Even so, some phosphor dots of the wrong colour may still be energised at the edge of the screen, this time due to manufacturing variations in the scanning deflection coils etc. When this occurs, the scanning coils can be moved up and down the tube neck to obtain correct purity at the edges of the picture.

Before adjusting the purity, the green and blue electron guns are first switched off. Adjustment of the purity magnets and scanning coils is then repeated several times until the purest possible red raster is obtained. When the blue and green rasters are subsequently viewed

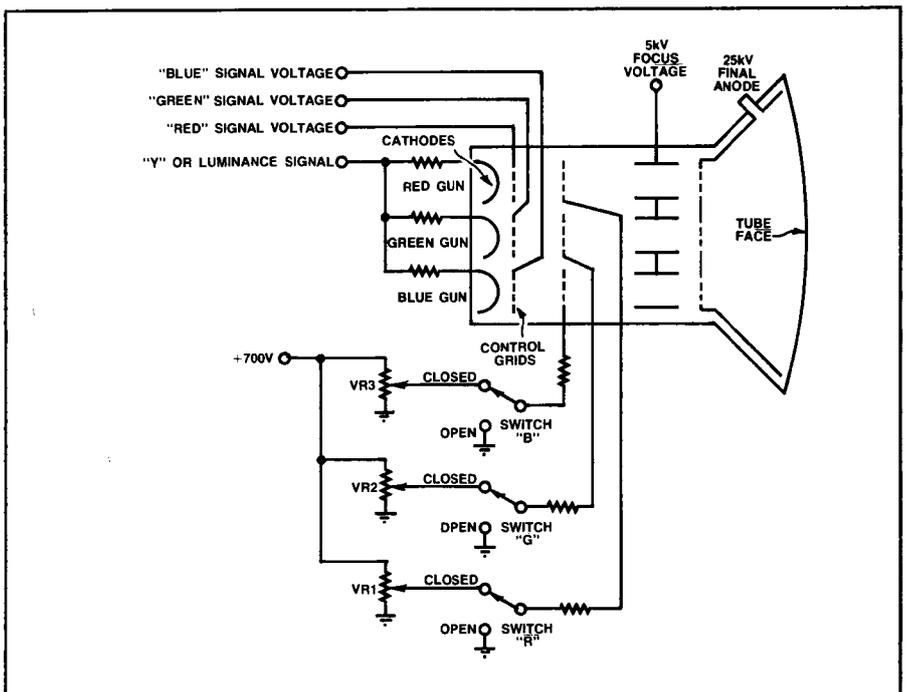


Fig.3: Basic schematic of the shadow mask picture tube.

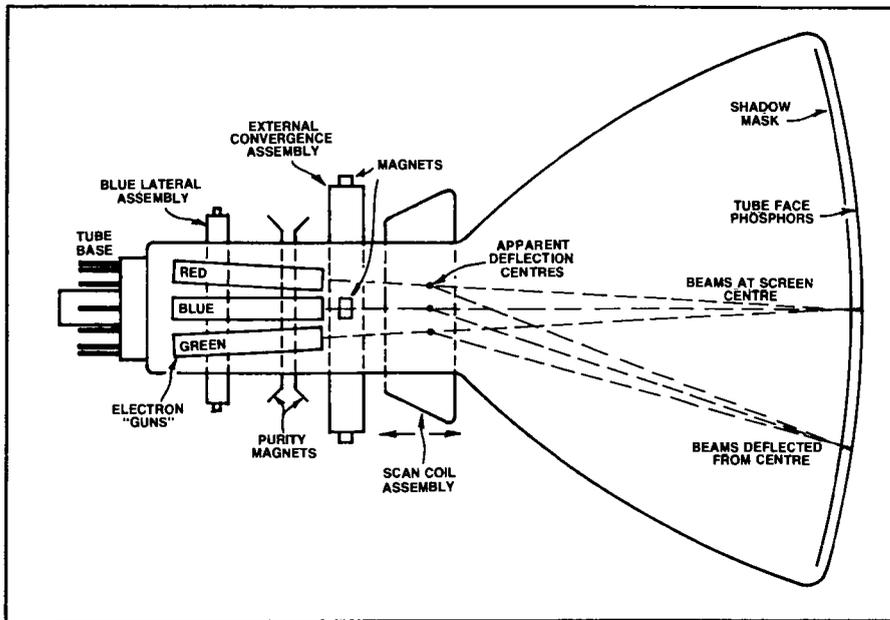


Fig. 4: Basic arrangement of the shadow mask picture tube showing the electron guns and the external convergence assembly. The shadow mask is positioned just behind the faceplate.

separately, they should also now be pure in colour.

That is not the end of the story, however. Although the three rasters may now be pure in colour, the three electron beams may not necessarily enter the same perforations in the shadow mask as they scan across the picture tube. The result is a picture with colour fringes, or even three separate pictures not in registration with each other.

To correct this condition, a *convergence* assembly containing three adjustable permanent magnets, together with coils energised by electrical currents derived from the television receiver circuitry, is fixed on the neck of the picture tube.

Inside the tube are pole pieces through which the three electron beams pass.

Each of the three adjustable permanent magnets act on one set of pole pieces in the picture tube. By adjusting the magnets the individual beams can be moved, as shown in Fig. 6.

Mounted on the tube neck, between the purity magnets and the picture tube base, is the blue lateral magnet. This adjustable magnet moves the blue electron beam horizontally, to the point where the red and blue beams cross.

These static magnetic adjustments control convergence at the centre of the picture so that the three rasters merge as one.

However, because the electron beams are deflected both horizontally and vertically by circuitry in the colour television receiver, misconvergence will still be seen at the top, bottom and sides of the

picture. To correct this condition, *dynamic convergence* adjustments are provided, which control currents passed through the coils in the convergence assembly. More about this in a later part.

Another source of colour problems is the shadow mask itself. Because it is made of steel, it can become magnetised and ruin the purity of the picture by producing patches of incorrect colour on the screen.

To prevent this, a magnetic shield containing a coil is fitted on the outside of the cone of the picture tube.

This coil is known as a *degaussing coil*. It is arranged so that, whenever the receiver is switched on, an alternating current at mains frequency passes through the coil for a short period of time.

The resulting alternating magnetic field produced by the coil demagnetises (or degausses) the metal shadow mask. The current then gradually dies away.

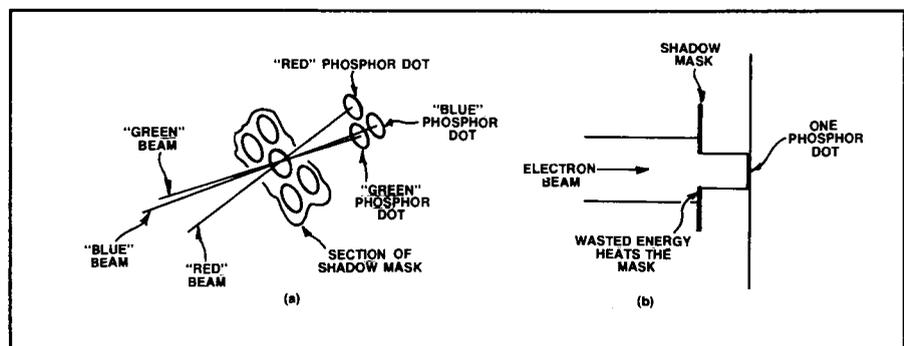


Fig. 5: The shadow mask ensures that the electron beams hit the correct phosphor dots.

The colour picture

The three preset controls, VR1, VR2 and VR3 shown in Fig. 3, can be adjusted to control the relative intensities of the red, green and blue electron beams so that the eye sees a white raster at maximum brightness.

The Y or luminance signal is supplied to the three cathodes of the shadow mask picture tube by the receiver circuitry.

Thus, the intensity of all three beams at each point on the tube raster is controlled by the received brightness signal from the TV studio camera via the television transmitter, transmission path and TV receiver.

Because the receiver raster scanning is synchronised with the camera scan, a black and white picture will be seen in the case of a monochrome transmission.

When a colour broadcast is received, the detail or brightness signal is produced as for a monochrome transmission.

In addition, signal voltages proportional to the red, blue and green colouring are applied individually to the three control grids of the picture tubes, thus decreasing or increasing the brightness of each of the three electron beams.

If we view a discrete area in the picture which is pure green, the red and blue electron beams will be completely cut off in that area of the scan.

As varying intensities of the beams occur according to the received colour signals, mixtures of red, blue and green are produced so that the viewer sees a wide range of colours. Because these colour areas and the detail of the luminance signal are combined, a complete colour picture is produced.

This method of driving the colour picture tube is known as *colour difference drive* and was used in early colour receivers.

Practically all modern receivers use *RGB drive*. With RGB drive, the luminance signal drives all three cathodes

as the colour difference drive method. However, the three signal voltages proportional to the red, blue and green colouring of the picture are supplied, not to the control grids of the tube, but individually to each cathode.

Brightness variations still produce the detail of the picture, but the red, blue and green signal voltages now control the relative values of the cathode voltages, varying the relative intensities of the three electron beams. As in the colour difference drive method, a mixture of red, blue and green hues combined with the monochrome signal produce the complete colour picture.

Drawbacks

Although the delta-gun shadow mask tube is capable of displaying excellent monochrome and colour pictures, it does have drawbacks. Look again at Fig.5b and you will see that the shadow mask absorbs a great deal of energy as the electron beams strike it — energy which is wasted in heating up the metal of the mask.

After a period of use this heating effect may cause the shadow mask plate to warp, or even to become loose, making it impossible to obtain correct purity.

Another problem is caused by the shadow mask. It reduces the size of the electron beams and so the picture brightness is also reduced. To overcome this problem, an extra high tension supply (EHT) of 25 kilovolts is required for the final anode of a 63cm picture tube.

This accelerates the electron beams to a velocity of 321,800 kilometres per hour, with a maximum beam current of one milliamp.

This high voltage makes the electron beams more difficult to deflect, so that

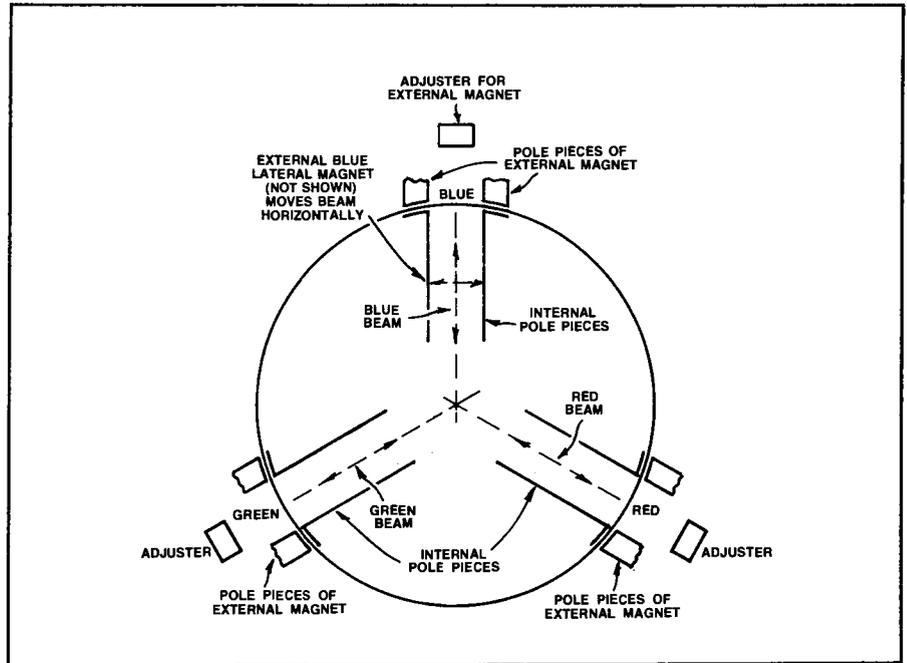


Fig.6: Convergence of the red, green and blue rasters at the centre of the screen is achieved by adjusting the external magnet assemblies.

increased energy must be supplied to the scan coils.

An electrical shock from this EHT supply is very dangerous and could prove fatal. This is so even after the colour TV receiver is switched off, because the internal capacitance of the shadow mask tube may retain a high voltage charge for a considerable period of time. A further problem is that, after some use, the complex purity and convergence adjustments tend to drift and must be reset.

Since the invention of the original shadow mask tube, several new types of picture tubes have been developed. Let's take a quick look at how they operate.

The Trinitron

Sony Corporation's Trinitron tube was first produced in 1968 and has been improved over the years. It employs a single in-line gun that emits three electron beams, each beam being emitted from its own individual cathode. Fig.7 shows the basic arrangement of Sony's latest Trinitron tube (using their new PanFocus Gun). RGB drive circuitry is employed.

Because a single gun is used, a much smaller and sharper spot size is possible, giving greatly improved resolution. And instead of a shadow mask having thousands of circular perforations, Sony use a special 'aperture grille' system.

The use of this grille results in a much brighter picture. As in the shadow mask tube three kinds of phosphor are deposited inside the tube faceplate. However, in the Trinitron tube, these are arranged, not as triangular dot groups, but as vertical colour stripes.

Further advantages of the Trinitron picture tube are excellent purity and convergence without the need for the complex adjustments required by the shadow mask tube. Static convergence controls move the two outside electron beams to meet the middle beam, then simple dynamic adjustments are made.

In-line tubes

This type of tube has three electron guns but, instead of being arranged in delta formation, they are arranged in a

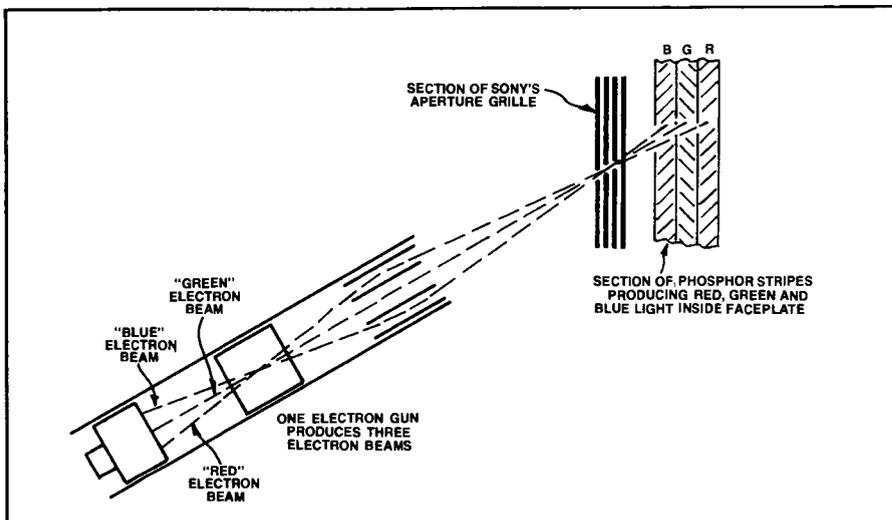


Fig.7: Basic arrangement of the Sony Trinitron tube.

horizontal in-line configuration. The tube neck is fitted with specially designed deflection coils, while the shadow mask uses slotted holes. The colour phosphors inside the faceplate are in stripe formation.

This type of tube is capable of producing a brighter picture than the older delta-gun configuration, due to the slotted shadow mask which blocks less of the electron beams. Because of this, some type of slotted shadow mask is now used in most modern colour TV tubes. The main exception is, of course, the Sony Trinitron tube.

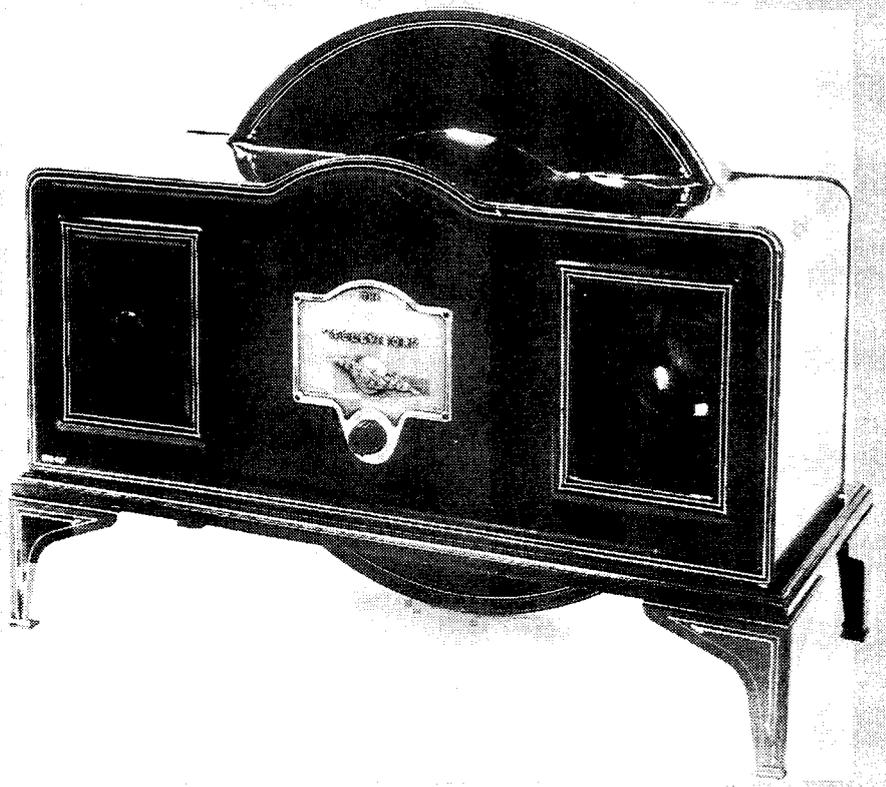
One modern tube, the Philips 20AX, uses three in-line electron guns, is made to extremely accurate tolerances, and requires only minor convergence adjustments. But even these adjustments are unnecessary with the Philips 30AX tube, which features specially designed self locating scan coils, and internal factory set magnets fitted within the tube.

The very latest development is the FST tube. It features a virtually flat tube face constructed of extra thick glass, and has much squarer corners than conventional tubes. It also uses in-line guns, the exception being the latest Mullard/Philips 45AX version which has a three-beam single gun.

Projection TV

To obtain large size pictures, projection television systems are used. In these, three special projection picture tubes, each with a different colour face phosphor, and operated at very high final anode voltages, are fitted. The red, green and blue colour signal voltages, together with the luminance signal, are fed separately to each tube.

The three pictures are combined optically and the resulting colour picture is projected onto a screen. Customer preferred screen sizes are 90 to 94 centimetres (measured diagonally). It is best to view the picture in subdued room lighting due to inherent brightness limitations.



Just for the record, here's what the Baird Televisor looked like when enclosed in its case. The picture was viewed through the small rectangular window on the right hand side.

Liquid crystal displays

A liquid crystal display, as used in a watch or calculator etc., contains so-called nematic liquids which are normally transparent. When subjected to an electric field, however, they become opaque.

To construct a liquid crystal display that will produce a television picture, a screen containing thousands of tiny liquid crystal elements is used.

The received luminance signal controls the brightness of each point of the display so that a monochrome picture can be viewed.

You have probably seen, or may own, a pocket monochrome TV set featuring a

liquid crystal display. External lighting or a back light is needed to see the picture. Large sums of money are at present being invested by television manufacturing companies to try to produce a practical large flat colour display suitable for use in TV receivers.

Fitting different colour filters over each tiny crystal of an LCD display is a future possibility. By this means, variations in brightness and colour intensity between the tiny picture elements would cause the eye to see a colour picture.

Another method is to use combinations of LCDs, each display producing one of the primary colours. Projection TV using this idea is under development.

THE COLOUR DECODER - 1

Part 5

By far the most complicated part of a modern colour TV receiver is the colour decoder. Here we examine how the decoder circuit works and discuss how the various signals are derived.

In Part 3, we saw that the transmitted TV signal contains:

- the monochrome signal carrying the fine detail of the picture;
- the colour information consisting of U and PAL switched V suppressed carrier signals;
- the 'swinging burst' colour synchronisation signal;
- the line and field synchronising pulses needed to keep the receiver's raster in step with the camera scan; and
- the frequency modulated sound signal.

Since all the colour information is encoded before transmission, it must be decoded after demodulation by the receiver's video detector, so that these various signals can be applied to the correct sections of the receiver.

The colour bar signal

A standard colour bar signal produces a pattern of vertical bars on the screen of a colour television receiver. Viewed from left to right, the bars are white, yellow, cyan, green, magenta, red and blue (Fig.1). Notice that yellow, cyan

and magenta are produced by additive colour mixing.

This colour bar signal may be transmitted by the TV station or produced by a colour bar generator and fed into the receiver antenna socket. When an oscilloscope is connected to various points in the colour receiver, the various waveforms can be easily identified. This makes the colour bar signal very useful in the study (and servicing) of a colour TV receiver.

Fig.2 shows one line of a monochrome television picture, while Fig.3(a) shows a complete colour bar waveform where the signal is at 100% amplitude and with 100% colour saturation.

Fig.3(b) shows the colour bar signal as transmitted by the British Broadcasting Corporation at 100% amplitude and 95% colour saturation.

Fig.3(c) is the colour bar signal as defined by EBU standards for Europe with 75% amplitude and 100% colour saturation.

Notice how the ten-cycle colour burst signal sits on the 'back porch' of the line synchronising pulse.

To prevent the colour subcarrier interfering with the luminance signal and producing objectionable patterning on

the received colour picture, suppressed carrier modulation is used at the TV transmitter. The colour information of the transmitted program is then sent in the form of sidebands only (see part 3).

Thus, in the colour TV receiver, it is necessary to replace the missing carrier so that the original amplitude modulated colour signals can be recovered.

The colour decoder

Fig.4 shows a block diagram of a typical colour decoder. The decoder circuitry separates the various parts of the complete signal and demodulates the U and V colour signals.

You will remember that the U signal contains the (B-Y) colour information, and the V signal the (R-Y) information.

In Fig.4, point 'A' is where the signal from the video detector enters the decoder. If we tuned the TV receiver to a colour bar transmission, an oscilloscope connected to 'A' via a 10:1 isolating probe would display the complete colour bar signal.

From point 'A', the signal travels through a bandpass filter which removes the luminance signal, allowing only the chrominance information and burst signal

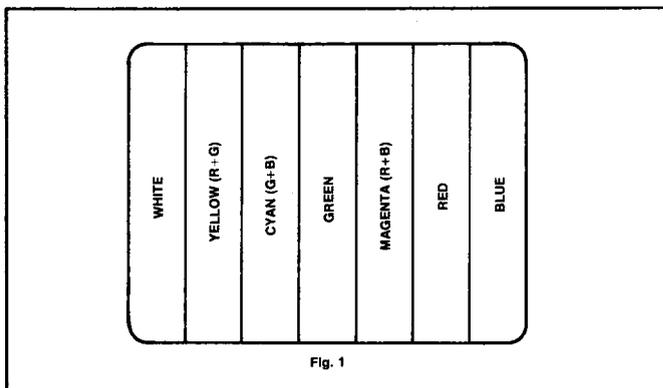


Fig. 1

Fig.1 shows the standard colour bar signals as displayed on the TV screen.

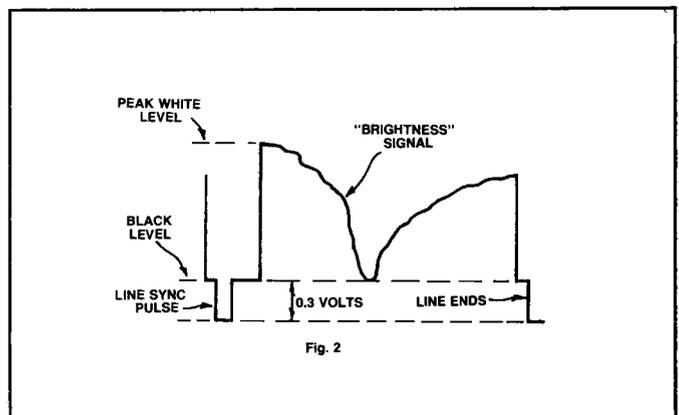


Fig. 2

Fig.2 shows one line of a monochrome video signal.

to pass. At point 'B', the signal appears as in Fig.5(a).

The following chrominance amplifier supplies the signal to a burst blanking circuit, which is controlled by pulses from the line time-base circuitry. This removes the 'swinging burst' signal so that the signal at point (c) appears as in Fig.5(b).

Because of the way it looks, this signal is often referred to as a 'cotton reel' waveform. Two detector circuits are needed, one to demodulate the V signal while the other demodulates the U signal.

From point 'C', the signal is fed to the PAL delay line and to the adder and subtractor circuits. The output from the adder circuit is the U signal, while the output from the subtractor is the V signal. Fig.6 shows the basics of the PAL glass delay line. The incoming electronic signal is first fed to a transducer which converts it to an ultrasonic wave. This wave is then detected by a second transducer and converted back to electronic form.

Because ultrasonic signals take time to travel through the glass, this gives rise to a delay time. In a PAL colour TV receiver, the delay line is manufactured to extremely tight tolerances to give a delay time of 63.943 microseconds.

Fig.7(a) shows the delay line and adder and subtractor circuitry of a typical commercial colour TV set.

Suppose that two lines of chroma information arrive at 'C' (Fig.4), each line possessing the same hue and saturation. The first line, which we'll call F1, is amplified by transistor Q1 and goes through the delay line, and emerges 64 microseconds later across coil L.

This means that the signals at points 'X' and 'Y' will be of equal voltage, but of opposite phase. The next line of chroma information, which we will refer to as F2, arrives directly at point 'Z' at exactly the same time as line F1. Thus lines F1 and F2 arrive together at coil L.

At point x on L, the plus and minus U signals will cancel out and the two minus V signals will add together, to produce a signal voltage of -2V (Fig.7(b)). At the bottom of coil L, the plus and minus V signals will cancel out, and the two U signals added to produce a voltage of +2U.

When the next line of signal arrives (line F3), line two will have passed through the delay line, and line F3 will arrive direct. The result will be as in Fig.7(c).

The U voltages will again cancel out, and the V voltages will add to give +2V. At the bottom of coil L, the V voltages will cancel and +2U will be produced. In any two lines, hue errors will occur in opposite phase directions. Because chroma errors will be a product of

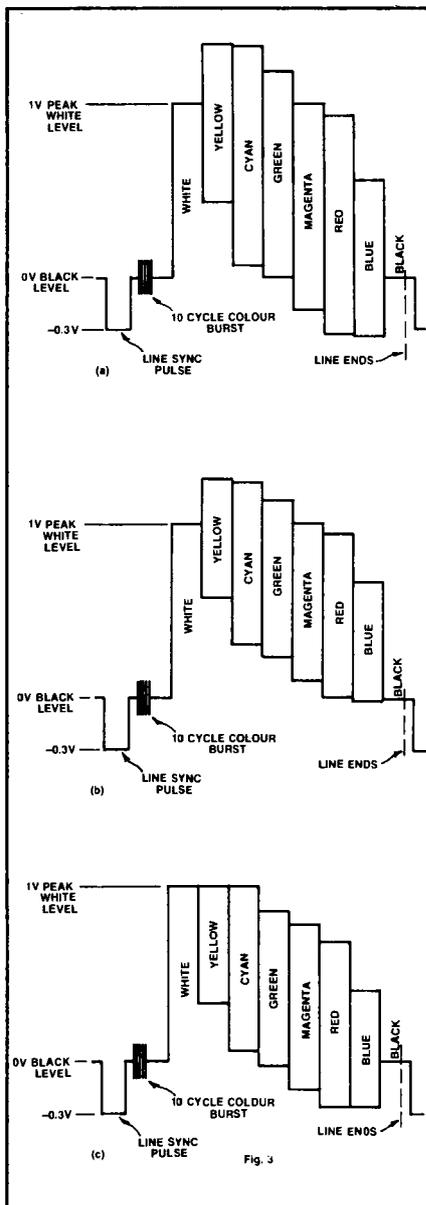


Fig.3: These diagrams show complete colour bar waveforms for varying amounts of amplitude and colour saturation (see text). Note the 10-cycle colour burst signal on the back porch of the line synchronising pulse.

two lines, the errors will cancel and the correct hue will be produced.

Similarly, because the 'burst' signal switches 45 degrees above and below the -U axis every other line (Fig.8), burst errors due to transmission errors will tend to cancel. We will see the reason for this when we discuss subcarrier recovery.

Note that the outputs at the top of coil L are V signals only, and those at the bottom of coil L are U signals only. So the PAL delay line and the adder and subtractor circuitry have separated the U and V signals.

VR1 in Fig.7(a) adjusts the gain of transistor Q1. Together with the preset

phase adjustment, this allows compensation to be made for any delay line and circuit variations.

The signals at F and G in Fig.4 now appear as in Fig.5(d). These U and V chroma subcarriers have a 90 degree phase difference between them and must be separately demodulated. However, before discussing how this is done we first need to know how the colour burst signal is used.

Separating the burst signal

The output of the chrominance amplifier, consisting of the chroma signal and the colour burst, is also applied to the burst gate and amplifier circuitry (Fig.4). A pulse from the line timebase circuitry controls (or gates) this amplifier, allowing it to operate only for the duration of the ten-cycle colour burst signal.

The amplified burst signal emerges at 'E'. It is then applied to the following phase detector stage, where it is compared in phase with the TV receiver 4.43MHz subcarrier oscillator.

This 4.43MHz crystal controlled oscillator is used to replace the missing subcarrier. While some texts refer to this as 're-inserting' the carrier, it is more accurate to say that the output generated by the receiver subcarrier oscillator is modulated by the U and V colour sidebands.

The resulting signals are then demodulated to reproduce the required colour signals. As shown in Fig.4, an automatic phase control (APC) loop signal is fed back to the phase detector. Fig.10(a) shows the basic circuit.

The colour burst signal is applied to connections '1' and '2' of transformer T. The signals on the secondary winding at points '3' and '4' are 180 degrees out of phase with each other.

Thus, current will flow through the diodes only during positive half cycles at position '3' and negative half cycles at position '4'. The output from the local 4.43MHz oscillator is applied to point '5'.

You will see from Fig.10(b) that the local oscillator sine wave output passes through its zero position at the peaks of the burst signal.

This can only happen when the phase of the oscillator 'lags' exactly 90 degrees behind the burst signal. It then follows that, because the diodes are centre connected anode to cathode, there will be no DC output voltage at 'H'.

We know that the colour burst signal swings 45 degrees above and below the -U axis during every other line of picture signal (Fig.8). Thus, the 'mean' or average of the phase of the colour burst signal is on the -U axis. The circuit is so designed that the subcarrier oscillator responds only to this mean value.

The subcarrier oscillator is thus 'locked'

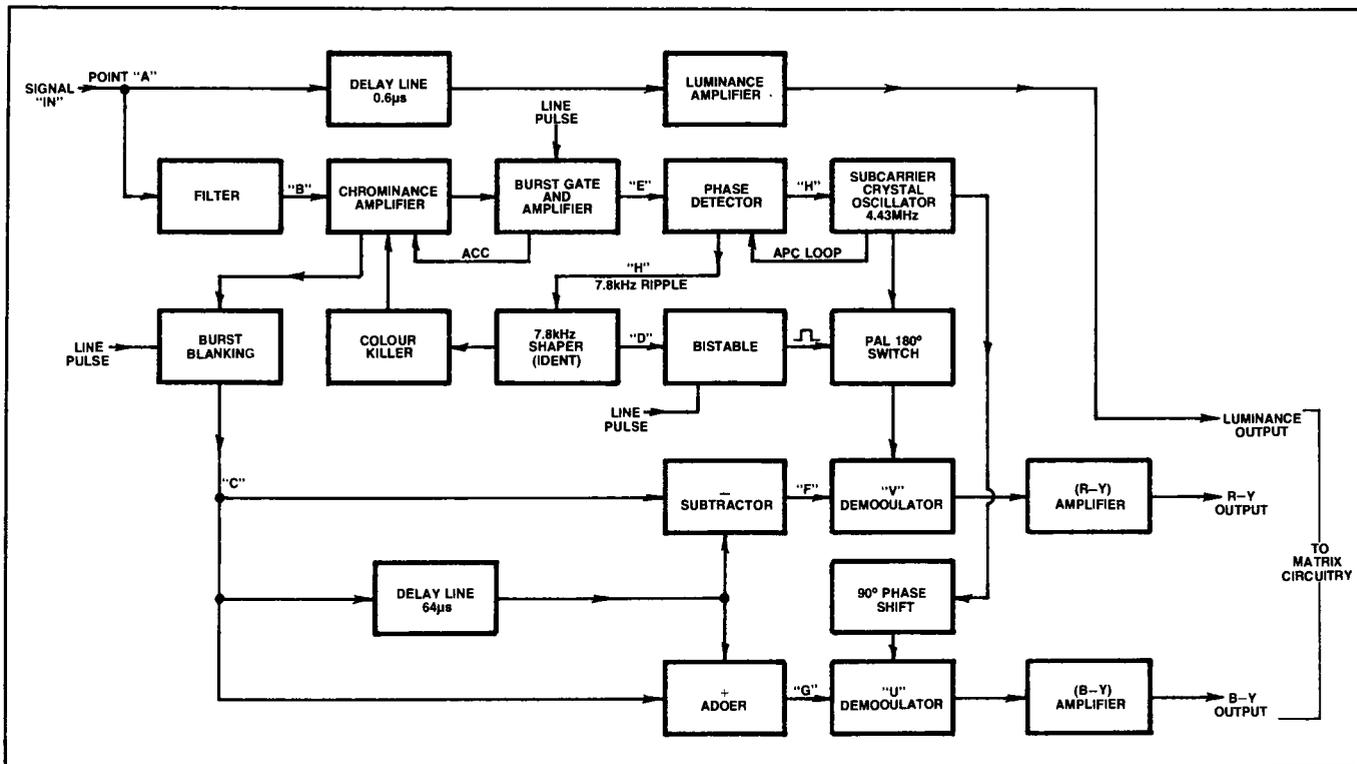


Fig.4: The block diagram of a typical PAL colour decoder. The way in which each block works is explained in the text.

to the same frequency and phase as the +V chroma signal. When the local oscillator 'lags' behind the mean of the burst signal by 90 degrees there will be no DC voltage output at the wiper of present resistor R1 (point 'H'), as stated previously.

However, if the frequency or phase of

the local oscillator changes, the currents flowing through diodes D1 and D2 will no longer be equal, and a positive or negative DC output voltage will be produced at 'H'. This voltage is then applied to the subcarrier oscillator to correct its frequency and phase.

The phase detector produces another

useful signal. As the burst signal swings above and below the -U axis, a 'half line frequency' (7812.5kHz) pulse is produced. This pulse is amplified and shaped to synchronise the PAL switch (see Figs.4, 5e and 5f).

Some early model colour TV receivers did not contain a 4.43MHz crystal oscillator. Instead, the colour burst signal was amplified and used to energise a 'ringing coil' circuit. The resulting 4.43MHz signal was then used instead of a conventional crystal oscillator, but the decoder adjustments were quite critical in such sets.

You'll find that many of the latest PAL receivers contain subcarrier oscillators controlled by an 8.867MHz crystal. This arrangement is becoming increasingly popular with manufacturers. Why and how the 8.8MHz oscillator is used will be discussed in a later part.

Demodulating the U and V signals

Fig.9(a) shows the circuit of a popular type of synchronous demodulator. The signal from the TV's 4.43MHz subcarrier oscillator passes through R1 and R2 to points 'X' and 'Y'.

The values of the components are selected so that when X approaches its positive peak and Y its negative peak, the diodes conduct.

It is only during this period of time that there is a path for the chrominance signal from point 'P' and the output. In

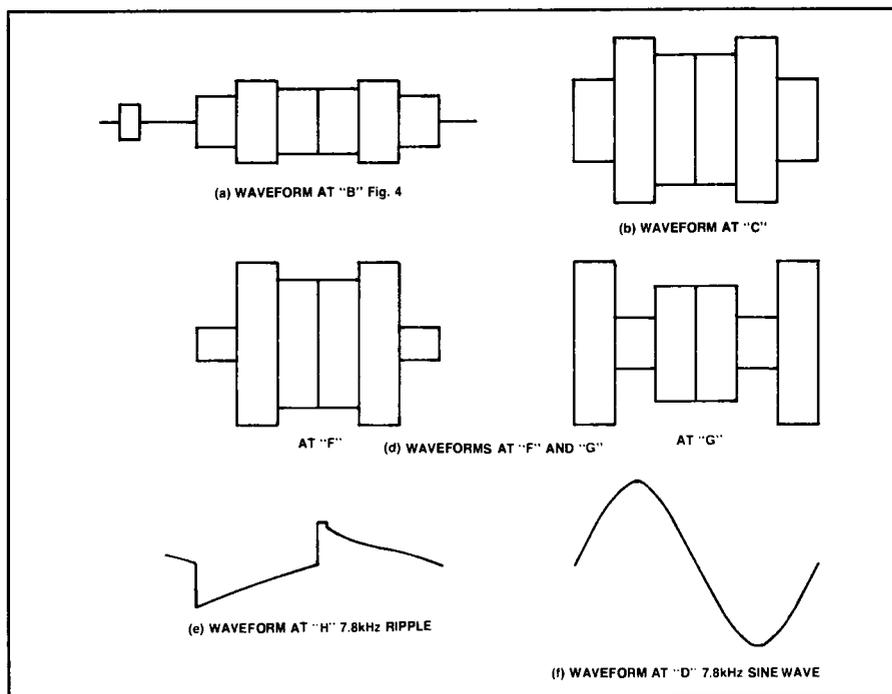


Fig.5: These diagrams show the waveforms at various points on Fig.4 (see text).

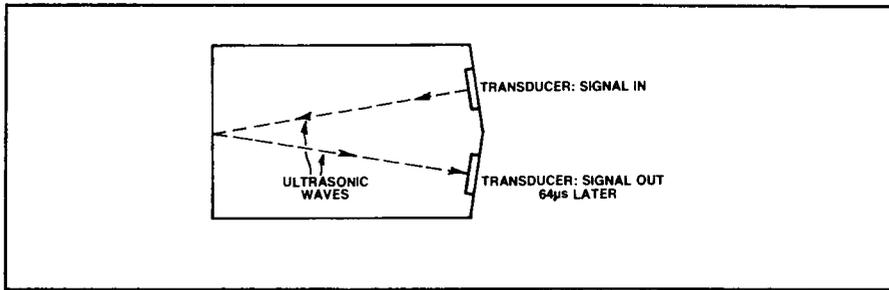


Fig.6: The basic scheme for a PAL glass delay line. The output signal emerges 64µs after the input signal.

Fig.9(b), the dotted line represents the waveform of the transmitted signal, and the solid line as it actually appears at point 'P'. The subcarrier frequency is of course 4.43MHz, but for simplicity is shown as just a few cycles.

Fig.9(c) shows the locally generated subcarrier, the solid portions of the line representing the periods when the diodes conduct.

Look carefully at the diagrams and you will see that, during period 'A', the positive peaks of the subcarrier occur at exactly the same time as the positive peaks of the chroma signal.

However, during period 'B' the phase of the incoming chroma signal changes by 180 degrees. Now the negative peaks of the chroma signal occur at the same time as the positive peaks of the local subcarrier.

The result is that, during period 'A',

the positive half cycles of the chroma signal are demodulated. Similarly, during period 'B', the negative half-cycles are demodulated.

Fig.9(d) depicts the resulting output waveform at 'Q'. The solid line across the signal peaks shows the output signal after filtering by choke L1 and capacitors C1 and C2. If the local oscillator signal is not in correct phase with the chroma carrier, the signal output at 'Q' will only be a slight ripple.

The filter stage then removes this ripple so there is no output signal. If, in Fig. 9(a), diodes D2 and D3 are replaced by suitable resistors, the circuit will still work and this configuration is in fact commonly used.

The two synchronous demodulators used in the colour receiver for demodulation of the U and V signals are usually identical.

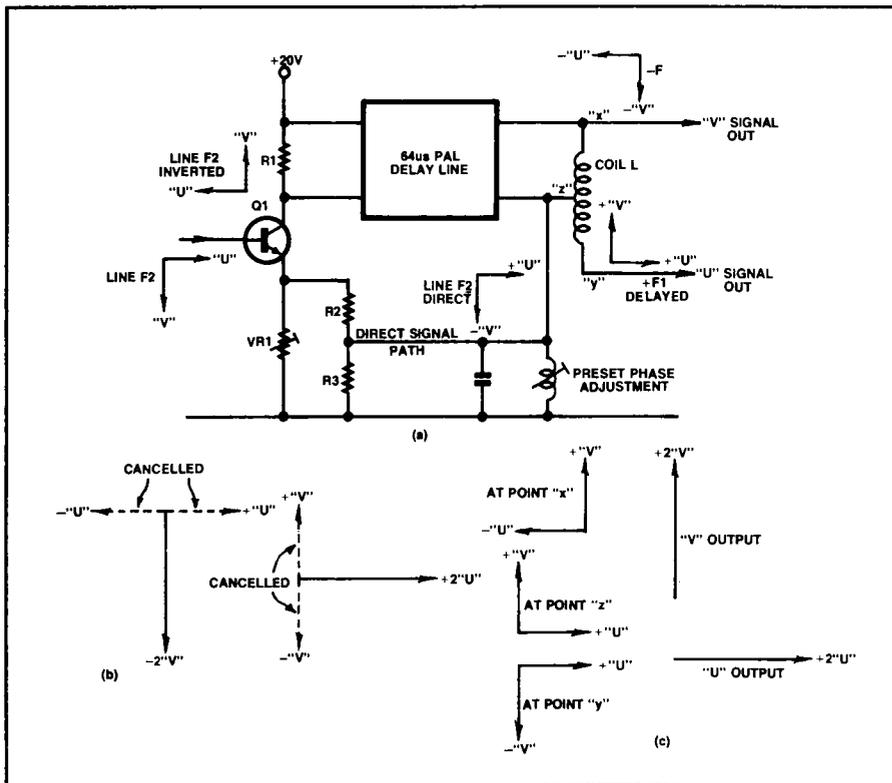


Fig.7: The delay line and adder and subtractor circuitry of a PAL colour TV set.

Synchronising the PAL switch

There is a phase difference of 90 degrees between the transmitted V and U colour signals. For this reason, the output from the crystal controlled oscillator is phase shifted by 90 degrees before it is fed to the U synchronous demodulator (Fig.4).

In addition, a signal is also fed from the subcarrier oscillator to the V synchronous demodulator via the 180 degree PAL switch.

The PAL switch must be properly synchronised to ensure that the subcarrier fed to the V detector is correctly 'in step' with the transmitted V signal.

You'll remember that the V signal is switched 180 degrees every other line at the TV station. The PAL switch is operated by the application of a square wave from what is called a *bistable* or 'flip-flop' circuit which has two outputs.

A square wave appears at each output in turn every time a switching pulse arrives from the receiver line circuitry. A 'triggering' pulse is required to ensure that the bistable circuit correctly synchronises the receiver PAL switch.

Without this triggering pulse the bistable circuit would still work. However, if the PAL switch is not correctly 'in step' with the switched V signal as received from the TV station, incorrect colour appears in the picture.

For example, if you look at the relative phase angle diagram shown in part 2, you will see that green colours would show as red.

You will see from Fig.4 that the 7.8kHz (7.8025kHz) half-line frequency ripple pulse produced in the phase detector is applied to a 7.8kHz shaper circuit. This signal synchronises the bistable circuit, ensuring that the TV receiver PAL switch is correctly in phase with the transmitted V+ and V- on each line of the chroma signal.

Because the 7.8kHz sine wave correctly identifies these lines, it is referred to as the 'ident' signal.

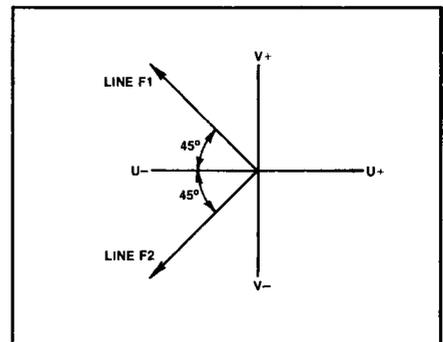


Fig.8: The colour burst signal swings 45 degrees above and below the -U axis, on alternate lines.

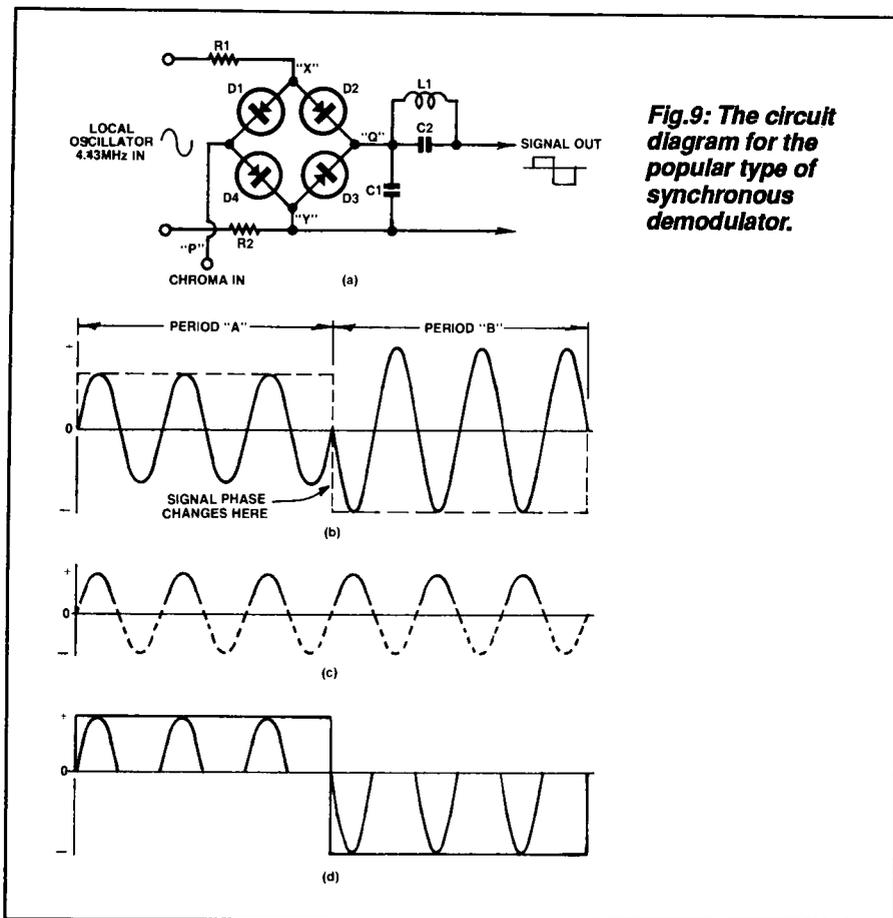


Fig. 9: The circuit diagram for the popular type of synchronous demodulator.

The 7.8kHz ident signal is also used to control the colour killer circuitry. As you can see from Fig. 2, during a monochrome transmission the colour burst signal is not transmitted. This means that the burst signal, the 7.8kHz pulse from the phase detector, and therefore the ident signal will not be produced.

The result is that the signal from the

colour killer to the chrominance amplifier is absent and thus the chrominance amplifier is based off. The reason for doing this is very simple — if the chrominance amplifier continued to work during a black and white transmission, colour patterns and splashes would be visible on the picture.

The ACC (automatic colour control) sig-

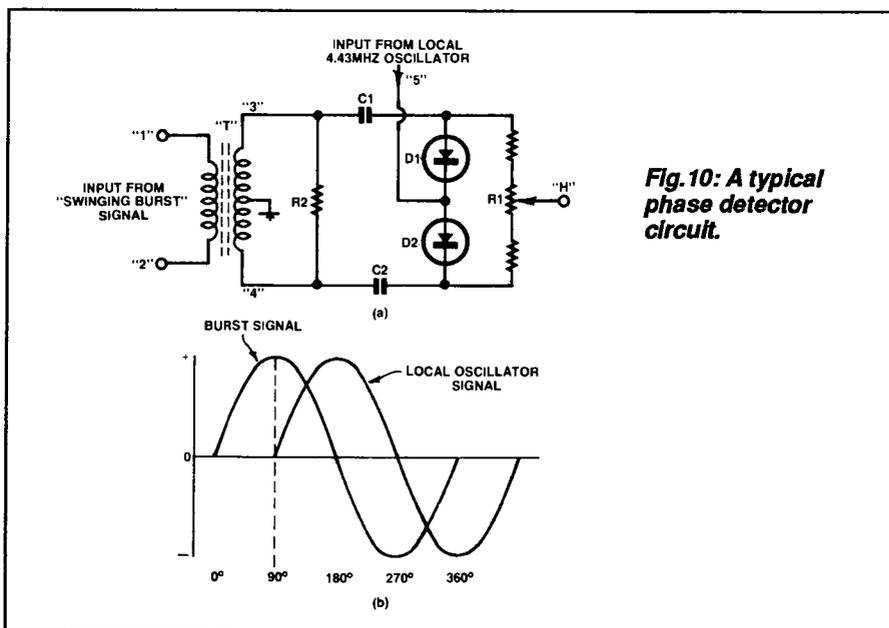


Fig. 10: A typical phase detector circuit.

nal from the burst gate and amplifier is fed back to the chrominance amplifier.

The voltage of this signal depends on the amplitude of the received colour burst and controls the gain of the chrominance amplifier. This keeps the level of the colour saturation of the picture constant if the received signal should vary in strength.

When the PAL switch is correctly synchronised to the signal, the local 4.43MHz carrier will be in the correct phase and frequency to be fed to the V demodulator.

As stated above, the 90 degree phase shifted oscillator signal is fed to the U demodulator. Following demodulation, the resulting (R-Y) and (B-Y) signals are amplified and fed to the matrix circuitry.

The NTSC decoder

An NTSC colour transmission, as you'll recall, uses I and Q signals, instead of V and U signals. The I signal is 33 degrees from the PAL V signal and the Q signal 33 degrees from the U signal (see part 2). The I signal is not switched every other line as is the V signal.

A block diagram of an NTSC decoder resembles Fig. 4 but the bistable and PAL switch circuitry would be absent.

The signal from the TV receiver's sub-carrier oscillator (3.579545MHz for the USA) is sent directly to the I demodulator which replaces the V demodulator in our block diagram.

PAL-S and PAL-D

Some early PAL colour TV receivers used PAL-S circuitry. In a PAL-S (PAL-simple) receiver, the PAL delay line and adder and subtractor circuitry is omitted. In any two lines, hue errors of the same colour occur in opposite phase directions.

When this happens, the PAL-S receiver relies on the eye to average out any differences in hue.

However, if there are large colour phase errors between two close lines of picture, bar patterns, known as 'Hanover' blinds, will appear on the picture.

To overcome this problem, a phase control was fitted between the subcarrier oscillator and the two synchronous demodulators. The viewer then adjusted this control for maximum reduction of the blind effect.

The PAL-D (PAL-deluxe or PAL-delay) decoder, as shown in Fig. 4, thus displays a superior colour picture when compared to the simple PAL-S receiver.

For this reason, all modern sets use PAL-D colour decoders. In fact, in the very latest designs, most of the decoder circuitry is taken care of by a single large scale integrated circuit.

THE COLOUR DECODER - 2

Part 6

In the last part, we discussed the operation of a typical PAL colour decoder. Before continuing our study of the decoder, we'll look again at the U and V signals and their relationship to each other.

Fig.1 is the horseshoe-shaped chromaticity diagram (see also Fig.6, Part 1). In this case, the diagram has been turned around so as to bring the 'red' light wavelengths slightly to the left of the top of the diagram.

The 'blue' wavelengths are now at the right and the 'green' wavelengths at the lower left. The 'axis' lines show the positions of the V and the U signals. This diagram will help us to understand how the relative values of the U and V signals produce various colours.

Remember that the hue of a colour is determined by the relative signal voltages of the U and V signals, and the saturation of a colour depends on the amplitude of the two signal voltages (see part 3).

Fig.2 shows the vector diagram for blue. The solid line of the phasor arrow represents a lightly saturated blue. Medium saturation is indicated by the arrow on the line of dashes, and a heavily saturated blue by the arrow at the top of the dotted line. The angle (and thus the hue) between the U and the V arrows remains the same, but as the saturation increases so does the phasor voltage.

Because the V signal in the PAL system is switched 180 degrees every other line of colour picture information, the signals for the next line are shown above the +U axis. On the third line (for the same hue) the signal is again below the +U axis.

Fig.3 shows the 'cotton reel' waveform of the chroma signal before it passes through the PAL delay line and the adder/subtractor circuitry of the decoder.

The colour represented by each section is marked on the diagram together with the proportional signal voltages. We need to know how this waveform is developed if we are to properly understand the colour signals.

You'll remember that the colour signals are 'weighted' to prevent overloading the TV transmitter. So the U signal is the (B-Y) signal multiplied by 0.493, and the V signal is the (R-Y) signal multiplied by 0.877.

Fig.1 shows the relative signal voltages of the weighted colour bar signals. Notice that the phasor arrow lengths are given for each colour. Compare these values with those shown in Fig.3 and

you will see how the 'cotton reel' waveform is formed. The U and V weighted signal values for the colour bars are as follows:

Yellow	V = 0.1	U = -0.44
Cyan	V = 0.62	U = 0.15
Green	V = -0.52	U = -0.29
Magenta	V = 0.52	U = 0.29
Red	V = 0.62	U = -0.15
Blue	V = -0.10	U = 0.44

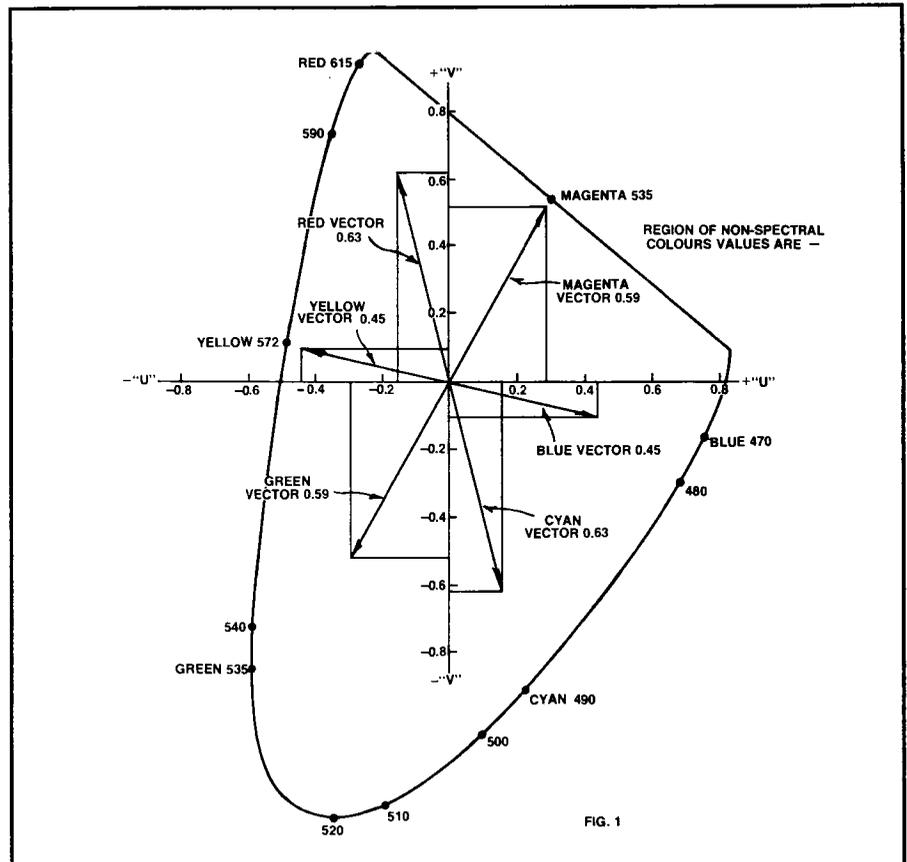


Fig.1: The horseshoe-shaped chromaticity diagram. The figures outside the perimeter are in nanometres. The hue of a colour is determined by the relative values of the 'U' and 'V' signals.

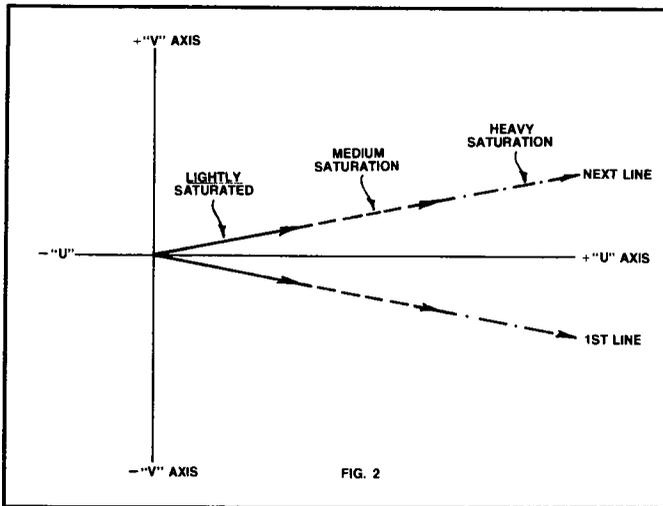


FIG. 2

Fig.2: The solid line represents lightly saturated blue, the arrow at the end of the dashes indicates medium saturation, and the dash-dot line indicates heavily saturated blue.

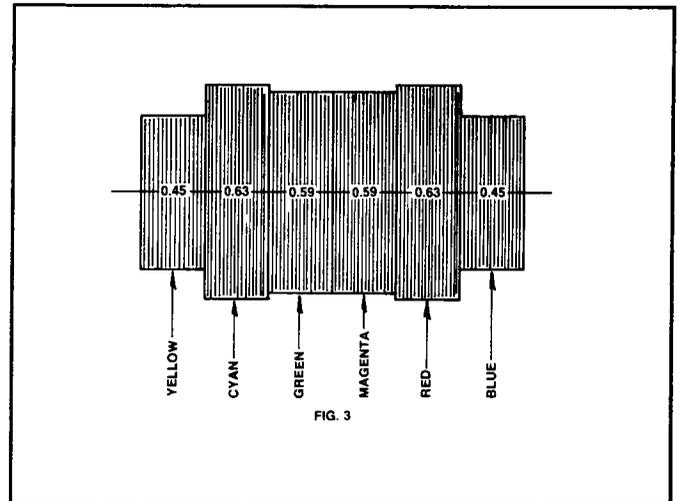


FIG. 3

Fig.3: The 'cotton reel' waveform of the chroma signal before it passes through the PAL delay line and the adder/subtractor circuitry of the decoder. Compare to Fig.1.

Figs.4(a) and 4(b) show the two colour signal waveforms after the V and U signals have been separated by the PAL delay line and the adder/subtractor circuitry.

The output from this circuitry consists of +2V or -2V to form the separated V signal, and +2U and -2U to produce the separated U signal. So in theory we should obtain signal outputs of twice the voltage of the input signal.

However, this does not occur in practice because of losses in the PAL delay line. But the proportional values of the colour bar signals remain constant provided we always consider peak white as equal to '1'.

Compare the values shown in Figs.4(a) and 4(b) with the V and U values above. In Fig.5(a), the (R-Y) waveform is shown as it appears at the output of the V synchronous demodulator. If you look at the positive and negative values of the V signals you will see how this waveform is formed.

Fig.5(b) is the (B-Y) waveform at the output of the U demodulator. This waveform is produced by using the positive and negative values of the U signal for each colour bar. Follow the values through carefully, comparing Fig.4(a) with Fig.5(a) and Fig.4(b) with Fig.5(b).

We now have the (R-Y) and (B-Y) signals, but need to recover the (G-Y) signal. But before discussing how this is done, we will first follow the luminance signal from the TV receiver video detector through to the picture tube cathodes. Fig.6 shows the path of the luminance or Y signal. Consider that we have a complete colour bar

signal at point 'A' (from the video detector). Signals passing through the narrower bandwidth chrominance circuits take longer to reach their destination than do the wider bandwidth luminance signals.

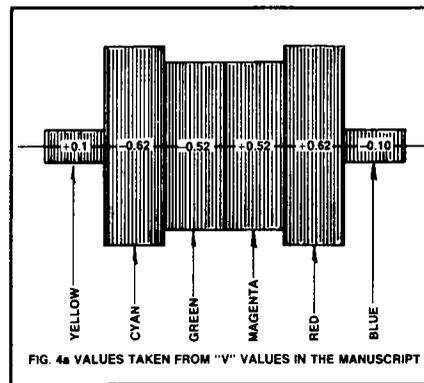


FIG. 4a VALUES TAKEN FROM "V" VALUES IN THE MANUSCRIPT

Fig.4(a): The 'V' signal after separation by the PAL delay line, but before demodulation.

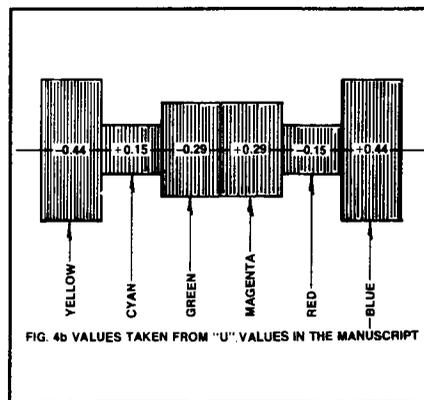


FIG. 4b VALUES TAKEN FROM "U" VALUES IN THE MANUSCRIPT

Fig.4(b): The 'U' signal after separation by the PAL delay line, but before demodulation.

To ensure that the luminance and chrominance signals arrive together at their destination, a delay line is used. This luminance delay line is quite different in construction from the glass PAL delay line. Because of its relatively long delay time and the higher frequencies contained in the Y signal, compensation must be included to prevent excessive phase distortion.

One method of construction is to use an insulated tube of Paxolin or plastic material with a strip of copper foil along its length. This is covered with plastic tape or plastic film. Finally, a coil of insulated wire (about 46 SWG) is neatly wound from end to end.

You can see the circuit symbol of the luminance delay line in Fig.6. The impedance of the delay line is 1k and the signal delay time is about 0.6ms.

Included in the luminance amplifier circuitry is a 4.43MHz 'notch' filter. This filter stops the chrominance information from passing through and causing dots and possible desaturation of colours on the displayed picture. The waveform of the luminance signal at point 'Y' is shown in Fig.6.

We know that the luminance signal controls the brightness of the picture and supplies the fine detail. The complete colour picture is then built up by additive colour mixing of the red, blue and green components.

Recovering the G-Y signal

The two synchronous colour demodulators produce the (R-Y) and the (B-Y) signals. You'll remember that the luminance or Y signal consists of proportions of voltages representing red, blue and green. These proportions are 59%

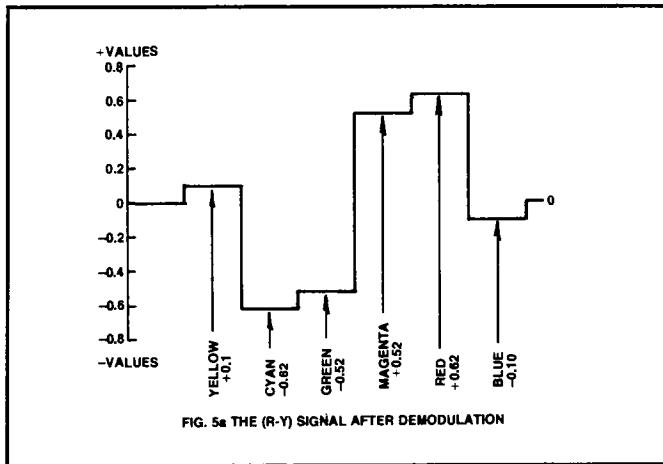


FIG. 5a THE (R-Y) SIGNAL AFTER DEMODULATION

Fig.5(a): The (R-Y) signal after demodulation.

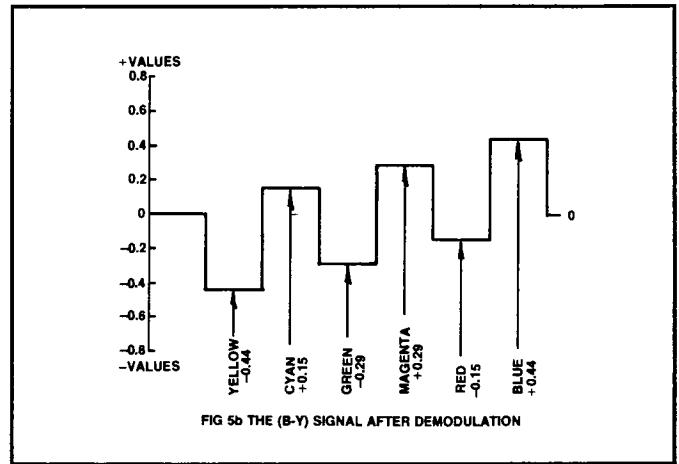


FIG 5b THE (B-Y) SIGNAL AFTER DEMODULATION

Fig.5(b): The (B-Y) signal after demodulation.

green, 30% red and 11% blue which we showed by the formula:

$$Y = 0.59G + 0.30R + 0.11B$$

Remember that the values of R, G, B and Y are each taken as being 1.

So to find the values of (B-Y), all we need to do is to take Y from B. So -

$$(B-Y) = B - (0.59G + 0.30R + 0.11B).$$

This works out as:

$$(B-Y) = 0.89B - 0.59G - 0.30R.$$

In the same way, we can take Y away from R to get (R-Y). This gives us $R - (0.59G + 0.30R + 0.11B)$.

This becomes:

$$(R-Y) = 0.70R - 0.59G - 0.11B$$

Again (G-Y) can be found by taking Y away from G because

$$(G-Y) = G - (0.59G + 0.30R + 0.11B).$$

This becomes:

$$(G-Y) = 0.41G - 0.30R - 0.11B.$$

51% of (R-Y) works out as

$$0.36R - 0.30G - 0.06B.$$

19% of (B-Y) is

$$0.17B - 0.06R - 0.11G.$$

Add these together and we obtain

$$-0.41G + 0.30R + 0.11B.$$

This is exactly the same as (G-Y) above, except that the plus and minus signs are reversed.

In the colour TV receiver, 51% of the (R-Y) signal is combined with 19% of the (B-Y) signal. Then the resulting signal is inverted by passing it through an amplifier. In this way, the (G-Y) signal is recovered. Fig.7 illustrates how this is done. Note that in the latest colour sets, the matrix circuitry is usually contained within a large scale integrated circuit,

together with the remainder of the decoder circuitry.

Transistor Q1 amplifies the (R-Y) signal and Q3 does the same for the (B-Y) signal. Inverted (R-Y) signals from transistor Q1 and inverted (B-Y) from transistor Q3 are applied to two trimpots (VR1 and VR2).

These trimpots are adjusted so that the base of transistor Q2 is supplied with a signal consisting of 51% - (R-Y) and 19% - (B-Y). This mixed signal is then passed through uninverted by transistor Q2 which acts as an emitter-follower, producing a (G-Y) signal at point 'G'.

Colour drive to the tube

In the late 1960's and early 1970's, almost all PAL receivers had colour difference drive circuitry (see Fig.6). In this

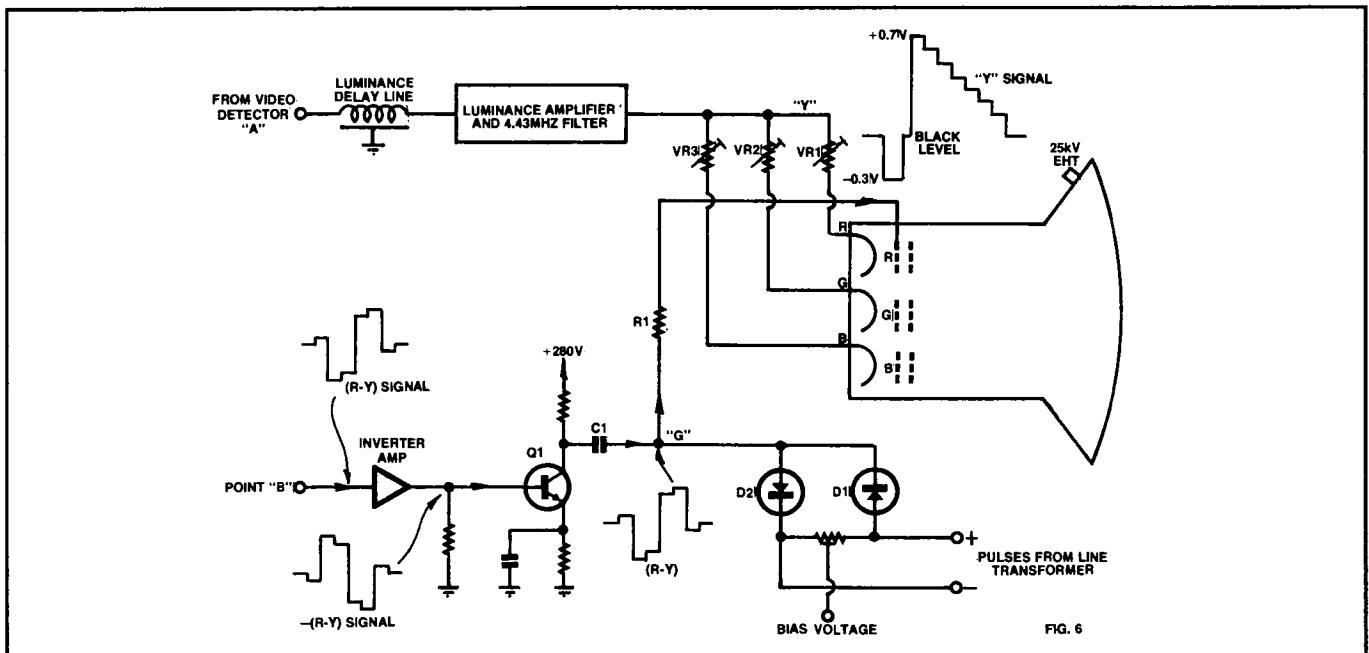


FIG. 6

Fig.6: The colour difference output stage. In this circuit, the luminance signal is applied to the tube cathodes while the colour signals are fed to the three control grids.

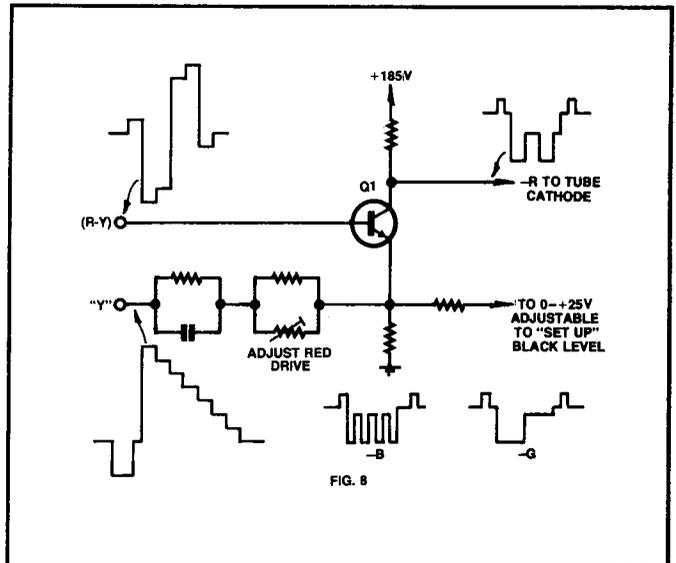
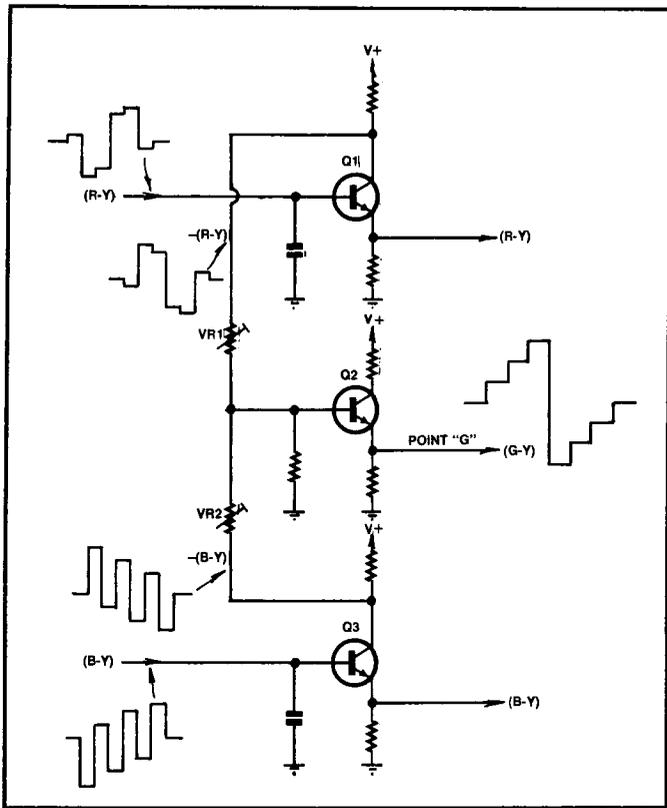


Fig.8 (above): Simplified circuit of the 'red' output stage of an RGB drive colour TV receiver. The circuitry for the green and blue stages is identical.

Fig.7 (left): How the G-Y signal is derived. Inverted R-Y signals from Q1 are mixed with the inverted B-Y signals in Q3 to give the G-Y signal at Q3's emitter.

type of circuitry the luminance signal is supplied to the tube cathodes, and the three colour signals are fed separately to each of the picture tube's three control grids.

Transistor Q1 in Fig.6 functions as a colour difference amplifier. Waveforms are shown on this diagram for an (R-Y) input with a colour bar input signal.

The (G-Y) and (B-Y) amplifiers are identical. The two diodes (D1 and D2) act as a 'clamp' and are driven by pulses that come from the receiver line output transformer. D1 and D2 conduct each time the pulses arrive at capacitors C1 and C2.

When this happens the DC voltage at point 'G' is practically the same as the bias voltage. The result is that the picture tube grid is held at a DC voltage corresponding to the 'black' level of the signal.

Look again at the waveforms in Fig.6 and note the black level. Capacitor C1 couples the collector of transistor Q1 to point 'G' and thence via resistor R1 to the picture tube grid.

A colour picture tube is more sensitive to changes of cathode voltages than it is to changes of grid voltages. So when the amplified colour signals drive the tube control grids, rather than the cathodes, the signal must be greater by about 30 to 33%.

You will see from Fig.6 that the Y signal is applied to each of the picture tube

cathodes. This means that the 'red' electron beam is controlled by the Y signal at the cathode, and the (R-Y) signal at the control grid labelled 'R'.

But because $-Y$ plus $Y = 0$, (R-Y) at the grid and $+Y$ at the cathode add up to R. The result is that the signal at the control grid acts as R only. In the same way, (G-Y) at grid 'G' becomes G, and (B-Y) becomes B at grid 'B'.

The fine detail of the picture is supplied by the luminance signal as we discussed in earlier parts. You'll remember that when a monochrome program is received — perhaps an old black and white film — the picture depends entirely on the luminance signal.

The brightness of each of the three electron beams must be adjusted so that in this case the viewer receives the sensation of a monochrome picture.

In other words, the brightness of the picture must vary from black through various shades of grey to peak white.

This setting up of the electron beams is called 'Grey Scale Tracking'. Fig.6 shows the preset controls VR1, VR2 and VR3 used for this adjustment.

Usually the 'red' drive Y signal needs to be greater in amplitude than the 'green' and 'blue' drive signals. This is because the 'red' phosphor on the tube face needs the largest electron beam current of the three beams in order to emit the desired amount of red light.

Having said this, keep in mind that colour picture tube design and tube face phosphor efficiency are constantly being improved by the manufacturers.

When a colour program is received, the brightness signal continues to supply the detail. The colour difference signals at the picture tube grids vary in intensity according to the colour of the transmitted picture so that a wide range of colours are visible in the picture.

These are, of course, produced by additive mixing of the three primary colours. Together, the luminance and colour signals make up the complete colour picture.

RGB drive

RBG drive is used in the newest colour TV receivers, with all colour and picture detail information being supplied to the tube cathodes.

Typical colour drive output voltages for a late model colour set are 90 volts peak-to-peak at the 'red' cathode, and 70 volts peak-to-peak at the 'green' and 'blue' cathodes.

Fig.8 is a simplified circuit of the 'red' output stage of an RGB drive colour TV. The circuitry of the green and blue stages is identical. Notice the waveforms of the +Y and the (R-Y) input signals shown on the diagram.

The (R-Y) signal is fed to the base of transistor Q1 and the +Y signal to the

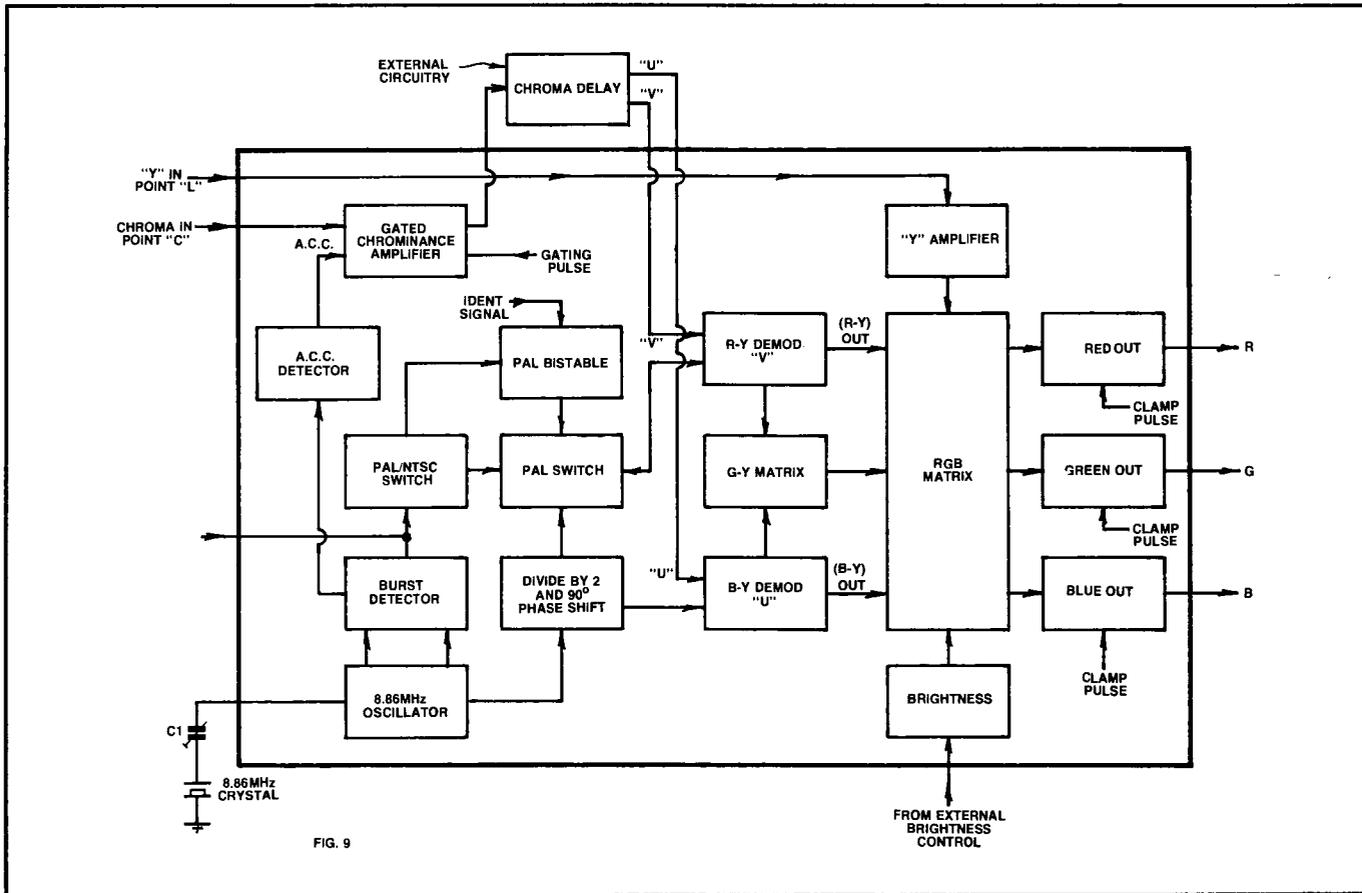


FIG. 9

Fig.9: A simplified block diagram of the TDA 3562A single-chip decoder IC.

emitter. The (R-Y) and +Y signals together produce a +R signal which is inverted at the collector and becomes -R. The -R waveform is shown. In the same way, in the 'green' output stage (G-Y) is added to +Y and inverted to give -G. Similarly, in the 'blue' output stage (B-Y) adds to +Y and is inverted to produce -B. The -B and -G waveforms are also shown.

The -R, -G, and -B signals are fed to the three cathodes of the picture tube. As the three electron beams move together across the picture tube face forming the raster, changes in brightness due to the detail of the picture affect all three beams equally, making the picture brighter or darker.

However, when one of three colour signals varies, only the particular electron beam controlled by that colour will be affected. In this way, the fine detail of the picture is displayed with the full range of colours added.

The one-chip decoder

A new development in colour TV receivers is the use of a single large scale integrated circuit which contains the entire decoder circuitry.

Fig.9 shows a simplified block diagram of such an IC. Notice that the frequency

of the subcarrier oscillator is 8.86MHz instead of the conventional 4.43MHz. The output of this 8.86MHz oscillator is simply fed to an internal divide-by-2 circuit to derive the required 4.43MHz signal.

The divide-by-2 circuit also produces a precise 90 degree phase shift in the sub-carrier signal fed to the PAL switch. This removes the need for any external phase adjustment control. Note that the 90 degree phase shifted 4.43MHz signal is supplied first to the PAL 180 degree switch and then to the V demodulator.

If you check the block diagram of the PAL decoder shown in the last part, you will see that the 90 degree phase shifted subcarrier signal feeds to the U demodulator. In fact, the 90 degree phase shifted carrier may be supplied to either the U or to the V demodulator.

The luminance signal, after passing through the luminance delay line, is applied to point 'L' which is the Y input pin connection to the IC. It then passes through the internal Y amplifier and feeds into the RGB matrix circuit.

The chrominance signal is supplied to point 'C' and into the gated chrominance amplifier. The output of this amplifier is

fed to external PAL/chroma delay circuitry. The resulting separated U and V signals then re-enter the decoder IC and are supplied to the (R-Y) V and (B-Y) U demodulators. Proportions of the (R-Y) and (B-Y) demodulated outputs supply the (G-Y) matrix circuitry.

The (R-Y), (G-Y) and (B-Y) signals are then fed into the RGB matrix. The output from the RGB matrix consists of R, G and B signals which are then further amplified. Black level 'clamping' (not shown) is applied to the signals within the IC.

The colour signals are then amplified by external transistors to drive the three cathodes of the colour picture tube. An external electronic switch allows the IC to operate on either the PAL or NSTC colour system.

You'll appreciate that our diagram (Fig.9) shows only the main features of this single IC decoder. Quite a lot of other circuitry is also contained within the IC. The important thing is that you understand the basic operating principles.

Next we begin considering the complete PAL colour television receiver and in particular, the tuner and IF stages, plus the power supplies, EHT generation and the other sections of the colour TV set.

THE COMPLETE PAL COLOUR TV RECEIVER - 1

Part 7

Now that we've looked at the basic concepts involved in PAL colour TV encoding, transmission, reception, decoding and display, we are in a position to analyse the operation of a typical PAL colour receiver in more detail.

Before considering the complete circuitry contained in a PAL colour receiver, we'll first take a look at the basic schematic of a standard 625 line monochrome receiver. This will assist us as we discuss the additional circuitry needed by the PAL colour receiver.

In the block diagram shown in Fig.1, the basic arrangement of the monochrome TV is shown. The block diagram of Fig.2 shows the additional circuitry of a PAL colour receiver.

During the transmission of a television programme the energy radiated by the TV stations is in the form of an electromagnetic field.

When this energy reaches the TV receiving antenna via the transmission path, an electrical signal is extracted. This signal is then fed down through the antenna cable to the TV receiver. In

the receiver the signal is taken to an RF tuner. The tuner is used to select the desired television programme broadcasting from among the other received signals present at the TV antenna socket.

Fig.3 shows the total station channel bandwidth used in Australia, together with the signal information arrangements.

The received signal is amplified by the signal frequency circuitry in the tuner. Since modern TV sets operate as superheterodyne receivers, the tuner contains a local oscillator which beats with the received and amplified station frequency signal.

Two intermediate frequency signal IF are produced, one carrying the vision signal, the other the sound signal. For Australia, the vision IF signal is 36MHz

and the sound signal 30.5MHz. Notice that the two signals are separated by 5.5MHz. In Britain the vision IF frequency is 39.5MHz and the sound IF frequency 33.35MHz — a separation of 6MHz.

Both vision and sound IF signals pass through and are amplified in the vision IF stages.

The circuit of Fig.1 includes an automatic gain control (AGC) circuit. This is needed because when changing from one TV station to another the signal strength of the received programme may vary.

Also in weak signal areas fading may be experienced. The AGC affects the gain of all the signals passing through the vision IF amplifier, to provide a substantially constant video output level. You will see from the block

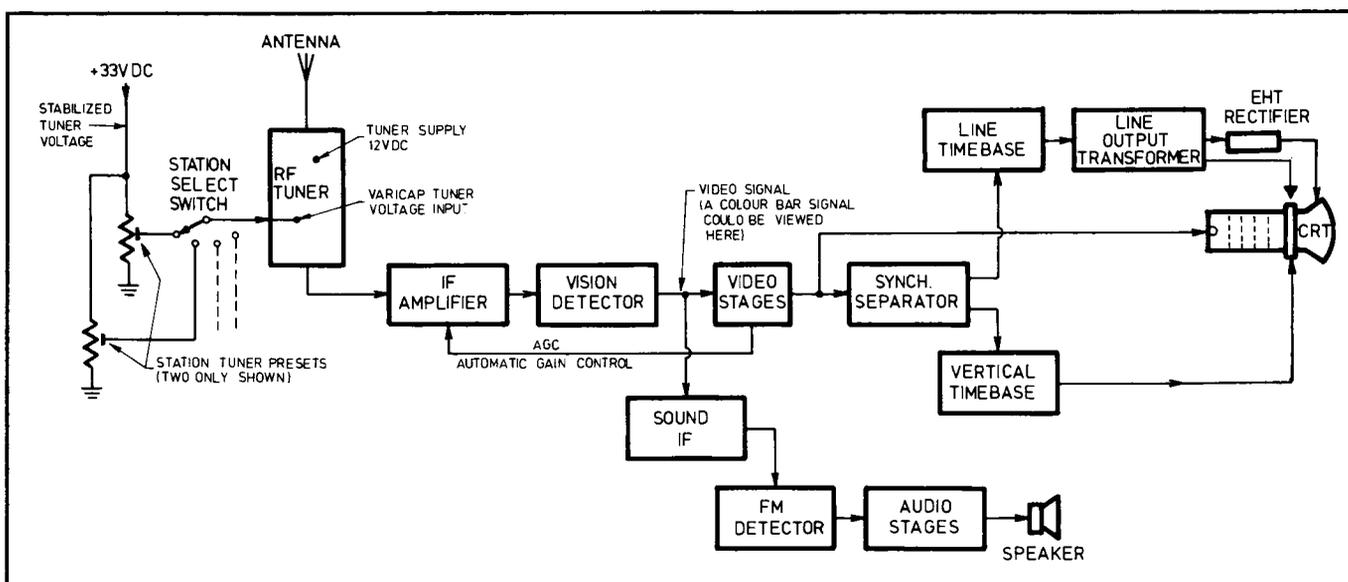
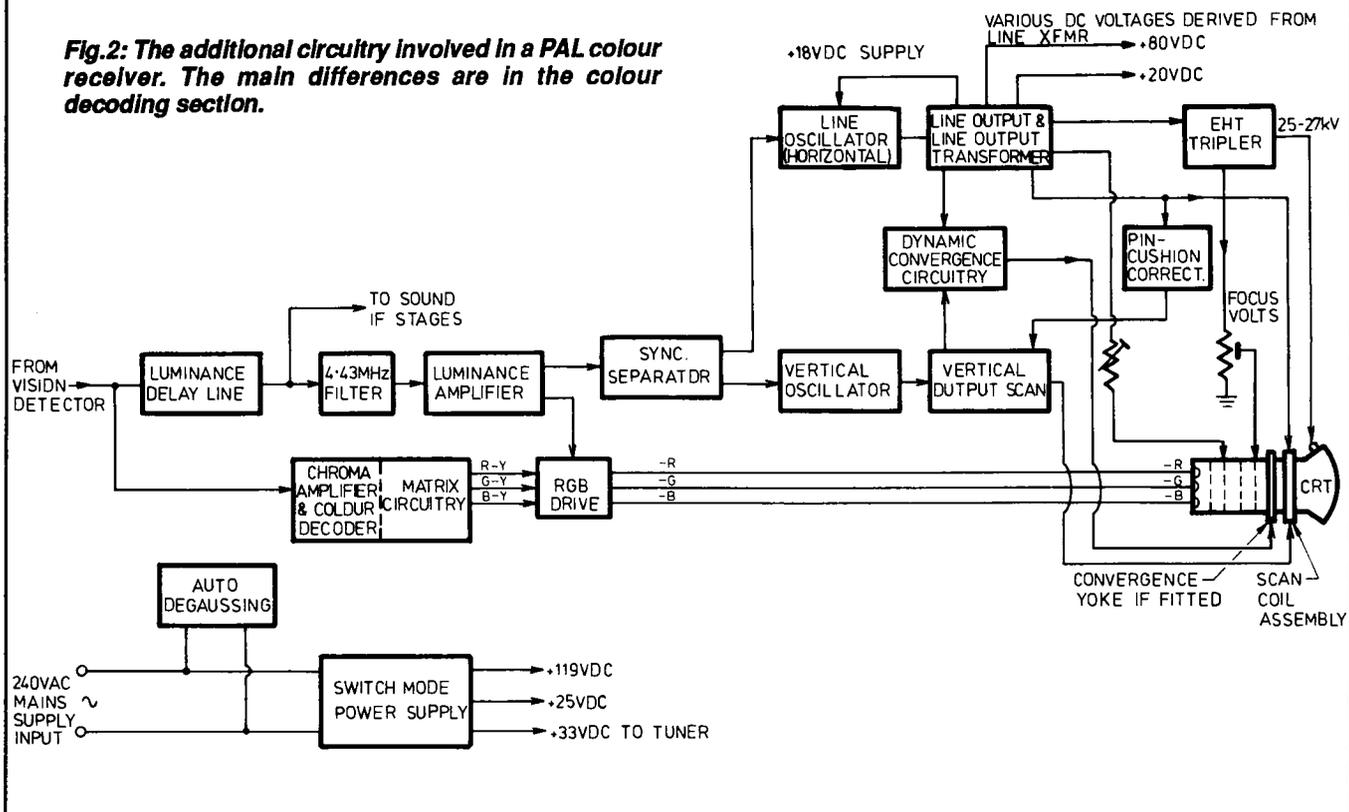


Fig.1: The block diagram of a modern monochrome TV receiver, in basic form. A colour set is virtually identical up to the output of the vision detector.

Fig.2: The additional circuitry involved in a PAL colour receiver. The main differences are in the colour decoding section.



diagrams of Fig.1 and Fig.2 that many sections of the circuitry of the monochrome and PAL colour receivers seem to be identical. However, there are certain additional requirements essential for colour reception.

After IF amplification the signals are then demodulated by the vision detector. The vision signal obtained consists of the entire vision carrier modulation and is known as the video signal.

If you supply a colour bar input signal to a good quality monochrome receiver, and connect an oscilloscope to the output of the vision detector, it will display the complete colour bar signal exactly as would be found in the colour TV.

In the monochrome TV, the demodulated video signals are directly amplified by the video stages and drive the single cathode of the monochrome picture tube.

The brightness of the picture at each point of the raster varies, as the received vision signal causes the tube beam current to increase and decrease. Provided the raster is correctly synchronised a picture will be viewed, in black and white.

Both the line timebase and the vertical timebase will run in the absence of any signal, producing a raster on the picture tube. However, it is necessary

that both timebases be exactly synchronised with the horizontal and vertical scanning of the camera at the TV transmitter.

When correctly adjusted the free running speeds — with no signal input to the TV — of the receiver timebases are slightly lower than those of a synchronised picture. The sync pulses 'trigger' both timebases, speeding them up so that both scan of the TV picture raster exactly 'in step' with the transmitted picture.

These vertical scan and line scan synchronising pulses are extracted and separated at the output of the video detector. In the PAL colour receiver similar synchronisation circuitry is used to 'lock' the picture raster to the transmitted signal.

The extra high tension voltage (EHT) required for the final anode of the picture tube is obtained by rectifying a portion of the energy developed by the line output transformer (Fig.1).

The low current EHT voltage produced may be between eight to 15 kilovolts, according to the size of the picture tube. Generally, at the present time only small portable monochrome TV sets are being manufactured.

After vision demodulation the 5.5MHz FM sound signal is also extracted. It's then fed to the sound

IF, the FM demodulator and audio stages.

Extra circuitry needed for colour

In the block diagram of Fig.2 you'll notice some extra circuitry. The video output stage of the mono receiver is replaced by the luminance output stage of the PAL receiver.

The luminance amplifier must drive the three cathodes of the colour picture tube, instead of the single cathode of a mono tube. For this reason the luminance stage has greater gain than does the monochrome TV video amplifier.

The notch filter shown at the input of the luminance amplifier is tuned to 4.43MHz. This filter is necessary to stop chrominance information passing through the luminance amplifier and causing dots or Moire patterns on the viewed picture.

Another additional component not found in a monochrome TV is the luminance delay line, which delays the luminance signal so that chroma and luminance information arrive together at the picture tube.

After demodulation by the video detector, the signal also passes through a bandpass filter which leaves only the chroma information. The chroma signal

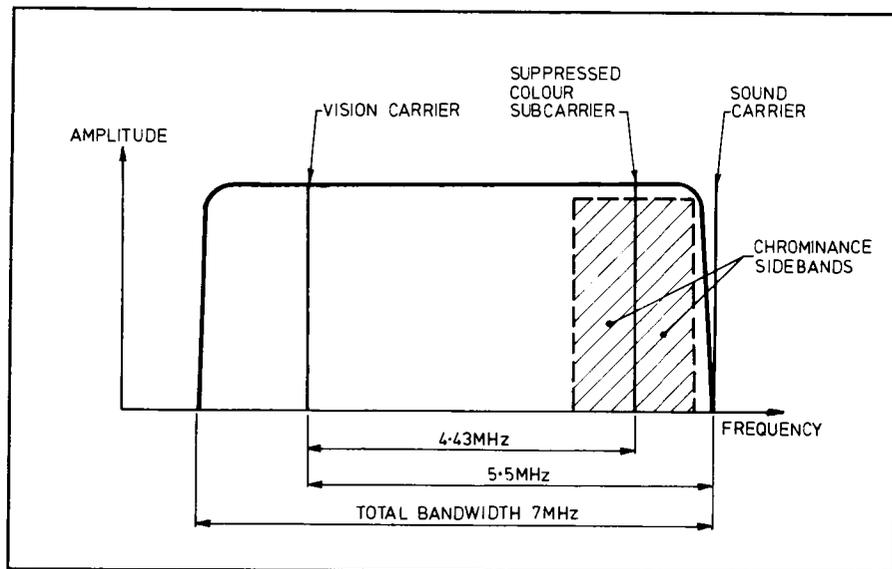


Fig.3: The total frequency bandwidth occupied by an Australian TV channel, showing the various signal components.

is amplified in the chrominance amplifier and passes to the colour decoder section (See parts 5 and 6).

You'll recall that the decoder output consists of the (R-Y) and the (B-Y) signals, and it supplies these to the matrix circuitry where the (G-Y) signal is recovered. The luminance and colour difference signals are then combined in the RGB drive stages and drive the three cathodes of the colour picture tube.

In older PAL colour TV's the decoder consisted of discrete circuitry using valves or transistors.

In the latest colour receivers, practically the entire decoder is contained in a single very large scale integrated circuit (see part 6).

However, the study of the discrete circuitry is helpful in understanding colour TV and decoder operation. That is why in the two articles dealing with the decoder, schematics using individual components were shown for these sections of the decoder.

One section we have discussed, but not shown, is the subcarrier oscillator whose carrier output is used to demodulate the U and V signals.

Fig.4 shows a typical schematic for such an oscillator. It's crystal controlled and conventional in design.

Tuner/IF requirements

Since the colour information in the transmitted TV signal is contained in the sidebands of the subcarrier, (see again Fig.3), the stability of the tuner is considerably more critical than it is in a monochrome receiver.

Further the tuner must have a

bandwidth broad enough to contain the complete colour subcarrier. This also makes it essential to have minimum change in the tuner's response curve when the AGC control voltage changes.

At the same time the tuner needs to have the ability to reject TV transmissions other than the desired signal.

The supply voltage (B+) to a TV transistorised tuner in a modern receiver is usually an accurately stabilised +12 volts DC. To tune in the various TV stations the use of varicap diodes is now standard practice.

Electronics Australia readers will know that varicap (or varactor) diodes are diodes that are biased in reverse at a voltage lower than their reverse

breakdown voltage value. If any diode has a reverse voltage applied then its barrier depletion area widens as the voltage increase (Fig.5a).

The N and P junctions of the diode act as the plates of a small capacitor, with the barrier area as the dielectric. This means that as the applied voltage changes so does the capacitance of the diode.

The varicap diode is designed to have a much larger internal capacitance than an ordinary diode. Fig.5b shows that as the voltage increases, the diode capacitance decreases.

The variable tuning capacitors used in the old type TV tuners are replaced in modern TVs by varicap diodes. An accurately stabilised variable tuning voltage supplied to the tuner causes the capacity of the tuner varicap diodes to change, and the tuned circuits to resonate at the desired frequencies. In this way the required TV station is 'tuned in' — see Fig.1. TV channel selection may be made by simple switch-type pushbuttons.

However it is now more usual to employ complex digital or infrared remote control methods. These different station selecting methods all operate in the same basic manner by changing the applied DC tuning voltage in order to select the desired programme.

The result is an accurately stabilised TV tuner which does not drift away from the tuned channel frequency. Further when a different TV station broadcast is selected the tuner 'locks in' to the signal at once.

Actually, the tuning stability of

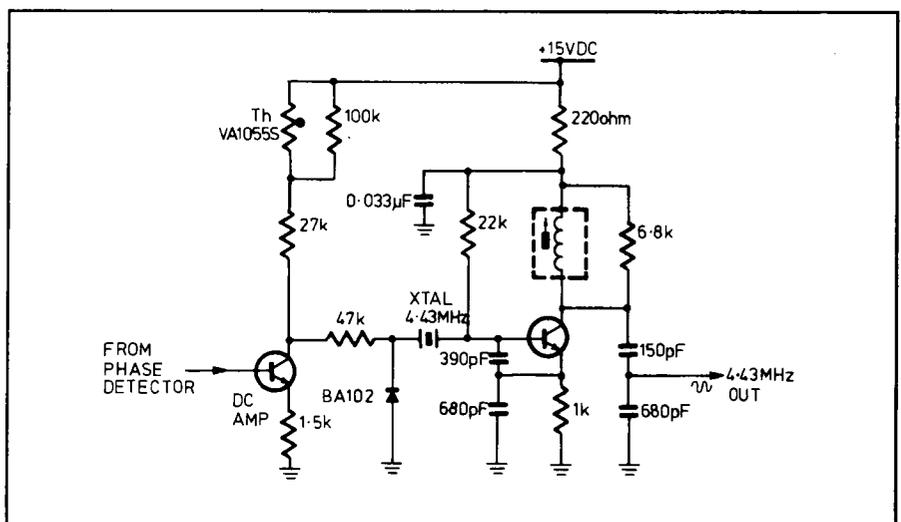


Fig.4: A typical colour subcarrier oscillator, used to 'restore' the suppressed 4.43MHz subcarrier for colour demodulation.

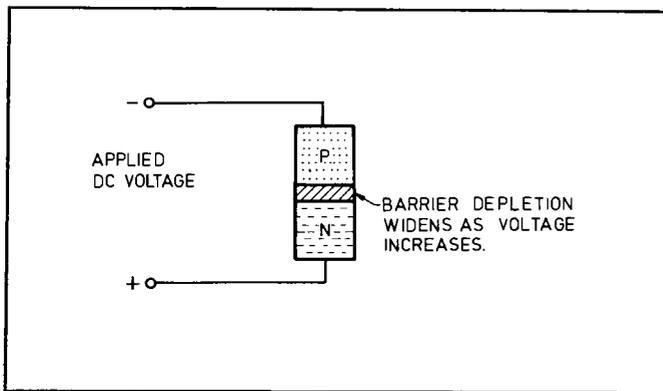


Fig.5(a): Basic structure of a reverse biased junction diode, as used for a varicap.

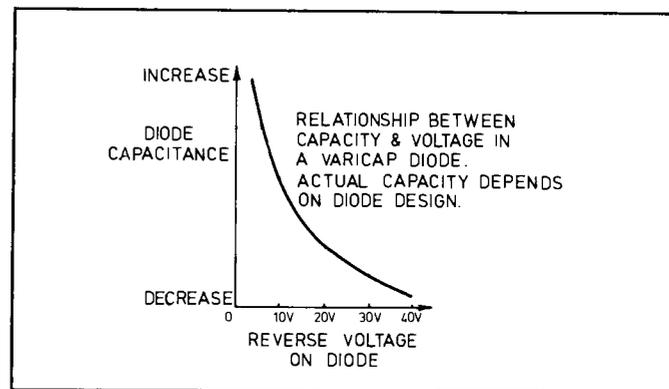


Fig.5(b): As reverse voltage on the varicap is varied, its capacitance varies inversely.

modern colour TV receivers is made even better, by the use of automatic frequency control (AFC). This involves a voltage fed back to the RF tuner's local oscillator varicap from the FM sound detector, with such a polarity to automatically correct any drift.

The intermediate frequency amplifier (IF) section of a PAL colour receiver has basically the same requirements as that of a monochrome 625-line set.

However, it is important that the chrominance signal remains undistorted, and is not attenuated by the IF amplifier. Older colour TV receivers used IF stages containing individual transistors (or valves) together with tuned IF transformers.

Fig.6 shows a section of such an IF amplifier. In the modern colour receiver some individual transistors together with integrated circuits may be found, but the trend towards the exclusive use of integrated circuitry is increasing.

Another device found in the IF circuitry of the modern PAL TV is the surface acoustic wave filter (SAWF). SAWF may be shown in the receiver schematic either as in Fig.7a or Fig.7b.

It is a piezoelectric device, about the size of a line output transistor such as a BU208.

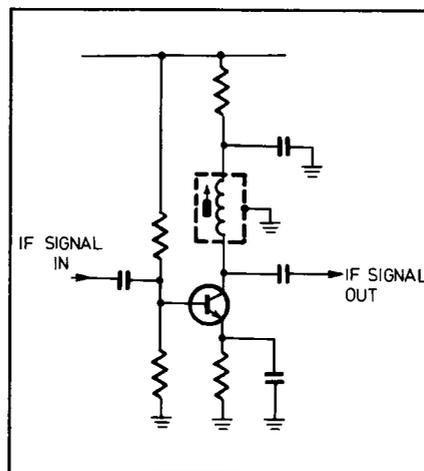


Fig.6: A typical LC-tuned IF amplifier stage, as used in older receivers.

Used in the PAL IF amplifier, the SAWF has the advantage of both better bandpass filter shape, stability of tuning and elimination of all the transformers when used with integrated circuits.

Fig.7a is basically a simplified schematic of a complete IF amplifier using a SAWF.

Power supplies

The mains power supply section of a modern PAL colour receiver is quite complex in design. In early PAL receivers using a valve design with perhaps just a few transistors, the stability of the power supply was not so critical.

However, modern PAL receivers contain transistor and integrated circuits that require accurately stabilised DC supply voltages to ensure correct and safe operating conditions.

These DC voltages must remain constant even if the load current taken by the receiver varies, or when reasonable variations in the AC mains supply voltage occur.

A further requirement is that in the event of any heavy overload, due to component breakdown in the TV, the power supply must switch itself off.

Practically all PAL TV receivers now contain switch-mode power supplies. A switch-mode power supply is one where the regulator (sometimes called the 'chopper') transistor is rapidly switched 'on' and 'off', usually in this case at about line timebase frequency (15.625kHz).

The longer the 'on' period lasts, the more current flows through the regulator transistor. If the 'on' period shortens then less current flows.

If the current consumption of the set increases or decreases, the DC output voltage of the power supply will try to change.

This is detected by the sensing circuitry, which alters the on/off ratio of the 15,625kHz pulse driving the base of the regulator transistor to compensate for this. Thus the DC output voltage is kept constant.

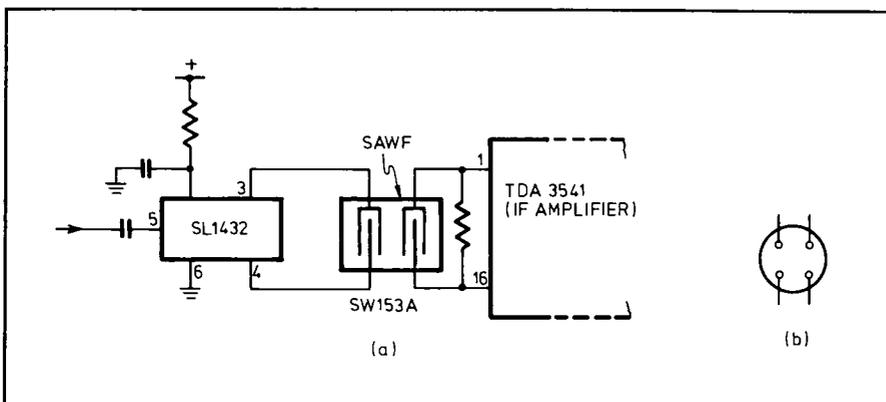


Fig.7: In modern receivers, all IF bandpass shaping is performed by a SAW filter. An alternative symbol is shown in (b).

Fig.8 shows a simplified block diagram of a switch-mode power supply of the self-oscillating type. You'll find this basic circuit in many late model PAL receivers.

A Siemens TDA4600 integrated circuit drives the BU208 regulator transistor. This power supply can operate on a wide range of mains input AC voltages ranging from 90 to 270 volts.

However, the basic design shown in Fig.8 is for an AC mains input of 240V. Tappings from transformer T1 supply various rectifier diodes and various DC voltages are produced across the electrolytic capacitors. Notice the 33 volts for the tuner varicap voltage supply.

Should excessive current due to an overload be drawn from the secondary winding of transformer T1, the power supply shuts down.

Power supplies regulated by silicon controlled rectifiers (thyristors) were popular in the 1970's. Today you will encounter many different versions of switch mode supplies.

Each type requires careful study in order to grasp its operating principles. In fact to properly describe all the different types of power supplies would take a series of articles on this subject alone!

Scanning circuitry

Scanning and synchronising the colour picture tube raster requires circuitry basically similar to that found in a monochrome TV. However, there are again significant differences.

Three electron beams must be deflected both vertically and horizontally in the colour picture tube. Also the EHT voltage is much higher on the colour CRT (24 or 27kV according to

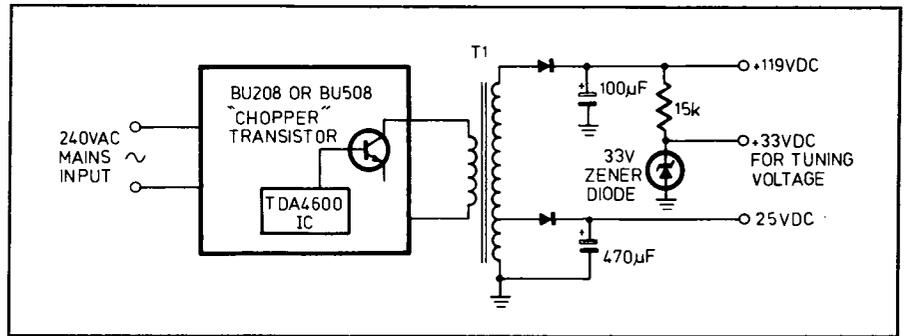


Fig.8: A simplified block diagram of the switch-mode power supply used in many modern receivers.

picture size). Thus increased power is necessary for the deflection circuitry.

In older receivers, discrete transistors or valves were used in the vertical oscillator, horizontal oscillator and synchronising stages (see again Fig.2).

However nowadays a single integrated circuit, such as a type TDA 2578A contains the line oscillator and the vertical scan oscillator, together with all the necessary field and line synchronisation circuitry.

In a colour TV the line output transformer which is driven by the line output stage) fulfils several functions. Besides energising the horizontal scan coils, it also produces anything from 400 to 800 volts DC for the A1 grid(s) of the picture tube. In addition, from various windings on the line output transformer are derived AC voltages which are then rectified to produce DC voltages that supply various circuitry in the TV. Further the transformer has an EHT winding producing just over 8kV.

Since approximately 25kV is required for the final anode of the colour picture tube, the 8kV is supplied to a 'tripler' rectifier configuration (Fig.9a).

When a line of picture is scanned at

the end of the line, a positive-going flyback pulse occurs as the beams return to the beginning of the scan. The capacitor C1 is then charged through diode D1 by a pulse from the EHT winding. As the input falls the charge on C1 passes via diode D2 to capacitor C2.

When the next positive-going flyback pulse arrives, C1 is again charged through diode D1. Capacitor C2 now receives an additional charge from diode D2.

The original 8kV on capacitor C2 now has a further 8kV added to it, so that the charge across C2 is now 16kV and capacitor C3 charges via D3. As the flyback pulse again dies away during the next line of picture, diode D1 transfers the charge on capacitor C3 to capacitor C4. There is now 8kV at point A, and 16kV at point B.

At the junction of diodes D1 and D2 the tube focus voltage is derived and taken via the focus circuitry to the focus electrode of the colour picture tube.

When the third flyback pulse arrives, the whole process is repeated, increasing all the potentials by a further 8kV.

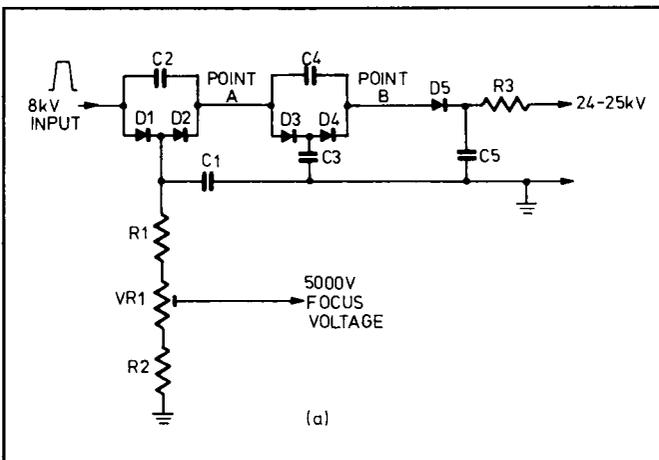


Fig.9(a): The basic voltage tripler frequently used to derive the 24-25kV EHT supply for a colour CRT.

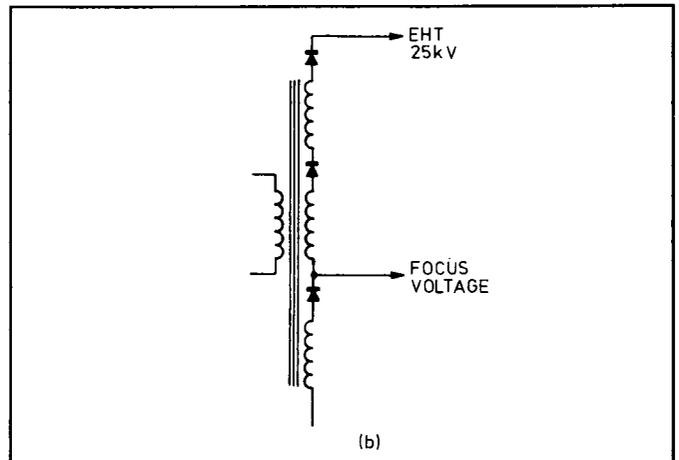


Fig.9(b): More recent designs use a split EHT winding with distributed rectifier diodes.

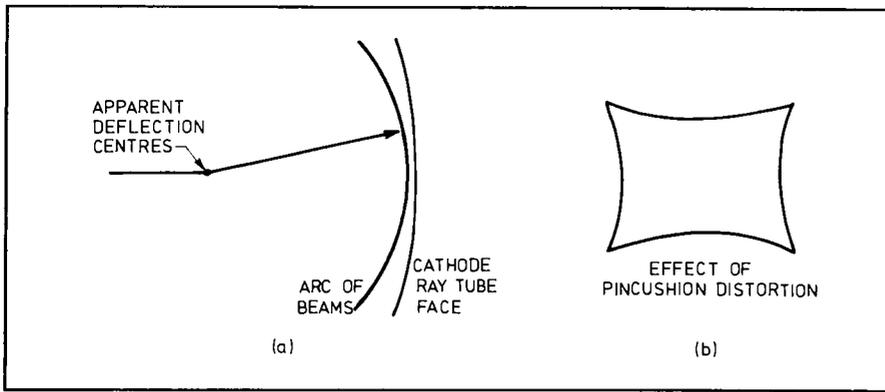


Fig.10: Because the electron beams are deflected with a radius much shorter than that of the CRT screen (a), this tends to produce a picture with 'pincushion distortion' (b).

Capacitor C5 now charges up via diode D5 to a potential of 24kV, which is taken through a safety resistor R3 to the picture tube's final anode.

The diode split line output transformer is rapidly replacing the separate tripler block.

The rectifying diodes are contained within the transformer itself, with the transformer windings providing the necessary capacitance (Fig.9b).

Pincushion correction

As explained in part 4, the three electron beams of the colour picture tube are deflected at the apparent deflection centres. The arc they describe is different from the much flatter tube face (see Fig.10a).

Fig.10b shows the effect on the shape of the displayed raster, which is known as *pincushion distortion*. Pincushion distortion also occurs in monochrome TV's, but is easily corrected by the use of small permanent magnets placed near the scanning coils.

However a colour picture raster consists of three rasters (red, green and blue), which merge and form a single composite raster. Used with a colour tube, small permanent magnets would

affect each of the three beams differently, ruining the convergence and purity. The solution is to use a *transductor*, which was developed by Mullard Ltd particularly for use with the shadow mask picture tube (Fig.11). The pincushion correction takes place at the apparent deflection centres of the colour tube, by allowing the horizontal and vertical scanning signals to interact in a ferrite core.

The current flowing through the line deflection coils is modulated by a parabolic waveform at vertical scanning frequency.

By means of this correction waveform, the sides of the composite raster are straightened. The transductor provides maximum correction at the centre of the raster, with gradually less correction falling to zero at the top and bottom of the picture.

Similarly the current flowing through the vertical deflection coils is corrected by a parabolic waveform at line frequency. At the beginning of each line of the raster this correction is zero; gradually increasing to maximum at the centre of each line and then slowly falling to zero again by the end of the line. In later developments of colour tubes,

other types of pincushion correction have been used. By careful design of the scan coil assembly, and by using special methods of winding the coils, pincushion distortion has been largely overcome.

However, particularly with larger picture tubes, some method of pincushion correction is still necessary.

Convergence

Convergence circuitry is provided so that the three rasters properly merge to form one composite raster over the entire surface of the picture tube face. In part 4, the basic method of converging the three red, blue and green rasters at the centre of the screen was described. This is known as *static convergence*. However to obtain proper convergence at the edges and corners of the picture, *dynamic convergence* is necessary.

With the earlier shadow-mask type of picture tube, coils were wound around the static convergence magnets contained in the convergence assembly. Controlled adjustable currents passed through these coils. Both line and vertical scan frequency parabolic currents were used.

The earlier colour TV receivers fitted with shadow-mask picture tubes thus contained a large number of preset convergence adjustments. A total of 20 or more (including both static and dynamic controls) were common. Each adjustment usually had to be repeated several times because of interaction in the circuitry.

A few of these receivers are still in use. Should you encounter one, remember that it is essential to first carefully study the TV manufacturer's service instructions before attempting any convergence adjustments. They're quite complex.

A warning

If you make any adjustment or measurement on or near a colour picture tube, remember that the 24-27kV EHT voltage can be lethal.

Even when the colour TV is switched off and disconnected from the supply mains, it is possible for the picture tube to hold a considerable charge of high voltage due to the tube's internal capacitance.

Fortunately, you'll find that colour receivers fitted with the very latest 'in line' colour tubes are practically self converging and need only minor adjustments. If the tube is a Philips 30AX, none at all will be required!

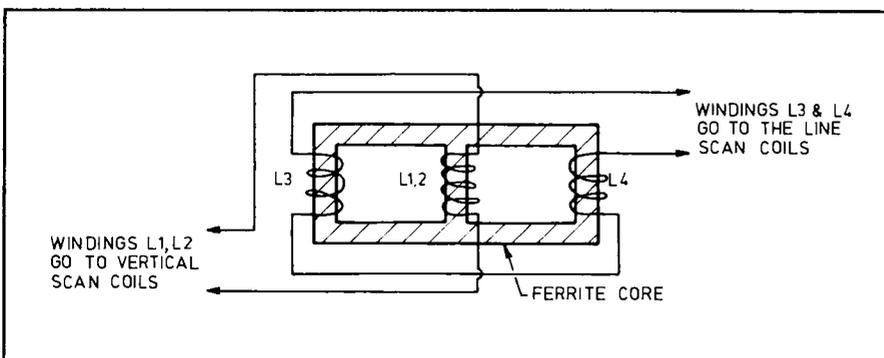


Fig.11: A transductor allows the line and field scanning circuits to interact, adding parabolic correction currents to each.

THE COMPLETE PAL COLOUR RECEIVER - 2

Part 8

In the final part of this section, the author looks in more detail at some of the circuit sections treated as blocks in earlier parts. He also provides some useful pointers to help in tracking down colour problems.

We'll start by considering schematics of some of the essential sections of the PAL TV receiver. These particular sections are the ones shown only as circuit blocks in previous parts in this series.

Of course *Electronics Australia* readers will appreciate that in PAL receivers using the latest technology, much of this circuitry is contained within a few integrated circuits. However, examining these individual sections in discrete form helps us to properly understand the complete operation of a PAL TV set. Furthermore many older colour TV receivers, still giving good service, contain such discrete circuitry.

Fig.1(a) shows the schematic of a typical video demodulator (detector). You will remember that the received signal information from the TV station passes first through the tuner and then through the vision IF stages to reach the demodulator. Diode D1 is the video detector. An oscilloscope connected at point A would display the complete vision carrier signal. With a colour bar input signal the complete colour bar signal would be viewed.

You will notice that the frequency modulated sound IF signal is taken from point B to the sound IF stages. An alternative method of recovering the FM sound signal is also shown. Here a separate intercarrier detector is used for the 5.5MHz sound IF signal.

Decoder section schematics

Schematics of sections of the decoder circuitry were shown and discussed in earlier parts of this series. You'll recall that these included the synchronous demodulators, the phase detector, the PAL delay line circuitry, RGB drive amplifiers, the matrix circuitry and the subcarrier oscillator. In order to properly understand the complete PAL receiver we need to consider some additional circuit sections.

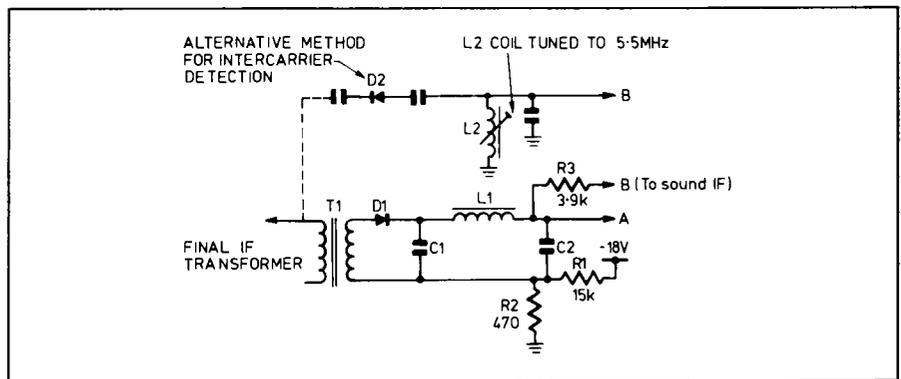


Fig.1: A typical video demodulator stage using discrete components, with the resulting video appearing at A. The 5.5MHz intercarrier sound 'F' signal can be tapped off via R3, or via a separate demodulator circuit as shown.

The output signal from the chrominance amplifier, consisting of the chroma signal and the PAL colour burst, feeds to the burst gate amplifier. (Please refer again to the colour decoder block diagram shown in part 5). Fig.2 shows such a typical burst gate and amplifier. A positive pulse from the line circuitry of the receiver switches transistor Q1 'on' during the line flyback period. This means that Q1 is switched 'off' when the chroma signal is present.

Because the 4.43MHz PAL colour burst

sits on the back porch of the line synchronising pulse, this means that transistor Q1 amplifies only the colour burst signal. The chroma signal information is not allowed to pass. The resulting 'gated' burst signal is then fed to the phase detector.

As described in part 5, the output of the phase detector locks the set's subcarrier oscillator to the same phase and frequency as the +V chroma signal. The 7.8kHz ripple produced by the phase detector

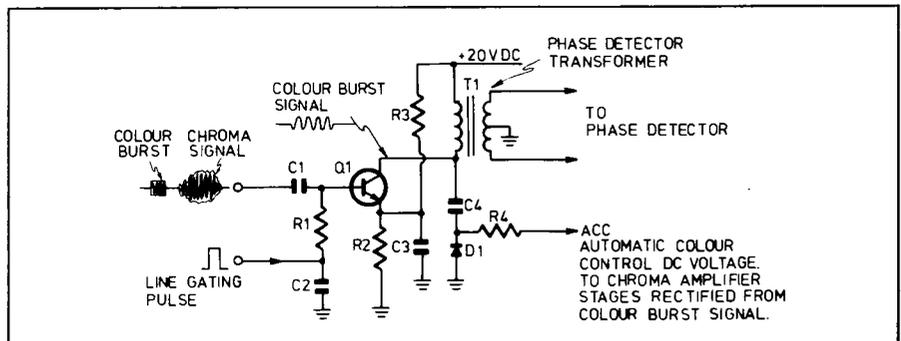


Fig.2: A typical colour burst gating stage, again using discrete components. Q1 only conducts during the line gating pulse, and hence only allows the burst to pass — not the chroma information.

due to the swinging bursts then passes to a further stage which amplifies and shapes the 7.8kHz signal (Fig.3).

The 7.8kHz ripple is amplified by transistor Q1, causing L1 to 'ring' at 7.8kHz. The arrow A in Fig.3 goes to the colour killer circuit, where the 7.8kHz signal is rectified. The resulting DC voltage is used to forward bias the chrominance amplifier.

When the PAL colour TV is tuned to a monochrome programme, a colour burst signal will not be received and the 7.8kHz signal is absent. Since there is now no DC bias present, the chrominance amplifier will be cut off. This prevents colour splashes from spoiling the black and white picture. Fig.3 shows one type of colour killer circuit. From point B in Fig.3, the 7.8kHz waveform is supplied to a bistable circuit (sometimes called a flipflop), used to operate the PAL switch.

The schematic in Fig.4 is that of one type of bistable circuit. The 7.8kHz signal is used to 'steer' the bistable, ensuring that each line of the demodulated V signal is kept correctly in phase with the transmitted V+ and V- signals.

We'll assume that at a particular moment in time transistor Q1 is conducting, and that transistor Q2 is cut off. When a triggering pulse from the receiver line circuitry arrives at point B, it reaches the cathodes of diodes D1 and D2 via capacitors C3 and C4.

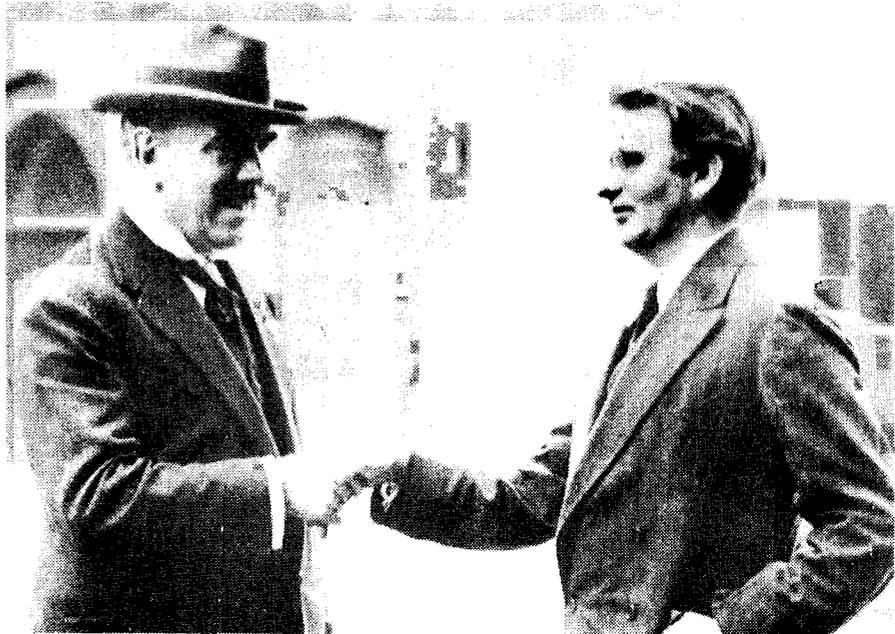
Transistor Q2 is already cut off, but now transistor Q1 will be cut off by the negative pulse at the anode of diode D1. As the current flow through Q1 ceases, the voltage rises at the collector of Q1. By means of the current flow through resistor R3 the base voltage of Q2 becomes more positive, so that now it is Q2 that conducts. As Q2 conducts its collector voltage falls and by means of resistor R4 the base voltage on Q3 drops.

Now it is the turn of transistor Q1 to be cut off. The circuit will remain in this condition with Q2 'on' and Q1 'off' until the next line pulse arrives at point B. This time the line pulse switches off Q2 and the Q1 again starts to conduct.

The outputs of the bistable are at points X and Y and consist of square waves that may be easily viewed on an oscilloscope. Through suitable circuitry these square waves are fed to the PAL switch.

Resistors R3 and R4, together with capacitor C1 and C2 serve to sharpen the output waveform. Resistors R5 and R6 keep the 'gating' of diodes D1 and D2 at the correct operating point.

To synchronise the bistable to the correct phase of the V signal, the 7.8kHz identification signal at point A is supplied to diode D3. The pulse through D3



A glimpse back into the past! John Logie Baird (right), the man credited with achieving the first colour TV transmissions in 1928, shaking hands with Sir John Samuel.

'triggers' the circuit, keeping the bistable in its correct mode.

An output from the 4.43MHz subcarrier oscillator is supplied by the PAL switch to the V synchronous demodulator. (As explained part 5). Fig.5 is the schematic of a PAL switch. The square waves from the bistable switch each diode on in turn. The result is that the input signal from the 4.43MHz subcarrier oscillator to the V demodulator is switched 180 degrees every other 'line' of the picture.

With the bistable in its correct mode the receiver PAL switch is kept correctly synchronised with the TV transmitter PAL switch. The secondary winding of the transformer T1 then supplies the switched 4.43MHz subcarrier to the V demodulator.

You'll remember from our previous discussions that there is a phase difference of 90 degrees between the 4.43MHz subcarrier oscillator signals

which are supplied to the U and V synchronous demodulators.

In older colour TV receivers this was often accomplished as shown in Fig.6. Capacitor C1 and C2 and preset capacitor VC3 form a phase shift circuit to produce the required 90 degree phase shift, before feeding the 4.43MHz subcarrier signal to the U signal demodulator. This 90 degree phase shift depends for its accuracy on the close tolerances of C1 and C2, and also of setting of VC3. If these values change, as they sometimes do, the colour reproduction of the displayed picture will be impaired.

In an integrated circuit of the type that contains the entire decoder circuitry (as for example, the type TDA3652A), this 90 degree phase shift is made very accurately within the IC.

The IC circuitry includes an 8.86MHz 'clock' oscillator stabilised by an external 8.86MHz crystal. How may two signals of

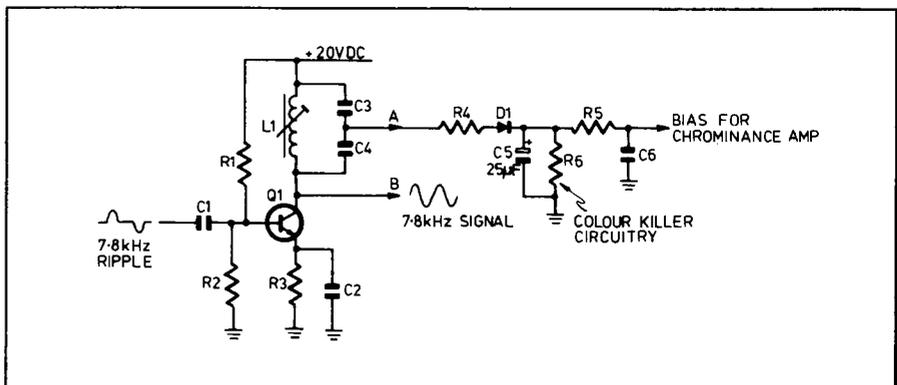


Fig.3: Simplified schematic of a shaper/amplifier stage and colour killer detector, using the 7.8kHz ripple signal produced by the PAL signal's 'swinging burst'.

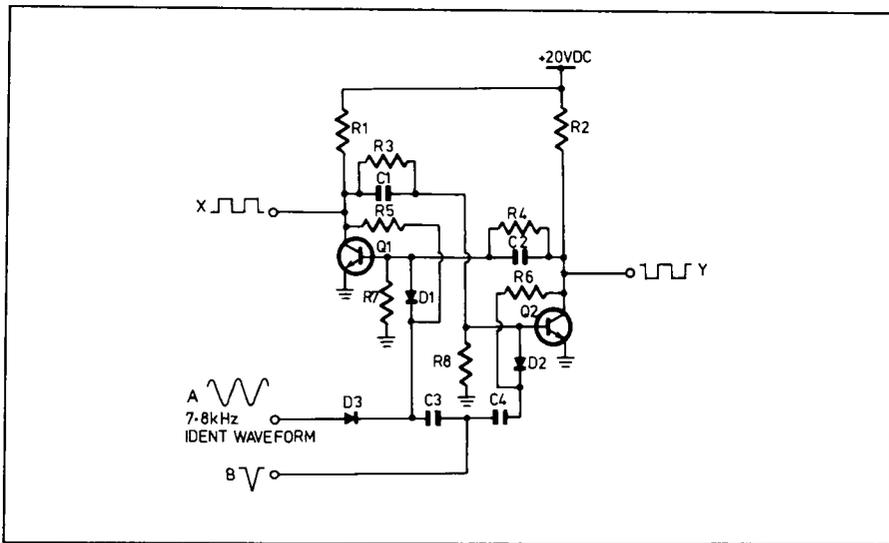


Fig.4: A PAL demodulator bistable flipflop, again using discrete components. The 7.8kHz Ident signal is used to 'steer' the flipflop in terms of phasing.

4.43MHz of the desired phase be obtained from this signal? A JK flipflop divides the frequency of an input clock signal by two. So one solution is to use two such flipflops within the IC, both dividing this frequency by two, but with a difference.

One flipflop is designed to respond to the *rising* edge of the clock oscillator waveform, the other to the *falling* edge of the waveform.

The result is that two 4.43MHz signals are produced, differing in phase by precisely 90 degrees. Fig.7 illustrates this. Signals B and C are now passed through further circuitry to produce corresponding sinewave signals. These are supplied to the U and V colour signal

demodulators contained within the same IC.

Passive subcarrier regenerator

Because you may encounter the subcarrier *regenerator* in some PAL colour receivers, it is worth discussing its operating principles.

In place of the internally generated subcarrier oscillator in a PAL receiver, a 'ringing burst' circuit can be used. This is known as a passive subcarrier regenerator (Fig.8).

The PAL 'swinging burst' signal from the burst gate and amplifier is taken to the primary of transformer T1.

From the bistable circuit which controls the PAL switch, half-line frequency pulses

are supplied to points X and Y. These pulses cause diodes D1 and D2 to conduct as the burst signal 'swings' on alternate lines of picture signal.

In this way a 'non-swinging' burst signal of fixed phase is produced, and feeds via capacitor C1 to the base of transistor Q1. Q1 has 0 volts DC at its base, and so does not conduct. However, during the period when the burst signal is present on the transmitted signal, a positive pulse from the receiver line output transformer switches Q1 'on'. Coil L in the collector circuit of Q1, together with capacitor C2 and 4.43MHz crystal form a crystal-controlled 'ringing' circuit. The 4.43MHz signal produced this way is now amplified by transistor Q2. It is then used in place of the normal local subcarrier oscillator signal.

Passive subcarrier 'oscillators' may also be used in NTSC receivers. Because the NTSC burst is constant in phase, the switching circuit is omitted.

Synchronisation circuitry

The sync pulse separation circuits in a PAL receiver are similar to those of a monochrome TV. The separate horizontal and vertical pulses 'trigger' the vertical and horizontal scanning oscillators in the TV. In this way the picture raster is kept exactly synchronised with the transmitter camera scanning.

Fig.9 shows a basic schematic of a sync separator stage. A composite video signal from the luminance stage is supplied to the input. The values of capacitor C1 and resistor R1 are so chosen so that only the synchronising pulses can cause transistor

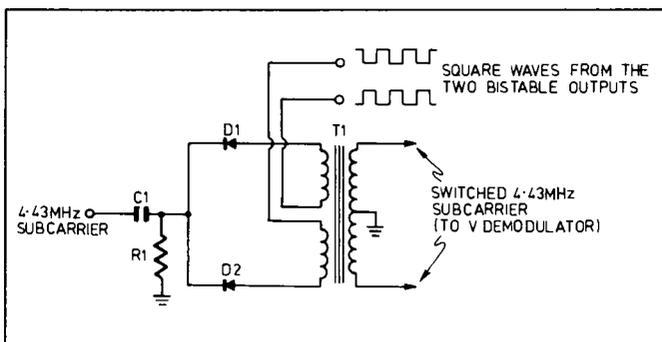


Fig.5: One type of PAL switch, using diodes gated by the square waves from the bistable flipflop.

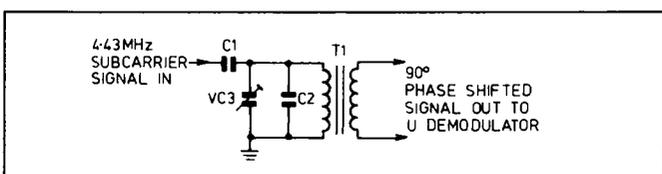


Fig.6: A simple phase shift circuit used to produce the 90 degree phase shift 4.43MHz signal needed for the U demodulator.

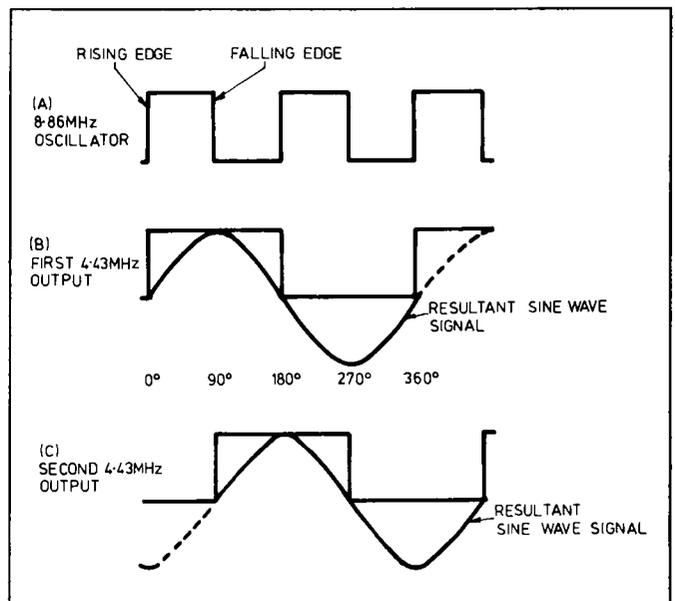


Fig.7: With an IC colour demodulator, flipflops are used to generate the local 4.43MHz subcarriers 90 degrees apart in phase, clocked from an 8.86MHz 'twice frequency' signal.

Q1 to conduct. Line sync pulses pass via capacitor C2 to the line oscillator, and vertical sync pulses pass via capacitor C3 to the vertical oscillator.

Line oscillator and line output stages

Special considerations apply to the line oscillator and line output stages of a PAL colour receiver. Higher power is required by the deflection circuits. There is also the need to provide a constant 24 to 27 kilovolt EHT voltage supply, from which sufficient current can be drawn for the three electron beams of the picture tube without the EHT voltage varying. The tube heaters are usually powered from a winding on the line output transformer.

Add to this the fact that various DC voltage lines are usually derived from the power generated by the line output transformer, often including the DC supply voltage for the vertical scan output stages. Any variations in these supply voltages immediately affect the picture and colour reproduction.

Fig.10 shows a simplified schematic of line circuitry similar to that found in some late model receivers. The receiver power supply is of the self-oscillating type described in part 7. This type of power supply enables the television manufacturer to greatly simplify the design of the line stages. In this way, the cost of production is lowered and reliability is increased. However, you will appreciate that the line and power circuitry of various makes of modern PAL receivers can vary considerably.

Notice in Fig.10 that instead of a line oscillator stage using perhaps a single transistor, the line oscillator is contained within a single integrated circuit. This IC also contains the vertical scan oscillator and all the sync separation circuitry, plus other functions. A 25 volt DC supply from the power unit feeds through resistor R to a 5V regulator IC, providing a regulated 5V supply. Notice that several other DC supply lines are also powered from the windings of the line output transformer.

The line drive output from the IC feeds to transistor Q1 driving, via transformer T1, the line output transistor Q2. Q2 in turn drives the line output transformer T2. This transformer is of the 'split overwind-separate EHT diode' type. The complex dynamic convergence and correction circuits found in the older PAL TV's are not required. This is because of the advanced design of a modern colour picture tube.

Faulty colour reproduction

As with all electronic equipment, faults can occur. Suppose such a fault causes incorrect, or no colour at all on the dis-

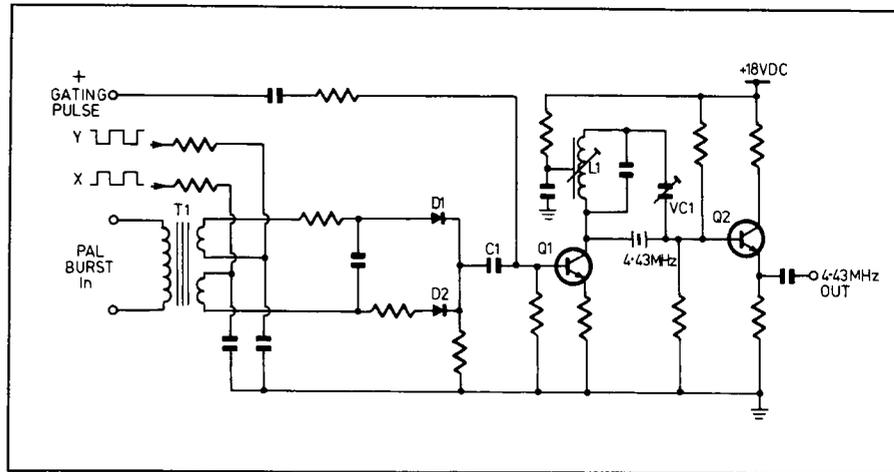


Fig.8: An alternative method used to produce the 4.43MHz local subcarrier signal, by direct regeneration from the signal's own colour bursts themselves.

played picture? Your knowledge of colour TV principles, including additive colour mixing will help to locate the cause. A colour bar generator, together with a suitable oscilloscope is generally essential for this type of fault finding. The correct sequence of the colour bars viewed from left to right on the picture tube is:

White, Yellow, Cyan, Green,
Magenta, Red and Blue.

The picture tube itself can be responsible for colour display faults. For example if the tube has three separate electron guns, (and assuming all the other circuitry is in order), complete failure of one electron gun — perhaps by internal disconnection of its cathode — can occur. This means that only two colours will be present in the picture.

We saw earlier that the colour bars are produced by additive mixing of red, green and blue as follows:

White bar	= Red + Green + Blue
Yellow bar	= Red + Green
Cyan bar	= Green + Blue
Green bar	= Green
Magenta bar	= Red + Blue
Red bar	= Red
Blue bar	= Blue

What will happen, if, for example, the green electron gun fails completely? The white bar lacking green will be red plus

blue — magenta. The yellow bar lacking green will be red. The cyan bar lacking green will be blue. The green bar will be black. The magenta bar, lacking nothing, will still be magenta. The red and blue bars will still be red and blue. And so on.

A sequence of cyan, green, cyan, green, blue, black and blue will be displayed if the red gun fails. Failure of the blue gun will produce yellow, yellow, green, green, red, red and black bars in that order.

Failure of one of the RGB drive output transistors, usually mounted on the cathode ray tube base panel, can result in the complete absence of one colour. It can also cause the predominance of a single colour in the picture, depending whether the transistor has shorted or become open circuit.

If a fault occurs in decoder circuitry that consists of discrete components, or a number of integrated circuits, fault location is generally straightforward. However, usually you will need the manufacturer's service manual.

Complete absence of colour at all can be due to a number of causes. First make sure that the DC supply voltages to the decoder are present. The next step is to put the colour killer circuit out of action.

This is necessary because if the 7.8kHz

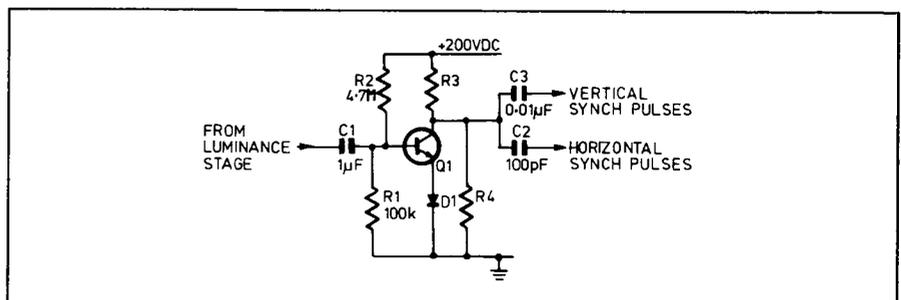


Fig.9: The basic form of a sync separator, using discrete components. Composite video from the luminance stage is stripped back to the sync pulses by Q1.

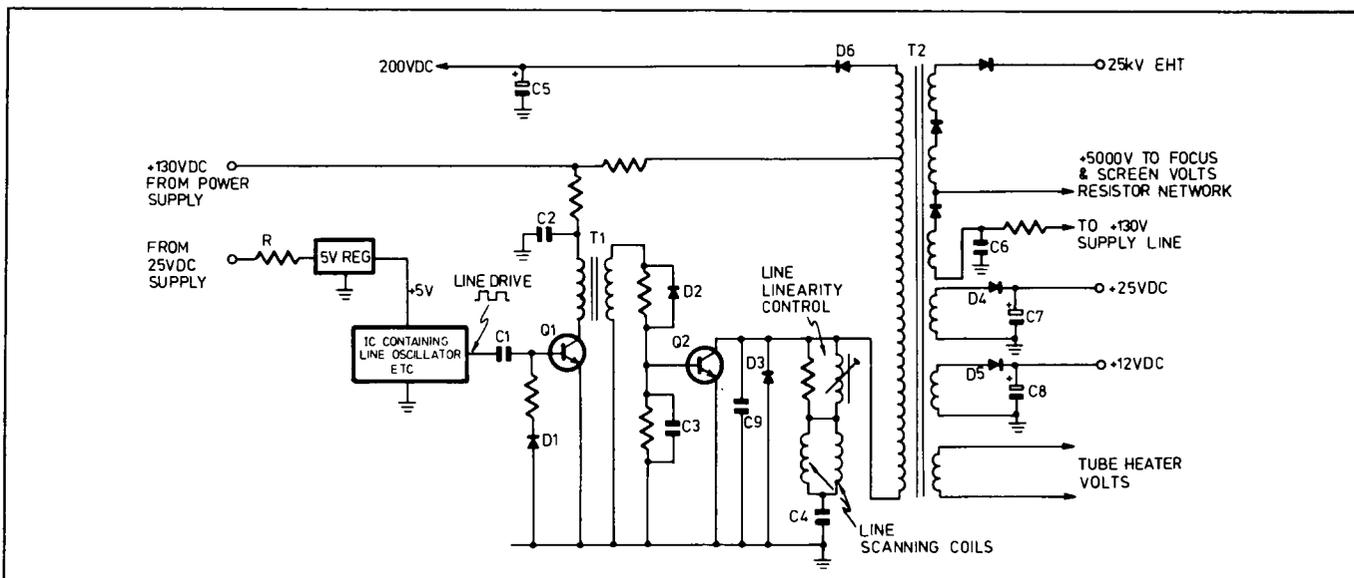


Fig.10: Simplified circuit for the line output section of a modern PAL colour receiver. The exact circuitry varies widely from one design to another, but this is the basic arrangement.

signal is absent, the chrominance amplifier will not function. To disable the colour killer, you'll probably need to consult the manufacturer's service data. If a good colour picture is now viewed, then the colour killer circuit is almost certainly faulty.

Absence of colour in the picture can often be due to the failure of the internal 4.43MHz subcarrier oscillator or its associated crystal. The oscillator output is easily checked with your oscilloscope. Check too the output of the chrominance amplifier. Incorrect colours — viewed with the colour killer out of action — are caused by a variety of faults. If the 4.43MHz oscillator is slightly off frequency, incorrect colour bars will be displayed. Faulty burst gate circuitry may produce a strange effect of multi-coloured bars, each composed of several different horizontal colour stripes.

A stopped bistable circuit results in a picture where every other line is the wrong colour. An inoperative output of one synchronous demodulator will obviously result in incorrect colours. As an example, consider the results of the failure of the (R-Y) demodulator. Since no (R-Y) will be present, red, yellow and green signals will all become signals consisting of only minus (B-Y) signal voltages. These three colours will now be the same hue but will have different amounts of saturation.

In the same way, magenta, blue and cyan signals will now consist of only plus (B-Y) signal voltages of the same hue, but again will have different amounts of saturation. Examine the phasor diagrams shown in parts 2 and 6, and you'll see that red, yellow and green become a

greenish yellow in hue. Magenta, blue and cyan show as a slightly magenta tinged blue.

Failure of the luminance circuitry leaves only the colour information, and produces a fuzzy colour image that lacks all fine detail. We only have space to mention some of the causes of colour troubles in the PAL receiver. However, remember that symptoms can vary with different designs of colour TV's.

In the case of the latest PAL receivers all the decoder circuitry is enclosed in a single integrated circuit. So if any of the

individual circuitry we have considered fails, then the IC must be replaced. Only a few external components need to be checked before changing the IC. However, the 'one-chip' decoder is extremely reliable, and seldom fails.

The modern PAL set

Infrared remote control handsets, special tuning facilities, teletext displays, stereo sound, digital and microprocessor circuitry, together with many other advancements, are some of the developments contained in the latest PAL receivers. For example, the TDA3562A 'one-chip' decoder contains facilities enabling a TV receiver which incorporates this integrated circuit to be used as a direct RGB-driven computer monitor, etc.

Fig.11 shows a photograph of the National Panasonic TX3370 receiver. It uses a 33-inch FST picture tube, has provision for stereo sound, computer controlled teletext and many other sophisticated features. This advanced receiver is, in a sense, a descendant of the first scanning disc colour 'television' demonstrated by John Logie Baird in 1928 - only 64 years ago!

In these articles the principles of PAL colour TV, together with the basic circuitry of the PAL receiver have been covered. You'll find it helpful to continue your study by examining the circuitry of both older PAL receivers and that of the newest models.

Keep in mind that all PAL TV receivers make use of the same basic techniques of the PAL colour system. A knowledge of PAL and colour TV techniques is also essential for an understanding of the operation of modern video cassette recorders.

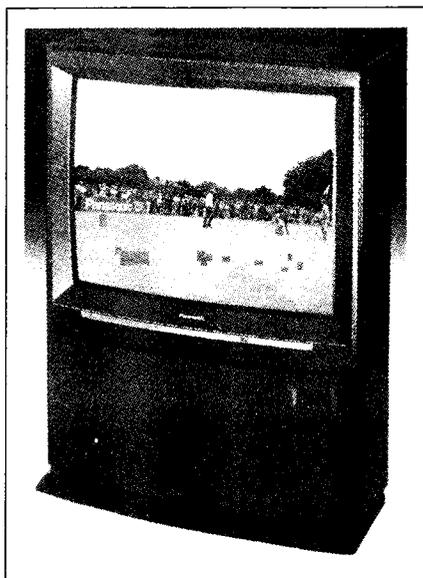
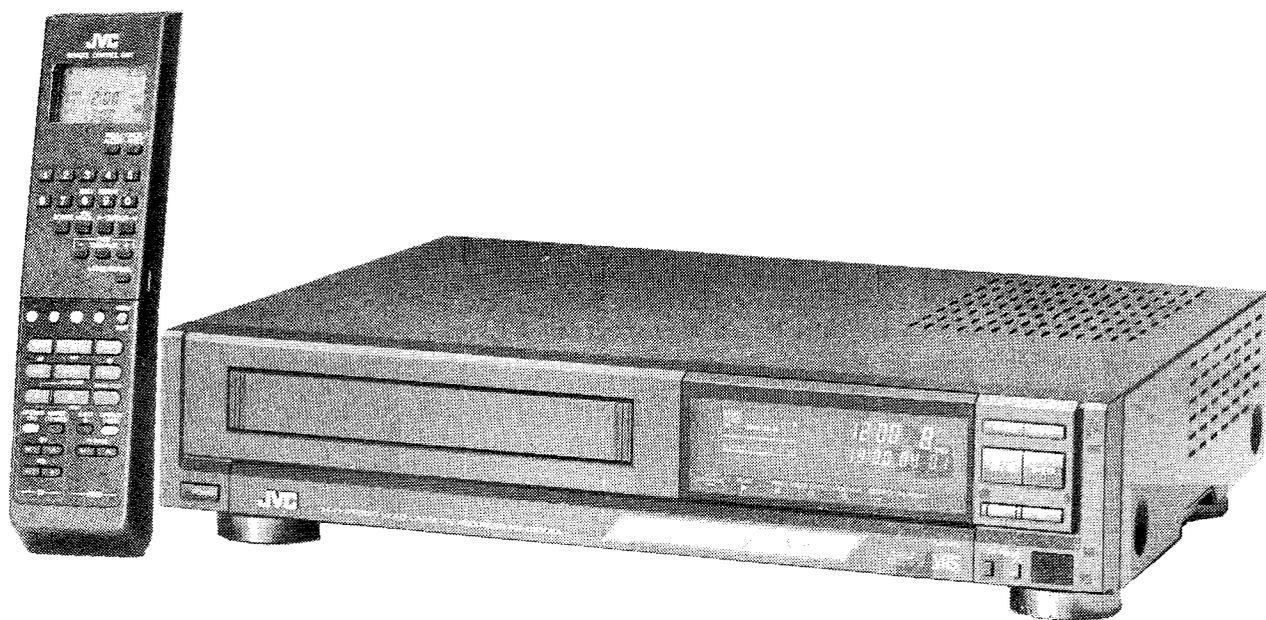


Fig.11: The National Panasonic TX3370 receiver is a British model, but illustrates the current state of the art. Featuring a 33-inch screen, it also provides stereo sound, Teletext and many other sophisticated functions.

VCRs



STORING THE VIDEO INFORMATION

Part 1

In this first part, we explain the operation of video cassette recorders — with special emphasis on the popular VHS, Betamax and Video-8 systems, and the author introduces the basic concepts of video recording.

In order to gain an understanding of the principles of video cassette recorders, we'll begin by considering the fundamentals of magnetic recording itself. By magnetic recording we mean the process during which some type of ferrous material is magnetised in accordance with an electrical signal variation.

With a reasonably priced domestic audio cassette recorder, audio frequency signals between about 60Hz and 10kHz can be recorded. Here the magnetised material is flexible tape coated with some type of ferrous oxide.

In such a recorder the sound waves are first converted to electrical energy by the microphone. This energy is then passed through an amplifier and supplied to the recording head. The tape passes over the head at a constant speed during the recording process.

The recording head consists of a

coil of wire wound on a core made of ferrite material.

When the AC signal is passed through the recording head, the core of which has its two ends close together, magnetic flux extends across the gap (Fig.1a). We'll refer to these ends as north and south magnetic pole pieces. They reverse their polarity as the AC signal goes through its cycle (Fig.1b). As the intensity of the AC signal increases and decreases, so the strength of the magnetic flux increases or fades away according to the strength of the signal.

During the recording of speech or music not only does the intensity of the AC signal vary but also the spectrum of frequencies. Each time the signal changes polarity so does the direction of the magnetic flux.

If the tape were stationary or moving very slowly, the magnetised areas would

cancel each other out so that no magnetic pattern would be produced on the tape.

The tape must be moved at a constant and sufficient speed across the head gaps, so that discrete areas are magnetised according to the signal content at each particular moment (Fig.2).

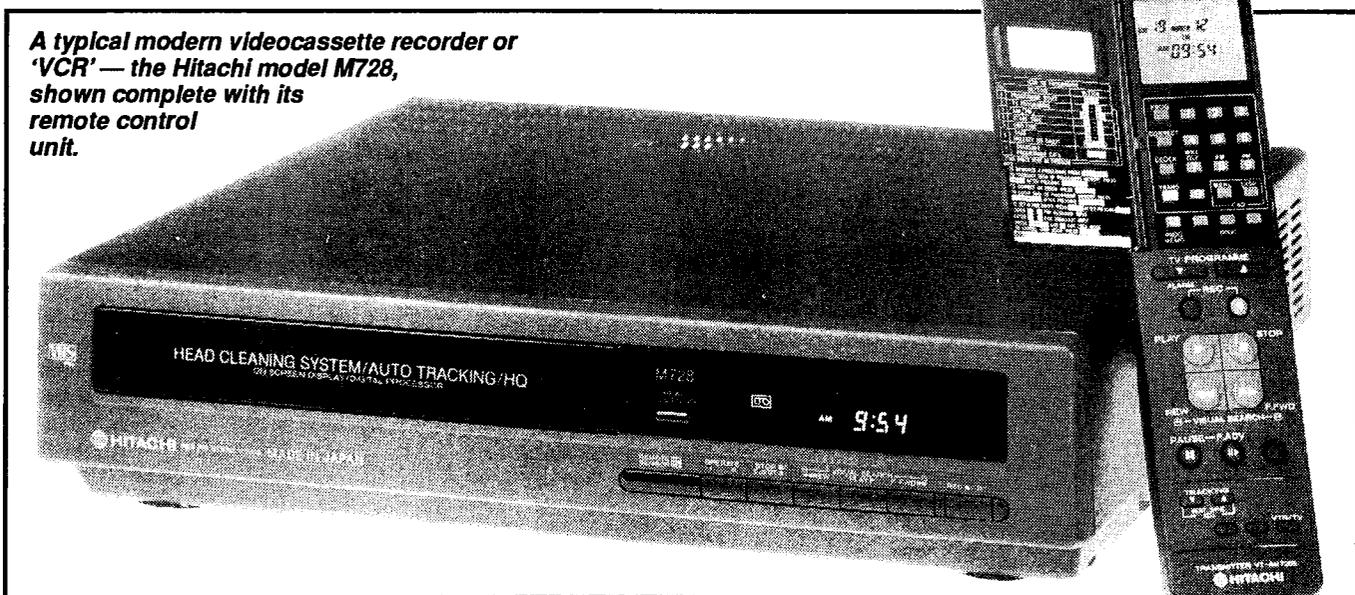
Notice the length needed to record one complete cycle of 360 degrees. This is known as the recorded wavelength. The basic formula for this is: -

$$L = V/F$$

where L is the recorded wavelength in metres, V is the speed of the tape relative to the head, in metres per second, and F is the frequency recorded, in Hz.

However, if the head gap size is made very small, the tape speed may be reduced. The approximate relationship is then given by $G = V/2F$, where G is the head gap width, and V and F are as before.

A typical modern videocassette recorder or 'VCR' — the Hitachi model M728, shown complete with its remote control unit.



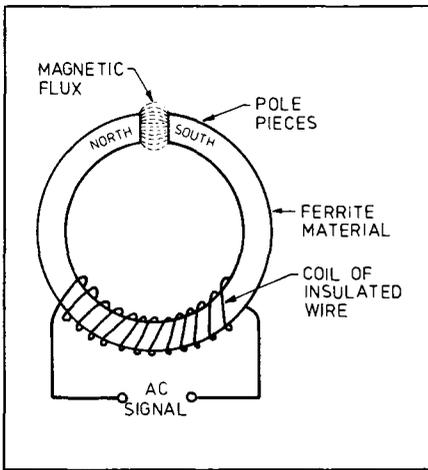


Fig.1(a): Basic idea of a magnetic tape recording head, as used for both audio and video.

Make a special note of these formulas, because they help in the understanding of the video recording/playback process.

When the magnetic force across the head gap doubles it does not produce twice the amount of magnetism in the recording material of the tape. The relationship between the tape head and tape is thus *nonlinear*. There is also the effect of magnetic *hysteresis* to consider — the fact that when the signal current in the recording head falls to zero, some magnetism is retained by the head. The distortion shown (Fig.3b) is largely overcome by the use of an AC bias voltage, plus careful head design.

A sinewave 'bias' signal having a frequency above audible range is generated by an oscillator contained in the recorder. A stronger version of the sinewave signal is also applied to another head called the erase head, to erase previous recordings.

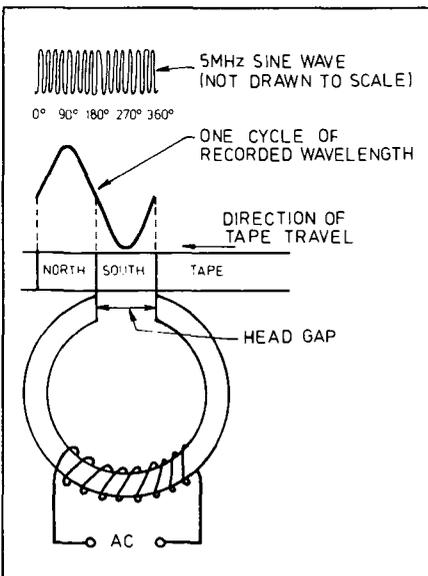


Fig.2: The wavelength recorded on the tape depends on both the tape/head speed and the frequency.

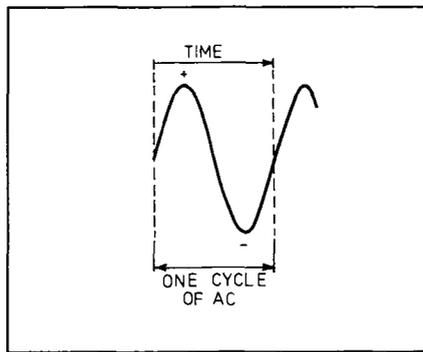


Fig.1(b): On alternate AC half-cycles, the magnetic poles are reversed.

With the bias signal added to the audio signal fed to the record/play head (Fig.3c), the result is as in Fig.3d. The effect of the bias signal is to prevent the head and tape from operating in the non-linear centre section of the characteristic, giving linear recording.

The diagram of Fig.4 shows the basic recording method used for audio recording. The same principles including the use of bias voltage apply to the sound recording circuitry of a video cassette recorder. (For example in the Sony model SL-C6UB VCR, the frequency of the sound channel bias signal is 65kHz, plus or minus 6.5kHz).

In an audio cassette recorder using standard cassettes the speed of the tape across the head is 4.75 centimetres per second or 1-7/8" per second. We'll refer to this as the head-to-tape speed.

When the recorded tape is 'replayed', by passing it back over the play/record head, the areas of magnetism on the tape set up a magnetic flux at the head gap. This induces a voltage in the coil of the head, which is amplified and fed to a loudspeaker. The output produced is a reasonable reproduction of the original recorded sound (subject of course to various losses and distortions).

Recording video

Although the same basic principles of magnetic recording we've described apply when recording signals of video frequencies, there are various complica-

tions to be considered. For example, you'll recall that video signals which contain the fine detail of a TV picture occupy a bandwidth of 5MHz. Can such a signal bandwidth be recorded on magnetic tape?

Look again at Fig.2. You will see that the polarity of a 5MHz signal will reverse 5000 times faster than say, an audio frequency signal of 1000Hz. If the head to tape speed remained at 4.75cm per second, the 'north' and 'south' fields would overlap on the tape — cancelling out the signal.

Another problem is that as the signal frequency increases, so does the impedance of the tape head's coil, as it is basically an inductance. This means that a far greater signal voltage must be used to 'drive' the head, to obtain the same head current and magnetic flux strength. In point of fact the recording head voltage would need to be thousands of times greater at 5MHz than at 10Hz!

A further characteristic of magnetic recording/play heads is that on *playback*, the head generates a voltage that is proportional to frequency (assuming a constant magnetic flux level on the tape at all frequencies).

This means that with a video head designed to handle frequencies up to 5MHz, the signal output at very low frequencies will be practically zero.

In standard audio tape recorders in play mode, the lower frequencies from the head are boosted to the level of the higher frequencies by post-equalisation. When recording, pre-equalisation is given by boosting the high frequency signals. However, remember that for audio recording, the frequency range covered is typically only 50 - 20kHz — a little over eight octaves. (*Electronics Australia* readers will remember that frequency doubles for each successive octave).

In comparison, the frequency range for a full video signal will be 17-18 octaves. Each time the frequency is halved, the video head output voltage drops by 50%. So the output at very low frequencies would be around 250,000 times smaller than that at the highest frequency. Such a

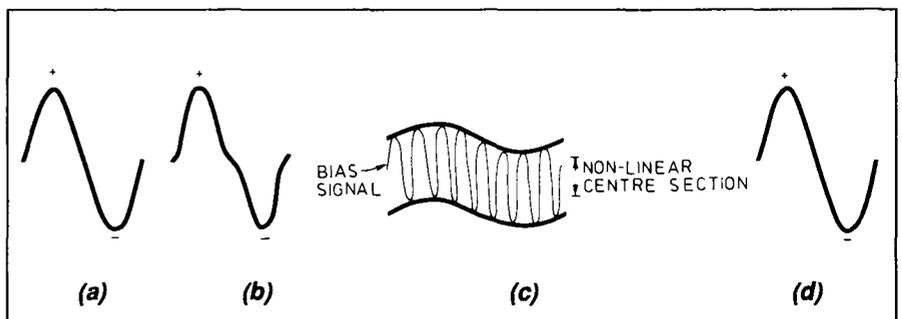


Fig.3: Using supersonic bias to obtain linear recording. (a) shows the original signal, and (b) the recording without bias. This bias signal is added to the audio (c), to 'skip' over the nonlinear magnetic region and produce a linear output (d).

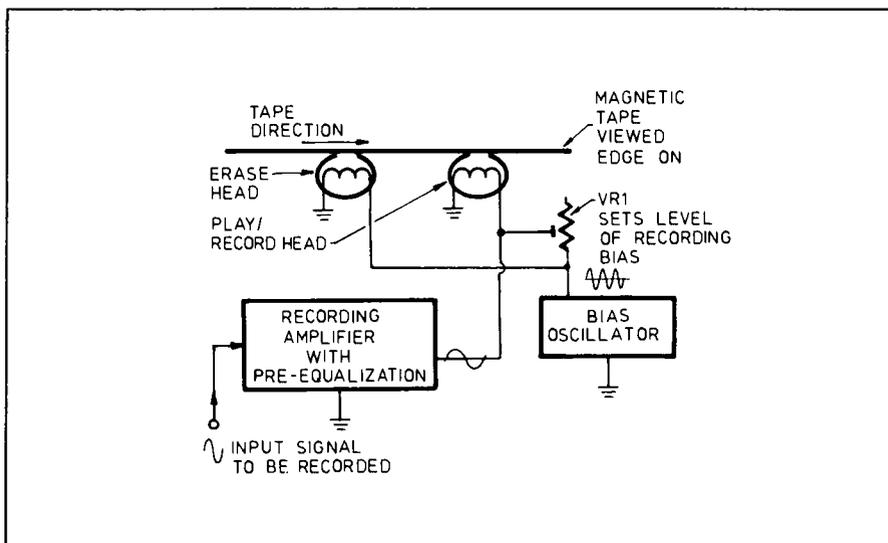
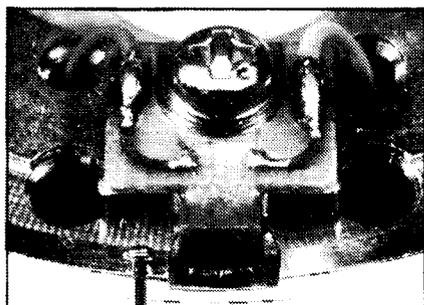


Fig.4: The basic arrangement for conventional audio recording, using a supersonic signal both for erasing the old recording and providing 'bias'.

range could not be compensated using an equalisation process.

Forgetting this problem for a while, what tape speed would be required in



Above: A close up of one head .

order to record signals of up to 5MHz — assuming a head gap of say one micrometre, and a straight reel to reel cassette machine?

The approximate speed is calculated by the formula — $V = G \times 2F$ — where V is again head to tape speed, G is the head gap width, and F is the frequency. So for a 5MHz bandwidth, the required tape speed would be 0.000001 times 2 times

5000000, or 10 metres per second. To play such a VCR tape for one hour, you'd not only need a giant cassette holding 36,000 metres of tape, but also a VCR of colossal size. This would of course be unacceptable.

However, the tape format in a domestic VHS-type VCR is such that the linear tape speed is actually only 23.39mm per second, +/-5%. In fact a standard one hour play 'E60' VHS cassette contains just over 88 metres of magnetic tape. Yet the head to tape speed is obviously sufficient to handle the video signal — so how's it done?

Helical recording

The secret is the use of helical recording, which enables the linear speed of the tape itself to be reduced, while increasing the relative speed between it and the heads. Instead of a single fixed play/record video head, two heads are set diametrically into a small drum which rotates. The tape wraps around the drum as it moves forward, and in this way both heads and tape move forward together.

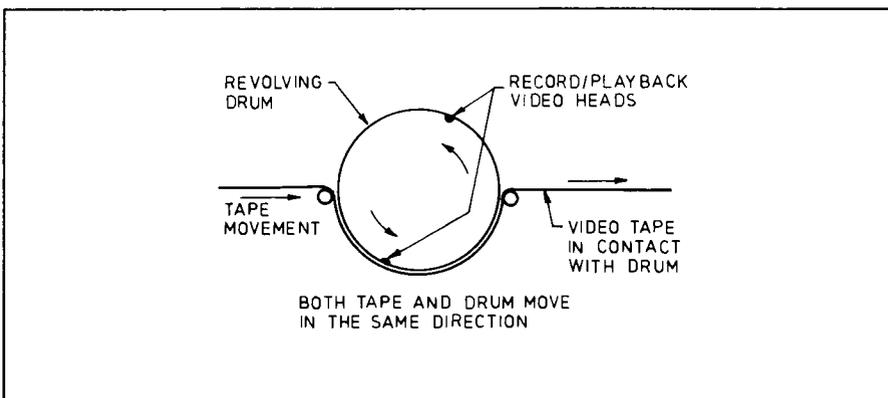


Fig.5: In a VCR, the video heads are on a drum which rotates at 1500rpm, to achieve the necessary head-to-tape speed.

However the head drum is tilted at an angle to the tape, and this plus the fact that the drum is rotated at quite high speed causes the heads to 'scan' the tape in slanted tracks.

Because the heads move across the tape at speed, the linear tape speed can be considerably reduced. You can see from Fig.5 that the drum moves in an anticlockwise direction and so does the magnetic tape. (This diagram shows the basic VHS system — the Betamax arrangement will be discussed in a later article).

To slow the tape speed still more, and also to reduce the width of the magnetic tracks, the head gaps of each head are reduced in size to about 0.3 micrometres. Since the heads are smaller, less head material is used — reducing their efficiency. This is overcome by careful design, extremely precise construction, and the use of hot-pressed ferrite material for the cores.

Two video heads are needed because as the drum rotates, only one of the heads is in contact the the tape at a given moment. Fig.6a shows the path of the tape around the drum.

Notice that the two heads are removed from each other by 180 degrees. A rotary transformer set inside the complete drum assembly conveys the signals between the heads and the VCR circuitry. The rotating drum has a diameter of 62mm for VHS machines.

From Fig. 6a you can also see that the tape is wrapped round the drum in the shape of a helix, because of the drum being tilted.

A further complication is that the two heads are not set in the drum with their gaps exactly at right angles to the direction of rotation. Instead they are each set at an angle of 6 degrees plus or minus from this 'zero' position (i.e., one is at +6°, and the other at -6°). This angle of six degrees is known as the azimuth angle.

The two different 'opposite polarity' azimuth angles are used to ensure that each head identifies its own tracks for playback — see Fig.6b.

As each head moves across the tape once, the resulting magnetic track is used to record one TV picture field, consisting of 312.5 lines (each complete picture, or frame consists of 625 lines).

The video head-to-tape speed is called the *writing speed*, and for the VHS format this is 4.85 metres per second. In the same format the linear tape speed is only 23.39mm per second. Because the vertical scan rate of a TV picture is 50 fields per second, each head has to scan 25 tracks per second, a total of 50 tracks. This means that the video head drum has to rotate at 25 revolutions per second, or 1500rpm.

The width of each of these video tracks is 0.049mm. The total width of the tape is 12.65mm. Besides the video tracks, the tape carries one or more sound tracks, and a control track for synchronising the tape speed. These tracks are all recorded in the normal linear fashion, as in Fig.4.

The VHS video head to tape writing speed is considerably slower than the 10 metres per second previously discussed. Partly this is due to the use of head gaps of only 0.3µm.

Yet another reason why the head to tape speed can be reduced is that — with a domestic VCR — the full 5MHz bandwidth of the luminance or detail signal is not present. In the colour record mode, the VCR circuitry passes the complete TV signal through a lowpass filter, which removes any chroma content and allows only a luminance signal with a bandwidth of about 30Hz — 3MHz to pass.

However, some VHS video cassette recorders allow a luminance bandwidth of about 4MHz when recording a monochrome signal. Despite the reduced bandwidth, a domestic VCR still produces quite a good picture, as most users would agree.

Just the same, if you examine a recording of a test pattern you will see that the very high frequency bars cannot be distinguished. This explains what is sometimes called the 'weakness' of the video signal produced by a VCR. However the latest generation of machines use a special image signal processing technique known as 'HQ' (high quality) circuitry, and this produces a significant improvement in the picture.

Frequency modulation

Earlier we referred to the fact that the very wide bandwidth of a video signal tended to pose a problem, due to the way that the inductive impedance of the recording head rises with frequency. Because of this, for normal magnetic recording as in Fig.3, we would require thousands of times more head voltage at say 5MHz, compared with say 30Hz.

To avoid this problem, the wide bandwidth luminance signal is not recorded directly, but is instead recorded using a process of frequency modulation (FM), using a high frequency carrier signal. This doesn't actually reduce the bandwidth, but effectively moves it upward in frequency — reducing the ratio between the highest and lowest frequencies.

Using FM also gives better signal-to-noise performance than would be achieved using direct recording. FM signals of sufficient strength are far less sensitive to unwanted interference.

Keep in mind too that provision must

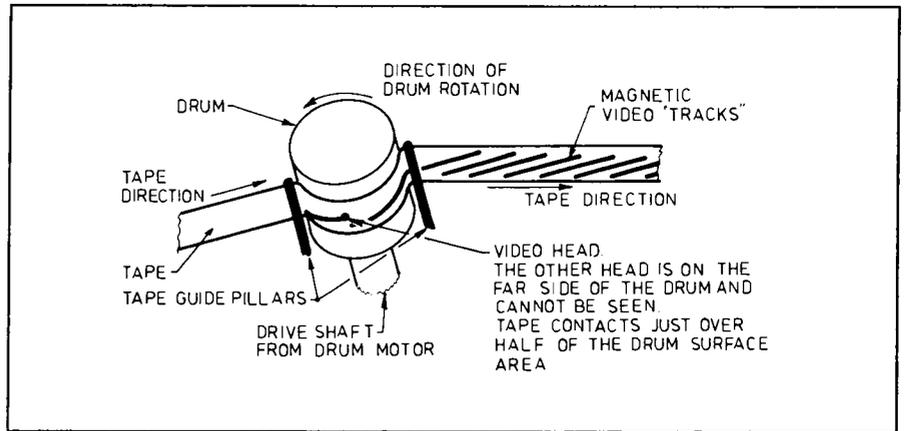


Fig.6(a): The head drum is tilted, so that the rotating video heads produce obliquely slanted 'tracks'.

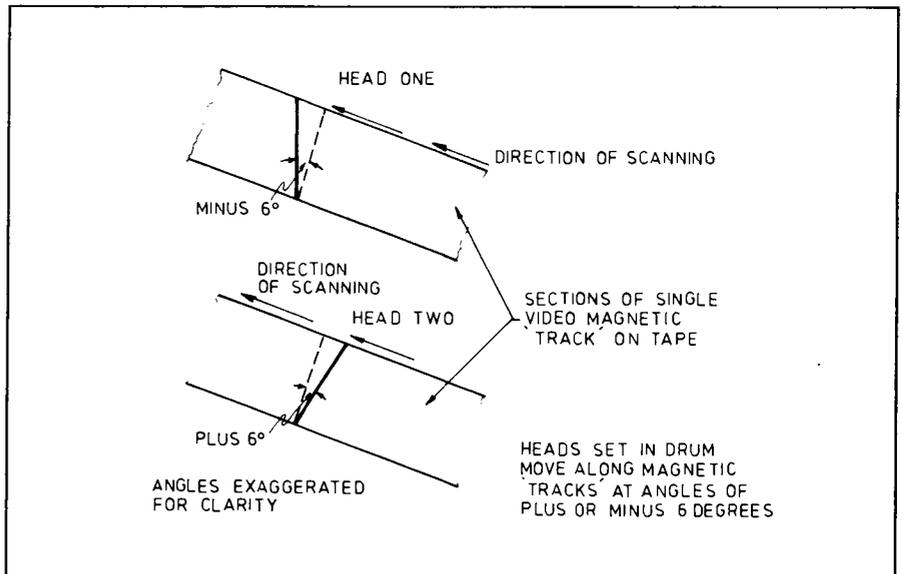
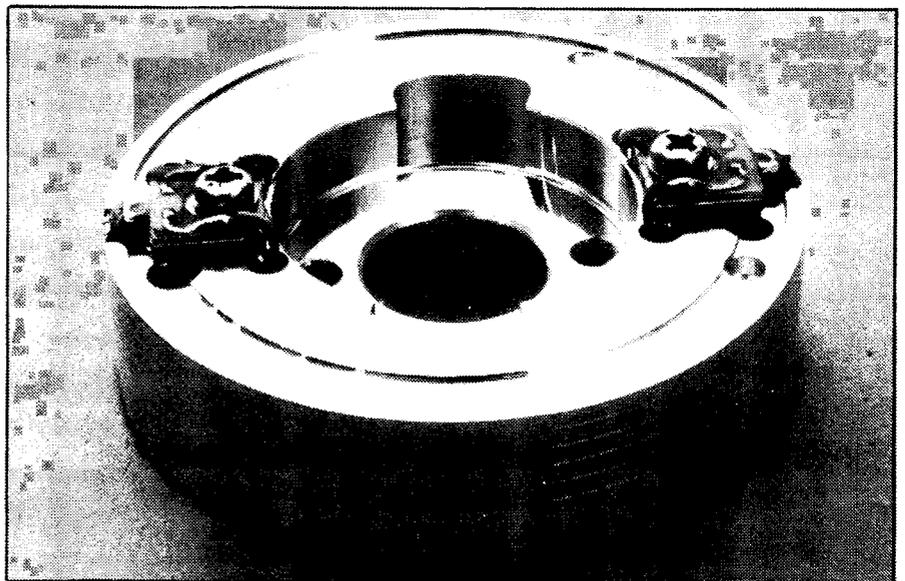


Fig.6(b): The two head gaps are also given opposite polarity azimuth angles, for correct track identification.



Left: The video head drum from a typical VCR, showing the two magnetic heads.

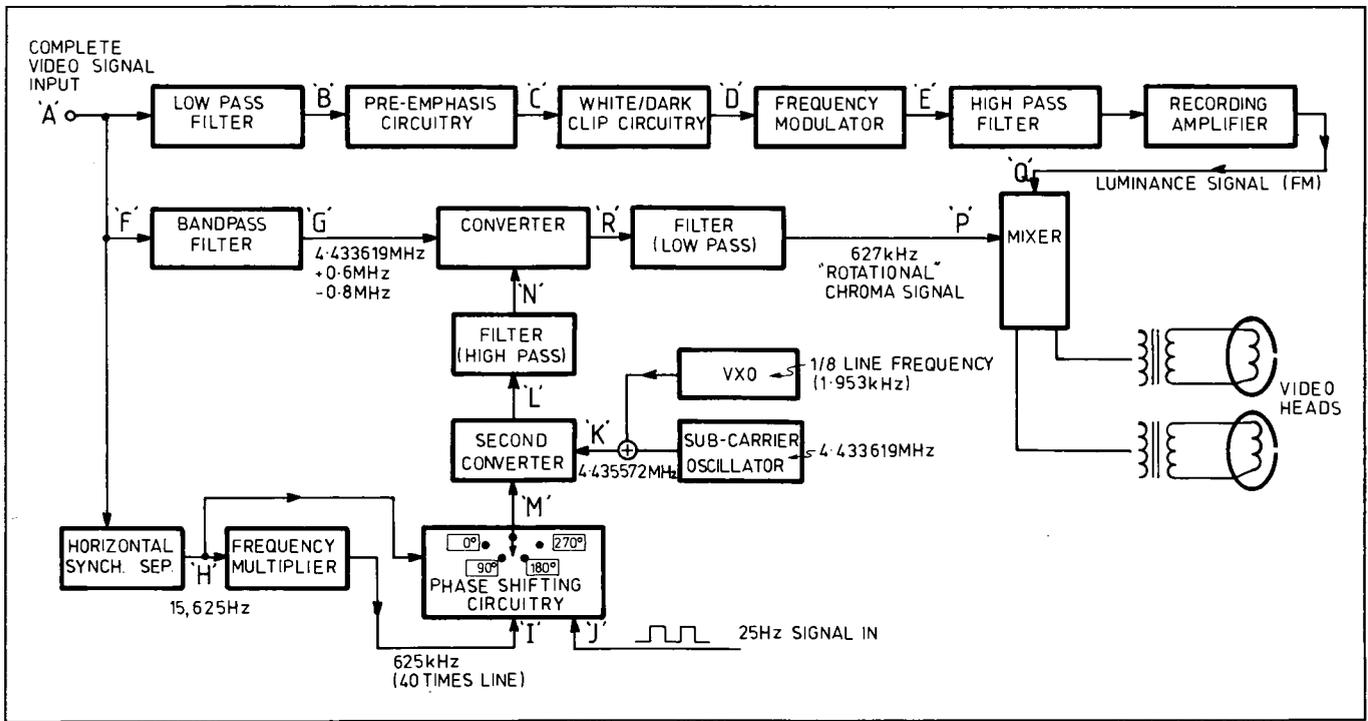


Fig.7: Block diagram of the luminance and chrominance recording section of a typical VCR. The frequency modulated luminance signal acts as bias for the chroma signal.

also be made for recording the colour and synchronising signals.

Recording the luminance

Fig.7 shows a simplified block diagram of the luminance and chrominance signal recording section of a typical VHS domestic machine. To understand the processing of the signals a knowledge of colour TV principles is helpful.

The complete video input signal enters the circuitry at point 'A'. The low pass filter removes the chrominance signal, leaving only the luminance signal — now reduced in bandwidth from 5MHz to about 3MHz. The signal next enters the pre-emphasis circuitry, (point 'B', where the high frequencies of the signal are boosted.

From point 'C' the signal passes through the white/dark clip circuitry. The W/D clip circuitry is required because after pre-

emphasis, the positive and negative going 'spikes' of the signal may be too large in amplitude for proper frequency modulation.

At point 'D' the signal enters the frequency modulator, which converts the luminance signal into an FM signal (point 'E'), which travels on via a high pass filter to the recording amplifier, and then on to the recording heads via mixer circuitry.

Colour conversion

Exact circuit arrangements vary in different VCR's, but the block diagram of Fig.7 also shows the basic method of colour signal conversion.

To prevent patterning on the recorded picture, due to 'beating' between the luminance and chrominance signals, the colour signal is passed through a bandpass filter, (point 'F') to converter circuitry (point 'G'). You'll see from the diagram that the video signal also goes to the horizontal synchronisation separator circuitry which then feeds 15,625Hz (TV line frequency) at point 'H' to a multiplier, and then to the phase shift circuitry.

The multiplier produces a frequency of 625kHz, which is forty times the line frequency. The 625kHz signal enters the phase shifter circuitry, (point 'I'), to the first subconverter but is delayed in phase by 90 degrees for each successive line of each individual picture field. You'll remember that each complete frame of transmitted picture consists of two fields (Fig.8). A 25Hz square wave signal, synchronised to the video head rotation enters the phase shifter at point 'J'.

Also supplied to the subconverter is a colour subcarrier signal (4.433619-MHz) to which is added a signal at 1/8th of the line frequency, or 1.953kHz (to four figures).

Adding the two signals produces a 4.435572MHz signal which enters the second converter at point 'K'. Notice that at point 'M', the continually phase shifted signal of 625kHz is presented. At point 'L', the 625kHz is added to the 4.435572MHz signal, to produce a frequency of 5.060572MHz. This signal feeds through a high pass filter and enters the converter at point 'N'.

The chroma signal at point 'G' has a bandwidth of approximately 1.2MHz, centred on 4.433619MHz. This is mixed in the converter with the 5.060572MHz signal, to produce at point 'R' a down-converted signal of the same bandwidth, but centred on 626.953kHz. This frequency, you'll notice, is the sum of 40 times the line frequency plus 1/8th of the line frequency. It is usually referred to as the 627kHz rotational chrominance signal.

The 627kHz rotational chroma signal is taken through a low pass filter, to enter the final mixer circuit at point 'P'. The FM luminance signal fed to the mixer at point 'Q' is used as the bias signal for the chrominance signal.

The luminance and chroma signals are then taken to the two video heads and recorded on the video cassette tape. We discuss this recording process, together with the alternate azimuth-phase 'tracks' produced on the cassette tape in detail later.

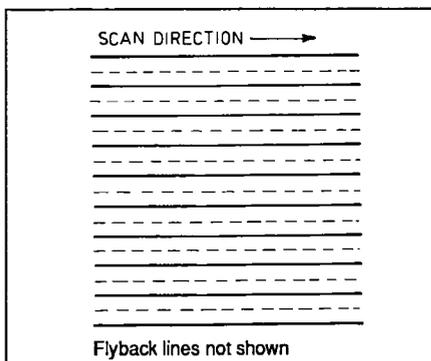


Fig.8: Showing the way that the scanning lines for alternate TV fields are 'interlaced'.

VIDEO RECORDING SYSTEMS

Part 2

Now we discuss the operation of video cassette recording and the author describes the way video signals are recorded using the VHS, Betamax and Video-8 systems.

One of the problems encountered in recording video signals is that the bandwidth of a modern 625-line TV receiver is several megahertz. Fig.1 shows the TV station bandwidth for Australia.

In part 1 of this series we discussed the use of helical recording. In this system you will remember two video heads with very small gaps are set into a rotating drum at an angle to the moving magnetic tape.

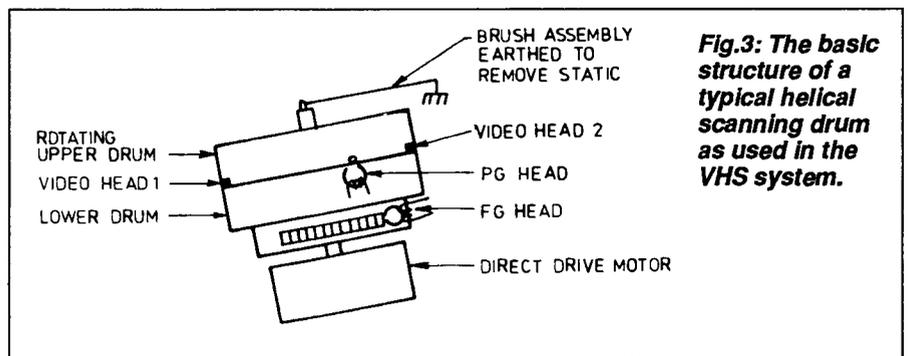
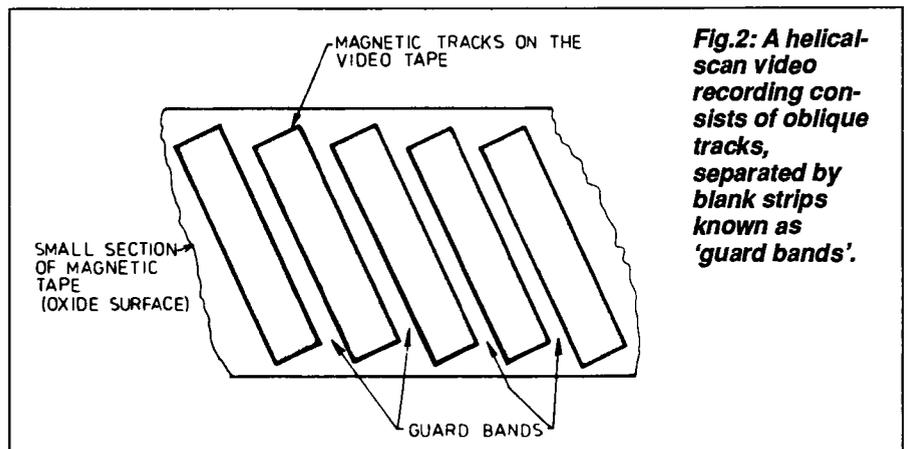
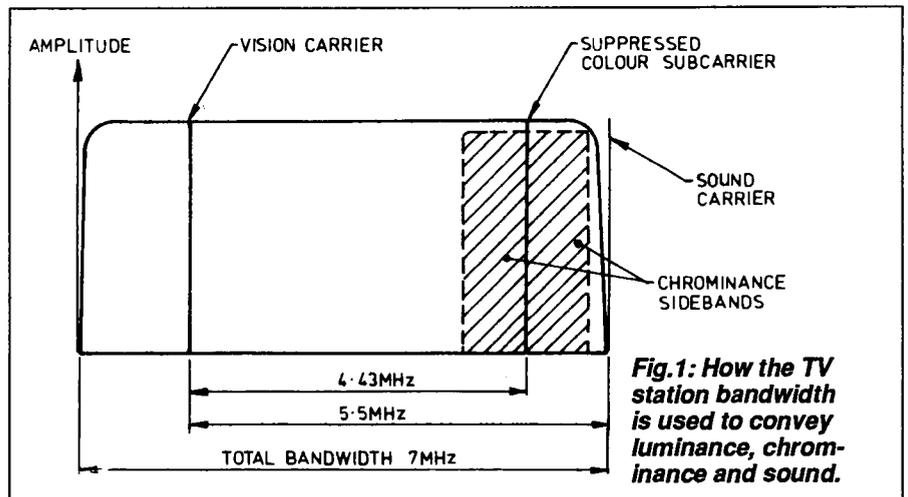
TV picture information recorded in this way first passes through a special filter circuit. This reduces the bandwidth to about 3MHz (a wider bandwidth is possible with the newer VCR's). The luminance or detail of the picture is then recorded as a frequency modulated signal, and the chroma information as a 627kHz 'rotational' signal using the luminance as bias.

In early video recorder systems, interference was experienced between the video 'tracks' because as the two video heads scanned the tracks, each tended to pick up some picture information from the two adjacent tracks. To prevent this occurring, *guard bands* were used (Fig.2). The space between the tracks became a wasted area and considerably decreased the total recording time on the tape.

The VHS format

The need for guard bands was overcome by the use of *azimuth recording*, where the gaps of the two video heads are not at 90° to the direction of writing along the track, but offset at complementary angles to each other — one at minus six degrees and the other at plus six degrees (VHS system).

Fig.3 is a sketch showing the basic construction of a typical VHS drum assembly. The magnetic tracks are then laid down as in Fig.4. The azimuth angle prevents the video head scanning say track 'X' from picking up any significant signal information from tracks 'W' or 'Y'. Similarly when track 'Y' is scanned information on tracks 'X' and 'Z' is not picked up. This results in



a greater density of recorded material and a longer tape playing time. As an example, in a standard two head VHS recorder an E-30 tape cassette contains approximately 45 metres of magnetic tape and plays for thirty minutes. An E-180 cassette contains approximately 258 metres of tape and runs for three hours.

The tape holding the magnetic material is typically composed on high quality polyester film. How the magnetic tape information is arranged on a VHS tape is shown in Fig.5. The letter 'A' on the sketch indicates the total tape width of 12.65 millimetres. The letter 'B' indicates the video track width (10.60mm).

Each video track has a width of .049mm. At the top of the tape the audio track is shown. Where a single audio track is used it is 1mm wide. If two separate audio tracks are required for stereo reproduction they are each 0.35mm in width. Alternatively each track may hold a different spoken language, in which case the desired language can be electronically selected by the VCR circuitry.

At the lower edge of the tape is an 0.75mm control, or synchronisation track. We will discuss this track in more detail in the next chapter.

The VHS cassette and deck threading format is shown in Fig.6. The tape speed is 23.39mm per second, +/-0.5%. A loop of magnetic tape is pulled out from the cassette by the VCR mechanism and arranged as shown.

The tape feeds from the supply spool past the supply guide pin 'A', the tension pin 'B' and guide post 'C'. It then passes over the surface of the full erase head 'D'. When the VCR is in the RECORD mode, this head is supplied with an AC sinewave bias signal which has a typical voltage of about 115V peak to peak. This signal removes any previous recording(s) that may be on the tape.

The tape next passes inertia roller 'E', over supply guide roller 'F' and supply slant pin 'G'. It now travels around the video head drum, contacting just slightly more than half of the drum at any given moment.

The direction of the drum's rotation is shown by the arrows. The tape now continues its journey and moves around the take-up slant pin 'H', around the take-up guide roller 'I' and across the heads of the audio erase/audio record/playback head 'J' and control head 'K'.

The tape next continues past the take-up guide pin 'N', through the capstan 'L' and pinch roller 'M' and back into the cassette onto the take-up reel. Notice that both video drum and tape travel in the same direction.

The tape-to-head or head writing speed is 4.85 metres per second. The VHS format is sometimes referred to as an 'M' for-

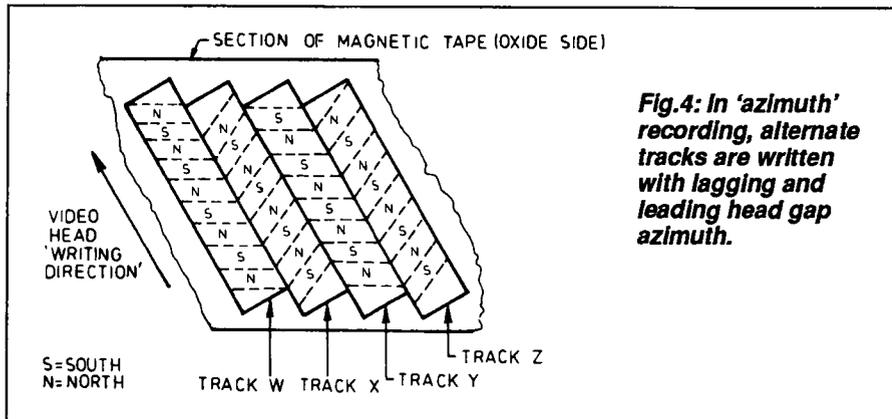


Fig.4: In 'azimuth' recording, alternate tracks are written with lagging and leading head gap azimuth.

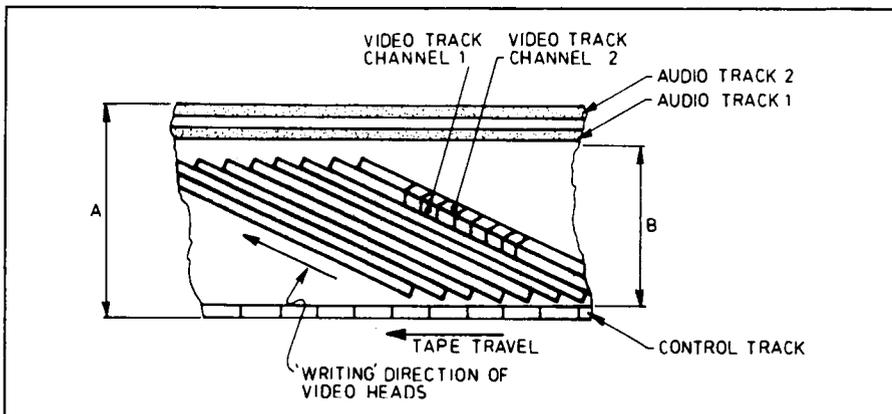


Fig.5: The basic track format used for the VHS system. Tape width A is 12.5mm, while video track width B is 10.6mm.

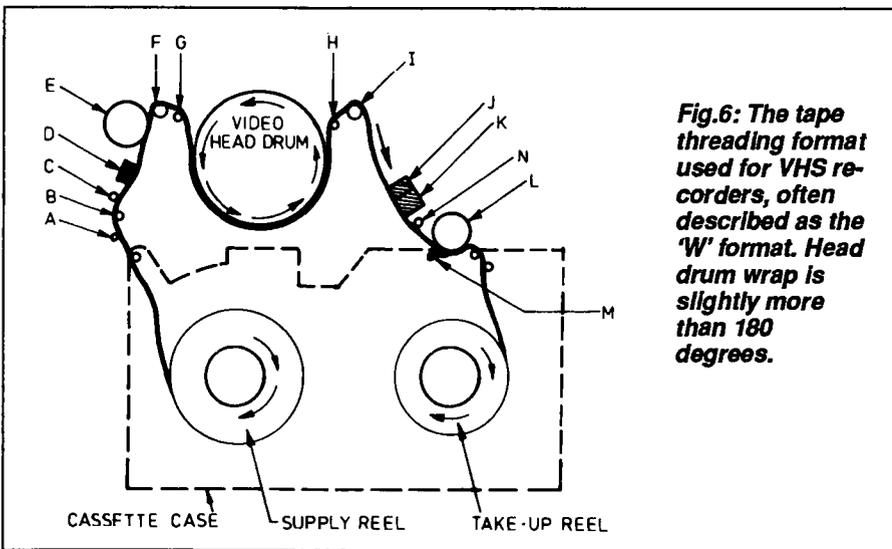


Fig.6: The tape threading format used for VHS recorders, often described as the 'W' format. Head drum wrap is slightly more than 180 degrees.

mat, because as you can see from Fig.6, the tape path resembles an 'M'.

'Pause' or still mode

As *Electronics Australia* readers will know, most modern VCRs are fitted with a 'pause' or still capability. When this mode is selected the tape movement stops, but the head drum continues to rotate and the two video heads continue to scan the video tracks. When the stationary tape is scanned by the heads the writing path of the two video heads inevitably changes in

relation to the magnetic video tracks. The dotted lines in Fig.7 show the stationary scanning path of the heads.

This means that in the 'still picture' mode, some picture information is lost. Remember an azimuth mounted head can only pick up signals from video tracks recorded at its own azimuth angle.

With a two head recorder this problem can be partly overcome by making the video heads slightly larger than the tracks to be laid down on the tape in the record mode. Each video head then records a

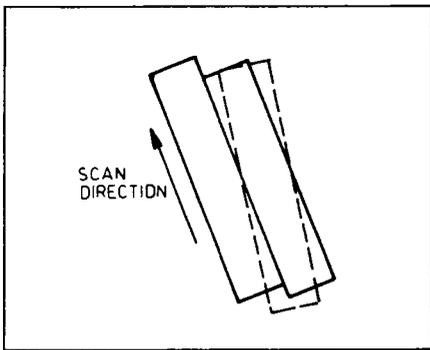


Fig.7: In 'pause' mode, the head scanning path overlaps adjacent tracks because the tape is no longer moving. Due to the azimuth recording, some information is lost.

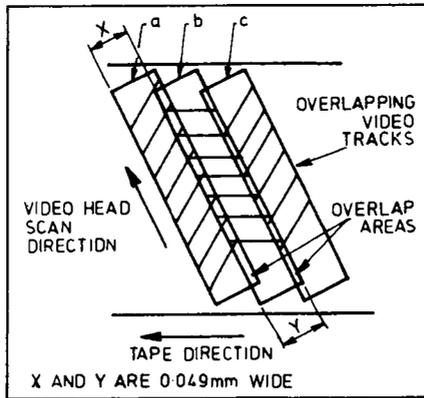


Fig.8: By widening the video tracks so they overlap, picture quality in pause mode is improved.

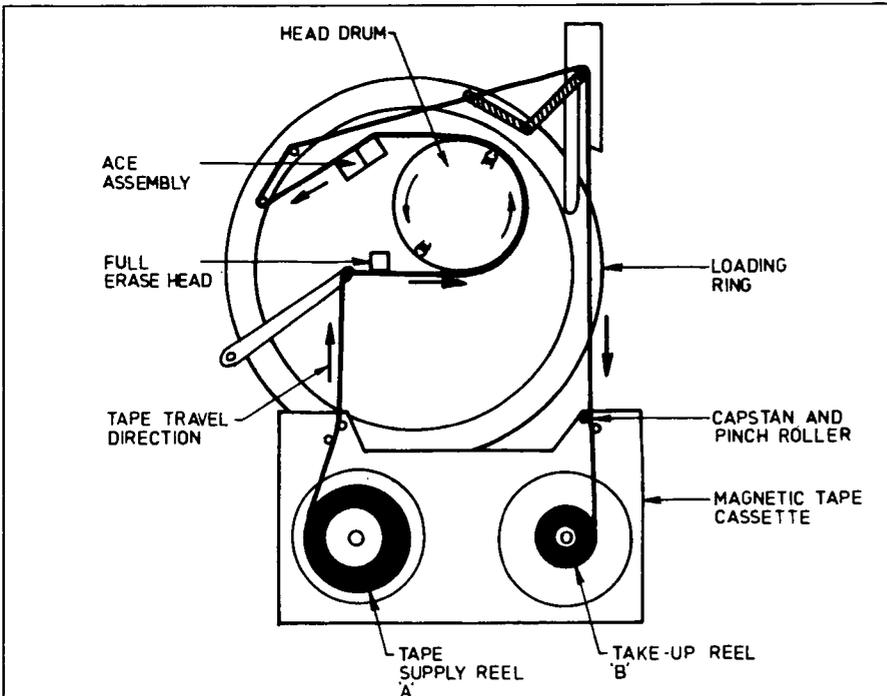


Fig.9: Tape threading format for a Betamax VCR, which is rather longer than with a VHS machine.

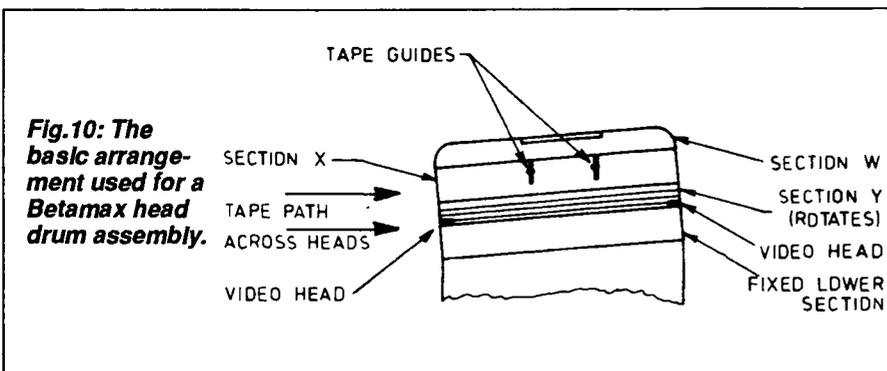


Fig.10: The basic arrangement used for a Betamax head drum assembly.

pattern that slightly overlaps the previous track, as shown in Fig.8.

With a recording made on track 'a', when a recording is next made on track 'b', a strip along the edge of track 'a' is erased and re-recorded. Then when a

recording is made on track 'c', the overlap strip of track 'b' is erased. In this way a pattern of video tracks exactly 0.49mm wide is laid down, as shown in Fig.4 and Fig.5.

Because of the slightly larger size of the

video heads, as each track is scanned on normal playback it passes over a portion of the two adjacent tracks. However because these tracks have been recorded with an azimuth difference of 12 degrees away from the correct track (due to the +6/-6° azimuth alternation), each head picks up signals only from its own track. Notice that although the wide heads overlap, the track widths at 'X' and 'Y' are still 0.49mm.

When the 'still' picture mode is required, because the video heads are now wider than the video tracks overlapping them, the video heads are able to pick up more of the picture information and a better picture is obtained. But the still picture may suffer from jitter and loss of definition.

However, many VCRs have extra video heads, and use other advanced techniques to produce excellent still pictures. For example the latest National VHS machines use a very advanced four video head system that produces still and slow motion pictures of superb quality.

How this is accomplished we'll discuss in later parts of this series.

Sony's Betamax system

Fig.9 is a sketch of the basic Betamax tape deck, showing the magnetic tape 'threaded' and ready to use. Reel 'A' is the supply reel and the magnetic tape passes via the guide and tension arms over the full erase heads. In the record mode this head is fed with a supersonic AC bias signal to remove previous recordings. (For example 65kHz in the Sony model SL-C6UB VCR).

The tape now travels around the head drum and over the audio/control head unit (ACE assembly) and continues via the capstan and pinch roller back to the cassette's take-up reel.

The design of the Betamax video head drum assembly is quite different from a VHS unit (see Fig.10). Section 'W' is the fan, section 'X' the upper drum assembly. Section 'Y' contains the two rotating video heads.

Sections 'W' and 'Y' rotate in the same direction as the tape movement. A rough comparison is to a slightly lop-sided stationary cream cake, with the cream layer and icing top rotating!

The azimuth angles of the video heads in the Betamax system are +7 and -7 degrees. For play and record modes the magnetic tape speed is 18.7mm per second, slower than the 23.39mm per second of the VHS systems. However the writing speed is 5.83 metres per second, which is faster than the head to tape speed of the VHS format.

Fig.11 shows the arrangement of the magnetic information on a Sony Betamax tape. The total tape width 'A' is 12.7mm.

Each video track has a width of .0328mm. The audio track 'C' at the top of the tape has a width of 1.05mm for mono sound. If stereo or alternative language tracks are used ('D' and 'E'), each is 0.5mm wide. The control track width 'F' is 0.6mm.

Incidentally, regular cleaning of the video heads is necessary with all VCR systems. This should be done ONLY with a proper video head cleaning kit and strictly according to the manufacturers instructions. Video heads are easily damaged if mistreated, and are expensive to replace.

Betamax recording

The bandwidth of the recorded luminance signal with Betamax is about 3MHz. As in the VHS system the luminance or detail information of the picture is converted and recorded as a frequency modulated signal. However the circuit arrangements are quite different.

The amplitude modulated PAL colour signal is down converted to a 687.5kHz rotational signal. Circuitry in the Betamax machine offsets this frequency to feed a 685.546kHz signal to one video head, and a 689.453kHz signal to the other.

There has been much discussion regarding the relative merits of the VHS and the Betamax systems. However both systems are the result of brilliant research and engineering.

Philips' V2000 system

This early system, developed by Philips, used two sets of video tracks. At the end of the tape play or recording process the cassette was withdrawn from the machine and turned over in a similar way to a compact audio cassette. It was then re-inserted so that the other set of video tracks could be used.

The video track width was only .0226mm. The system also used a special technique, known as *dynamic track following*. The head writing speed was 18.73 metres per second. Both moving and still pictures were of excellent quality. However Philips have now replaced the Video 2000 system with their own VHS system.

Sony's Video-8 format

This system, first seen in Britain and Australia in 1985 has proved extremely popular and looks certain to be one of the main systems in the years ahead. It uses helical scanning like the VHS and Betamax systems, but on tape only 8mm wide. The cassette used in the Video-8 system measures only 95 x 62.5 x 15mm.

This is much smaller than a VHS cassette (188 x 104 x 25mm), or a Betamax cassette (156 x 96 x 25mm). The cassette may contain either of two kinds of high quality magnetic video tape.

Fig.12(a) shows the composition of the

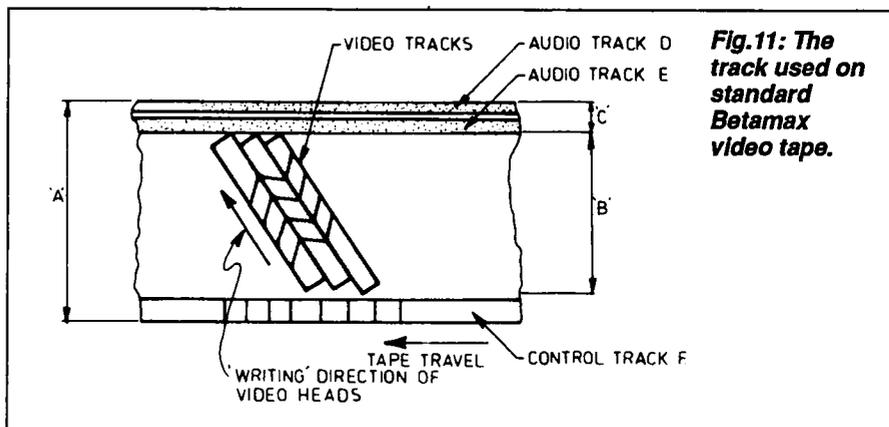


Fig.11: The track used on standard Betamax video tape.

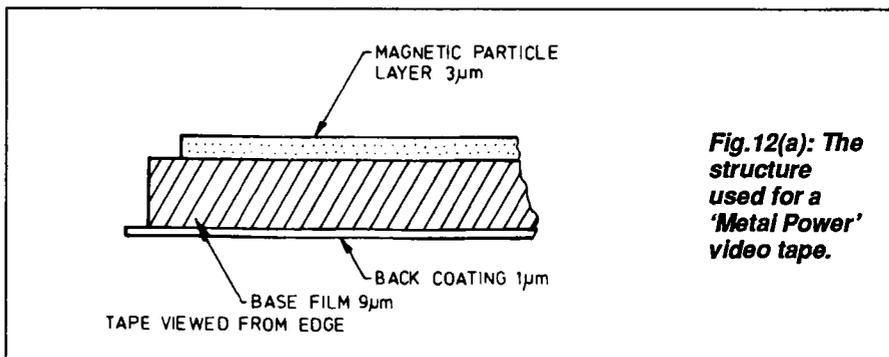


Fig.12(a): The structure used for a 'Metal Particle' video tape.

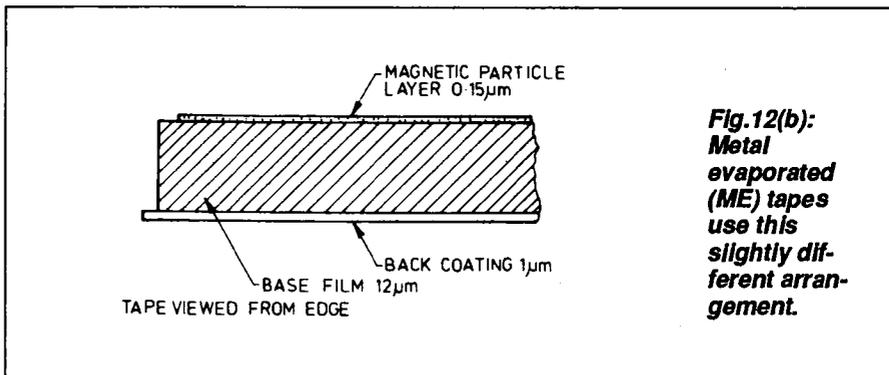


Fig.12(b): Metal evaporated (ME) tapes use this slightly different arrangement.

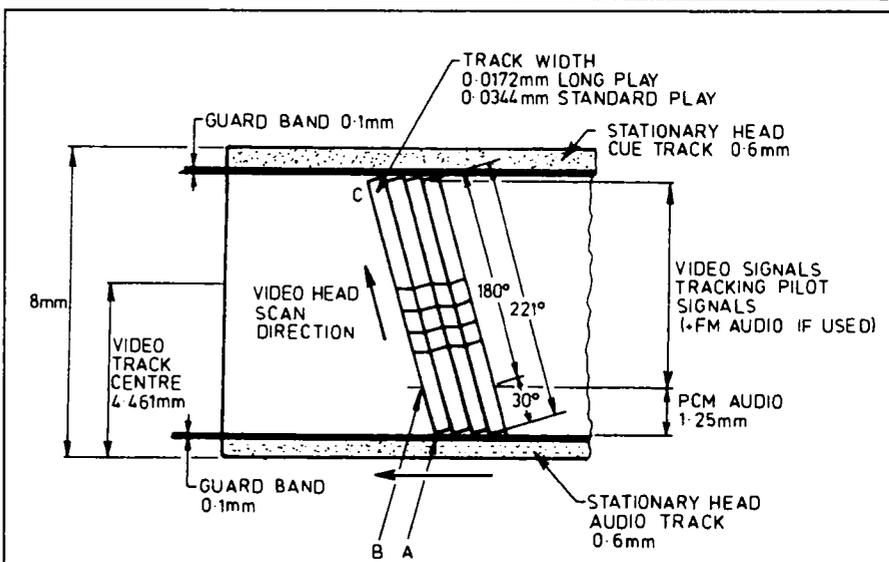
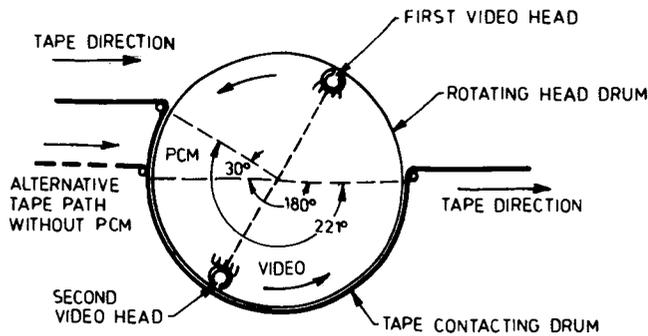


Fig.13: The various tracks on Video 8 recording tape. Note that the lower longitudinal audio track is not in current use.

Fig.14: With Video 8, the tape wraps around the head drum by either 180 or 221 degrees, depending on whether PCM is used to record the sound.



MP (metal powder) type. The magnetic track consists of powder of alloy of iron mixed with nickel and cobalt.

This type of tape has high durability and runs very smoothly through the tape transport mechanism. Fig.12(b) shows the metal evaporated (ME) type tape. ME tape is particular suitable for high density recording.

The tape speed for Video-8 (PAL colour system) in the standard play mode is 20.051mm per second. In the long play mode it is 10.058mm per second.

The magnetic 'tracks' on the Video-8 tape are arranged as in Fig.13. Notice that a section of each helical track is used for the pulse code modulation (PCM) audio.

PCM is an extremely sophisticated analog-to-digital recording process using compression/expansion.

Three methods are available for the recording and playback of audio signals in the Video-8 format.

1. Frequency modulated (FM) mono recording with compression/expansion (companding) via the video heads, on

the section of the tracks between 'B' and 'C';

2. PCM stereo audio, again via the video heads, on the section of the tracks between 'A' and 'B'; and

3. An auxiliary mono audio track via a fixed head, using the longitudinal track along the bottom of the tape.

All current Video-8 camcorders and VCRs are equipped with the FM audio systems. A few machines, such as the Sony EVS-700, also provide the PCM system.

When the record mode is selected and the video heads start to scan a track (see point 'A'), the PCM sound signals are first recorded.

Then when the heads reach point 'B', the video signals are recorded. In the playback mode the sound section of each track is again scanned first and then the video section.

The head writing speed is 3.12 metres per second in the standard play mode, and in the long play mode 3.13-metres per second.

This slower writing speed is made possible because of the use of very high quality magnetic tape cassettes, and video heads of advanced design with extremely small head gaps.

The azimuth angle of the heads is +10 and -10 degrees. In the standard play mode, the video tracks are .0344mm (34.4 microns) wide, and in long play mode they have a width of .0172mm (17.2 microns).

As in the standard video formats only half the head drum (180 degrees) contacts the magnetic tape at any time in order to handle the video signals (Fig.14). However you may have noticed that in machines using PCM, an additional 30 degrees is used in order to scan the PCM audio section.

The drum diameter is 40mm. This reduced drum size, together with the smaller tape width and tape cassette make the whole Video-8 system very compact.

Fig.15 shows the tape path in a Video-8 machine when loading of the cassette is completed. As you can see, it is broadly similar to that used in Betamax machines.

As in other systems, the luminance signal is converted in Video-8 recorders to a frequency modulated signal before being supplied to the recording heads. The chroma signals are down converted to 732.422kHz.

Automatic track following

In both the VHS and Betamax formats, signals are recorded on the control tracks in order that circuitry in the playback VCR can synchronise the head position with the video tracks at the correct speed.

The Video-8 format uses *automatic track following* (ATF) to accomplish this. With each field of the picture one of four pilot tones is recorded along with the luminance signal on one video track. There are four of these pilot frequencies: 101.024kHz, 117.188kHz, 162.760kHz and 146.484kHz.

These pilot tones are used by circuitry in the 8mm VCR to assure proper tracking, by controlling the phase of the capstan motor. This system was originally proposed by Philips, for the V2000 system.

Flying erase head

Mounted on the Video-8 head drum at 90 degrees from the main video heads is an additional head, known as the *flying erase head*. Using this head very precise erasing of only the desired video tracks is possible.

Bandwidths

Both the Video-8 format and the new super-VHS system (S-VHS) record and play back signals of improved bandwidth, giving superior pictures and colour.

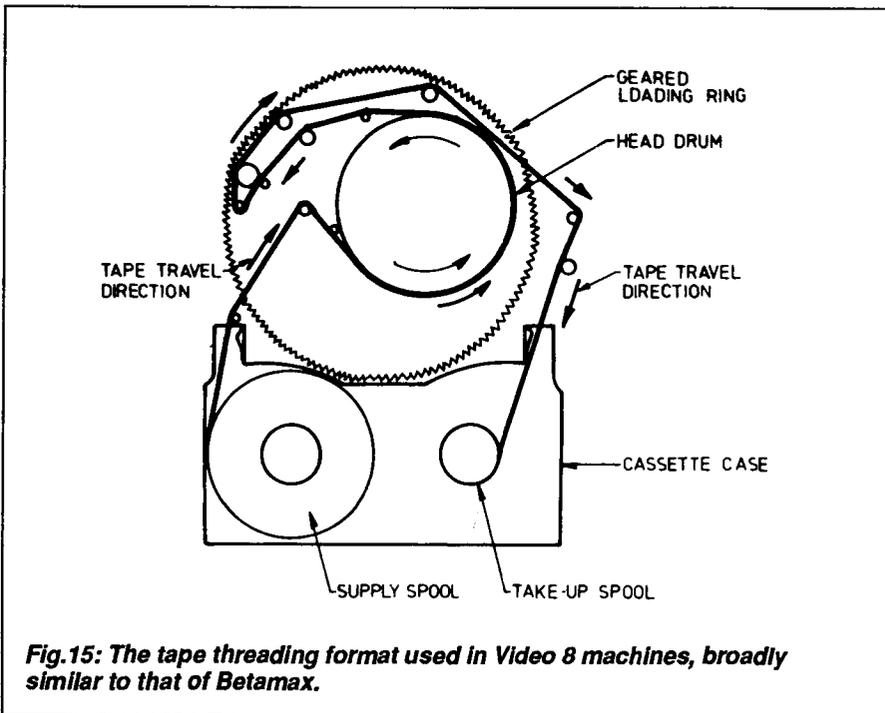


Fig.15: The tape threading format used in Video 8 machines, broadly similar to that of Betamax.

VCR CONTROL SYSTEMS

Part 3

We begin this part by discussing a typical microprocessor control system of the type found in a modern VCR. Then we'll look at the various servo systems used to control tape and head drum movements.

In early model domestic VCRs, the user selected the various functions, such as PLAY, STOP, REWIND, FAST FORWARD, RECORD and PAUSE by pressing hefty mechanical 'piano' key buttons.

However in the newer VCRs selection of the desired function is achieved by means of 'feather touch' control buttons, or by use of a remote control handset. This method of control of the VCR relies on the use of digital and microprocessor devices.

As most *Electronics Australia* readers will know, there are two basic kinds of electronic signals. Analog signals are those which vary continually, as in Fig.1a. Digital signals are signals that switch between two fixed values (Fig.1b); these values are known as digital or logic levels. For positive 'logic' the more positive voltage level — i.e., +5V in Fig.1b — represents a binary '1', while the less positive level (here 0V) represents binary '0'.

In Fig.1b, four digital signals or 'bits' as they are called are shown. If these digital signals were fed into logic circuitry following the direction of data flow shown by the arrow, the serial binary number would be 1010. In Fig.1b, the number is read from left to right. Fig.2 is a table of binary values and their decimal/hexadecimal equivalents, which you'll probably recognise.

Modern VCR circuitry is extremely sophisticated and may contain one, two or even three *microprocessors*. A microprocessor is an extremely complex integrated circuit (IC) device, the equivalent of the *central processing* or 'number-crunching' part of a computer.

It is intended for use with other digital circuitry in a microcomputer or other piece of digital equipment. It may be defined as a device contained within a single large scale integrated (LSI) circuit, which can perform a number of arithmetic and logic operations, receive instructions, and also send out its own instructions. To do this the microprocessor uses digital signals.

The special type of microprocessor used to control a VCR is more accurately known as a *microcomputer* chip. This type of chip incorporates all the facilities of a microprocessor, plus a ROM (read only memory) containing a specially developed program of instructions designed to control the various functions etc. of a VCR.

A microcomputer chip may be a virtually standard microprocessor that contains additional internal circuitry and instructions for use only in a particular VCR. For this reason, it is often referred to as a 'dedicated' device.

Fig.3 is a simplified schematic of a typical microcomputer VCR function control

system. It uses a 42-pin four bit device. Stabilised +5V and 10V DC voltage supplies are used.

A/D ramp circuitry

For simplicity just six function control buttons are shown in Fig.3. However, an increasing number of function controls are found on the latest VCRs. To avoid the use of complex and expensive scanning keyboards, many VCRs now use a variation of the A/D (analog to digital) 'ramp' circuitry shown in Fig.3 to select the required function.

The circuit uses two op-amps (operational amplifiers) A1 and A2, connected as voltage comparators.

An op-amp, you may remember, is a direct coupled multistage, high gain amplifier contained within a single IC. It amplifies the difference between the signal voltages fed to its positive (non inverting) input, and its negative (inverting) input. The input impedance of an op-amp is usually in excess of one megohm, and the output impedance quite low — perhaps a 100 ohms or less.

In our schematic, if the positive input of A1 is higher than its negative input, then the output of the device will be high (binary 1). If on the other hand the negative input is higher than the positive input the output will be low (binary 0).

When none of the function buttons is

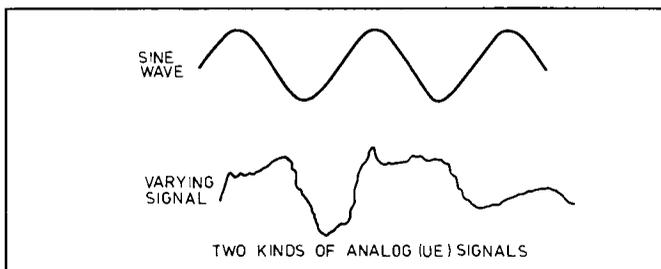


Fig.1(a): Two kinds of analog signal, a pure sinewave and a randomly varying signal.

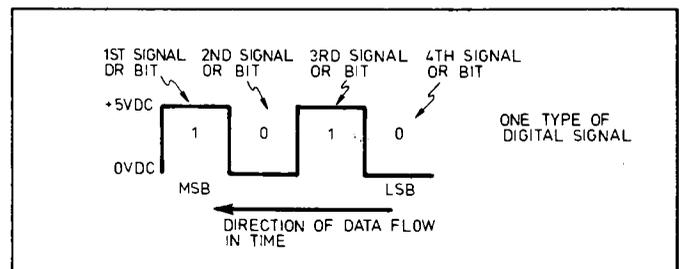


Fig.1(b): One type of digital signal, where '1' and '0's follow each other serially.

depressed, the voltage on the + input of A1 is at 10 volts DC. This makes it higher than the voltage on the negative input, so the output from A1 is high. This level is then fed into pin 2 (labelled data input) of port B of the microcomputer chip.

You'll notice that the microcomputer IC has a number of these 'ports', that are set up by internal circuitry to either receive or send digital information.

Fig.4 shows the output signals produced internally by the microcomputer of Fig.3, on lines 0 to 3 of port C. These signals are known as the key scan data. The numbers represent the binary values of these key scan waveforms. The four buffer amplifiers A3-6 and the 'ladder' resistor network connected to their outputs combine these waveforms, to produce the 'staircase' waveform shown. This is fed to the inverting (negative) input of op-amp A1. The binary values of the key scan data, read vertically from the MSB to the LSB, are the equivalents of the hexadecimal numbers on the 'staircase' (compare with Fig.2).

When one of the function buttons shown in Fig.3 is pressed, the flow of current through the resistor network for the pushbuttons reduces the DC voltage level on the positive input of A1 to an accurate pre-determined value. (Notice that for the record function to operate correctly, both record and play buttons must

Binary	Decimal	Hexadecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Fig.2: A table of the binary number values possible with four digital bits, with their decimal and hexadecimal equivalents.

be pressed together). For example, if the 'Play' mode is selected, the voltage at the + input of A1 is dragged down towards ground by resistors R7 and R8, falling from 10V to 2.99V. This is shown by the dotted line in Fig.5.

As the 'staircase' voltage rises above 2.99V, (point 'Z' on Fig.5), the output from comparator A1 now becomes low. This tells the microcomputer IC that a function button has been pressed, but not which one. Inside the microcomputer the four

bit data from port C now resets to zero (0000). Since the voltage at the inverting input of A1 will now go low, the output from A1 goes high again.

The key scan data at port C now begins to increment gain — that is, to increase its value in steps of one from 0000. This continues until in this case it reaches 0101 (see also Fig.6). This voltage on the inverting input of A1 now becomes higher than on its non-inverting input once more, and the output of A1 goes low again.

The microcomputer chip now knows that the PLAY function has been selected, by its internal timing of the staircase ramp steps. But just to be sure, after five microseconds it resets the count on port C and does a second count to see if it gets the same result. If so, the PLAY instruction is confirmed and the microcomputer next sends instructions to various sections of the VCR circuitry, to put the machine into the PLAY mode.

If the STOP function button is pressed, the + input to A1 would fall to 6.37V DC — higher than before, because the grounding path is now via R5 and R6 as well as R7-8. The digital count of the ramp voltage would in this case continue to a binary level of 1010 before the output of A1 becomes low, informing the microcomputer that the STOP function had been selected.

Since there are 16 different levels on

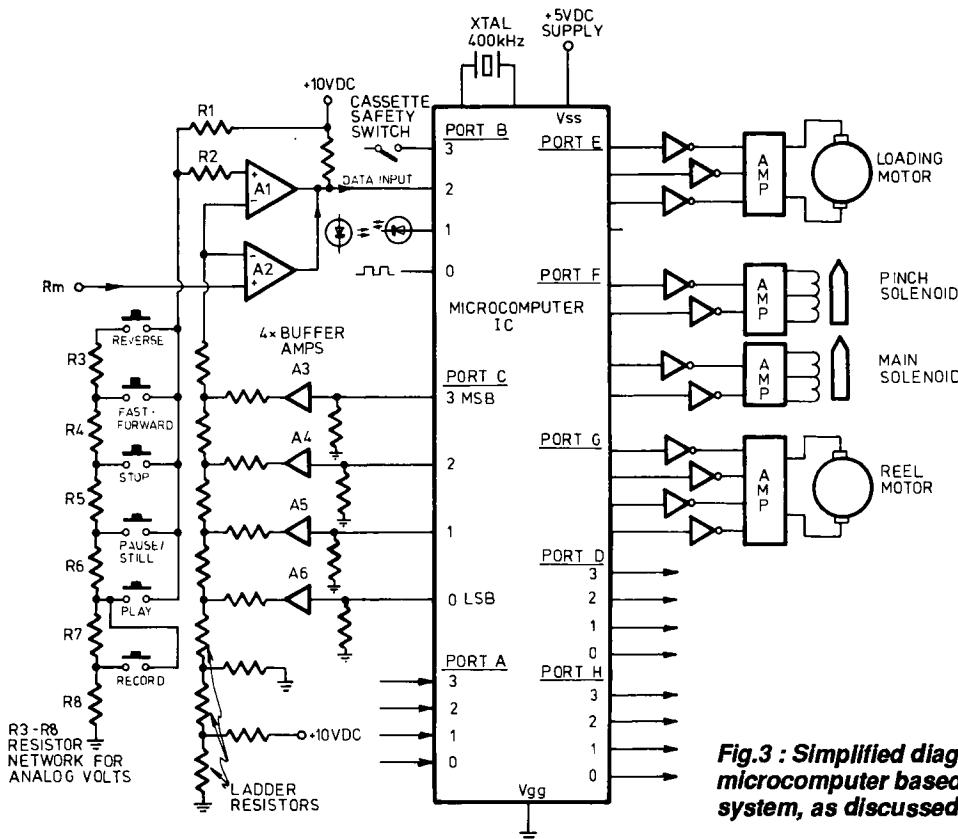


Fig.3 : Simplified diagram of a microcomputer based VCR control system, as discussed in the text.

the 'staircase' waveform, this means that up to 16 function commands may be included in a VCR design, by using the *simple ramp D/A circuitry* shown in Fig.3. This may be done simply by incorporating additional selector buttons and resistors.

You'll notice in Fig.3 a second op-amp comparator, A2. This is used to control the VCR by means of a handheld remote unit. The signal from the remote receiver in the VCR simply applies the necessary DC voltage levels to point Tm on the diagram (Fig.7). A2 then takes over from A1, achieving the same result as before.

Keep in mind that a resistor going 'open circuit' or changing its ohmic value in either the key pushbutton resistor network, or the ladder resistor chain (Fig.3), could stop the function buttons from operating or cause the selection of the wrong function .

The other ports

Remember that all ports of the microcomputer chip are capable of either accepting or transmitting data consisting of digital signals.

Port B handles three more input signals (Fig.3). The 0 line detects a 25Hz signal, that informs the microcomputer chip that the video head drum is rotating. The 1 line detects an input signal from a photocell reel sensor, so that if the cassette tape jams or breaks the microcomputer will know and stop the VCR.

The 3 line is fed a signal from a switch which sense whether the protection tab has been removed from the tape cassette. If this tab is missing, the microcomputer will thus be able to tell, and refuse to activate the record function.

Port A is also programmed for signal input. Its four lines are fed by multiplexer circuits, which monitor a number of con-

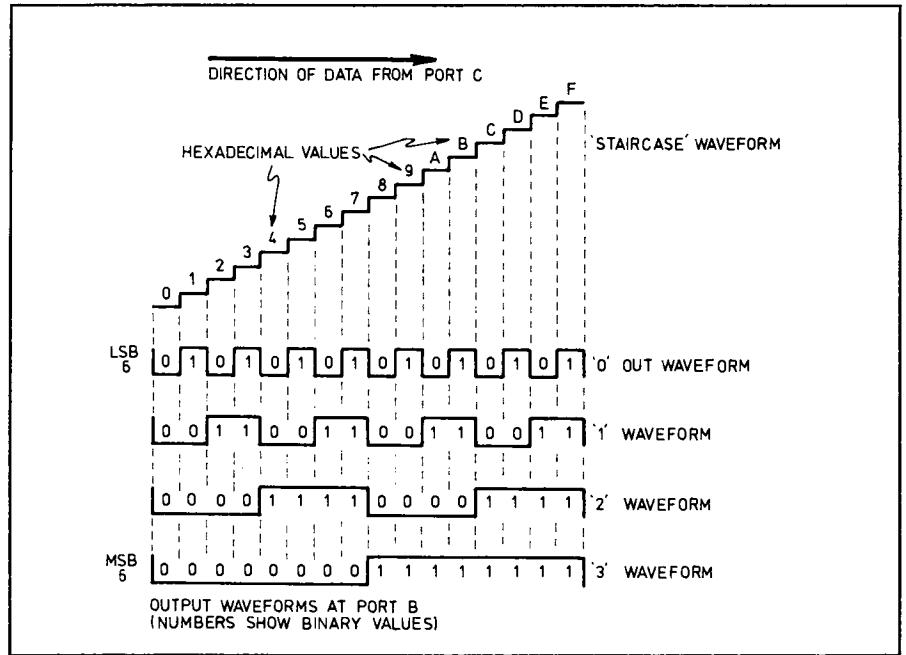


Fig.4: The output waveform at port B of the microcomputer of Fig.3, when no key is pressed.

ditions in the VCR. These include the tape start sensor, whether the cassette viewing lamp is in order, the various cassette microswitch conditions, tape loading conditions, timer mode, etc. We will discuss these in a later chapter.

Ports D, E, F and H are all programmed internally inside the microcomputer chip to function as signal output ports.

Port E generates signals that are fed via an amplifier to drive and control the loading motor, switching it on and controlling the direction of rotation.

Port G similarly controls the reel motor that winds and rewinds the magnetic cassette tape, while port F controls the two

electromagnetic solenoids that move the pinch wheel and various other sections of the tape deck mechanism.

Signals from ports D and H go via digital switching circuits (known as 'latches') controlling the various functions responding to the instructions fed into line two on port B. These signals also turn the LED (light emitting diode) function indicators on and off.

Servo systems

Servo systems are used to control the rotational speed of the various motors in a VCR, detecting and correcting any variations in speed or phase.

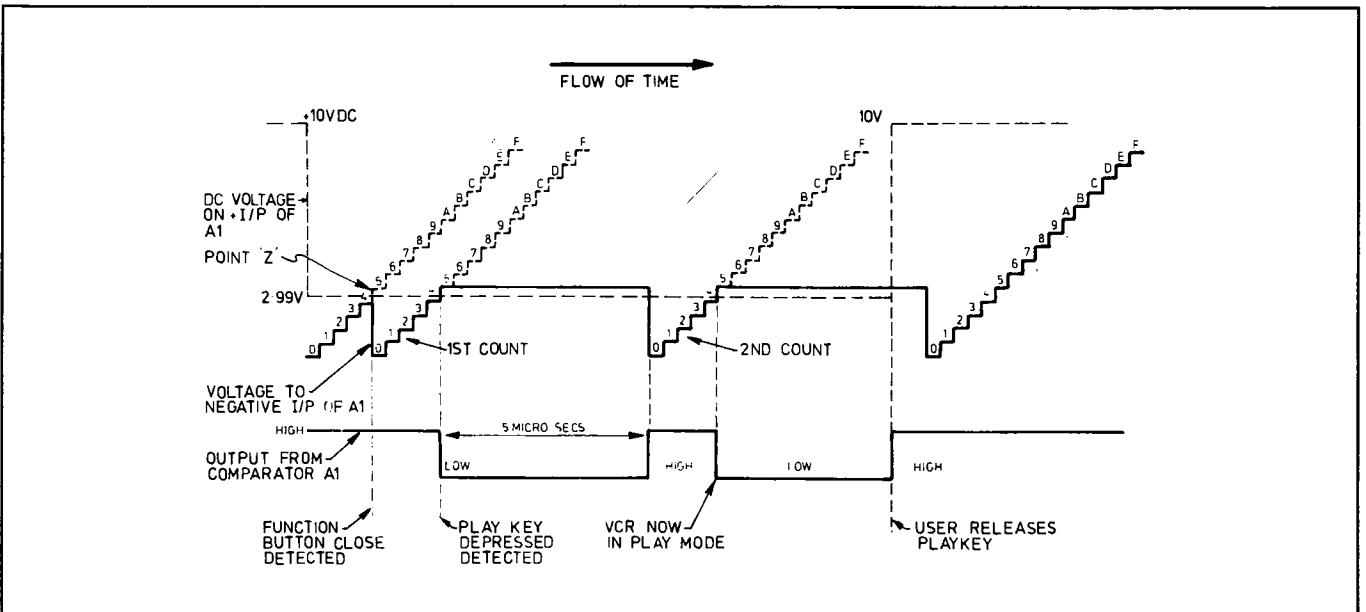


Fig.5: Operation of the ramp D/A comparator of Fig.3, when the PLAY key is pressed to select this mode.

Fig.6: How the data increments at port C when the PLAY key is pressed.

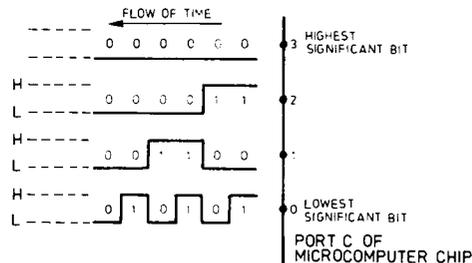


Fig.7: The way an infra-red remote control is connected into the control circuit of Fig.3.

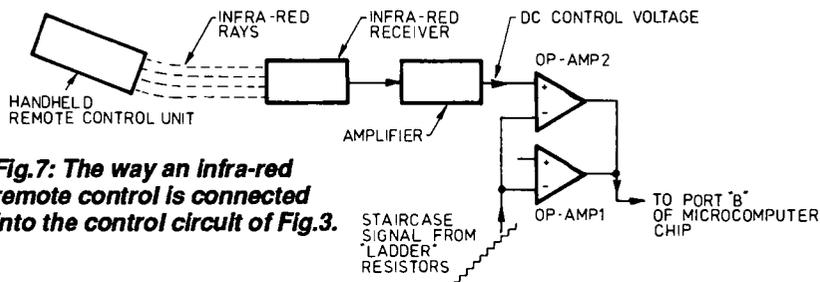


Fig.8: A reminder of how the magnetic tracks are recorded on the tape (not to scale).

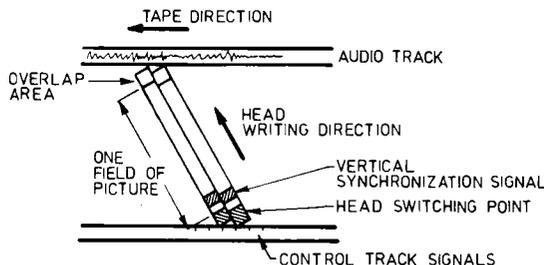


Fig.9: Details of the head drum frequency generator or 'FG', which produces a 1.5kHz sine wave signal when the drum is rotating.

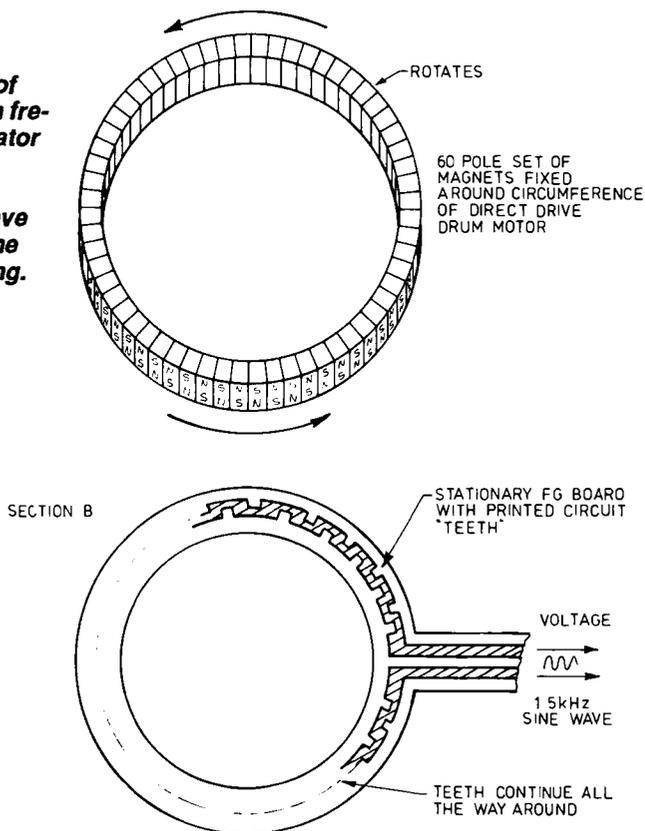


Fig.8 represents a portion of a VHS tape pattern (except for the azimuth angle — see part two). The patterns are similar in the Betamax format. Video head rotation must be kept at exactly one half of the vertical synchronising signal frequency of 50Hz, which is 25Hz.

Each field of the television picture is recorded on a single track by one video head, and the next picture field on the next track by the other video head. (You'll hopefully recall that each complete 'frame' of picture consists of two interlaced fields).

When the recording is 'played back' the servo system makes sure that the magnetic tape travels at the correct phase and speed so that the recorded video tracks are correctly synchronised.

The switching period from the first video track to the second video track occurs at the beginning of each video track. This prevents the head switching from producing noise during the active part of the picture.

To accomplish the above two servo systems are necessary. First, the *drum servo* circuitry which keeps the head drum containing the video heads at the correct speed and proper phase. And secondly, the *capstan servo* which ensures that the speed and phase of the magnetic tape itself are correct.

Head drum servo

In the case of a VHS machine using a direct drive motor, a number of permanent magnets are built into the motor. Detectors are built into the fixed FG (frequency generator) board (Fig.9).

When the direct drive motor rotates, voltage is induced by the magnets (section A), into the fixed printed FG coil (section B). Because the poles of adjacent magnets are reversed, the output voltage alternates between positive and negative. This produces the 1.5kHz signal shown in Fig.9.

Fig.10 is a side view of the servo controlled mechanism. Two magnets of opposite polarity are set into the motor 180 degrees apart. As the motor rotates a 25Hz pulse is generated in the pick-up head.

Fig.11 is a simplified block schematic of a typical VHS drum servo system. The 1.5kHz signal from the FG board feeds to amplifier 1, which converts the sine wave at point G into a square wave (H).

The signal now passes through a frequency to voltage (F/V) converter. If the frequency of the 1.5kHz signal becomes higher, the voltage output of the converter drops. Conversely if the frequency decreases, then the voltage output increases. The output of the F/V converter is taken to the positive input of op-amp comparator A1, feeding the drum motor

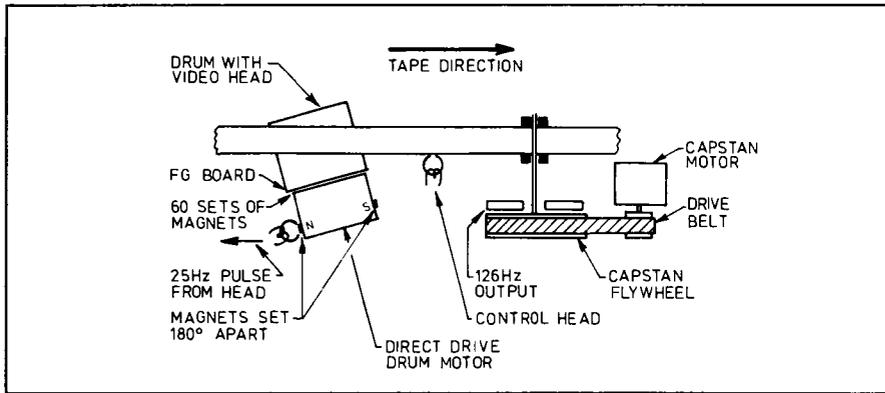


Fig.10: Sketch of the VCR mechanism showing the parts that are servo controlled.

drive amplifier. The negative input of A1 is supplied with a reference signal, C. When recording this signal is obtained by dividing the frequency of the field synchronisation pulses by two, whereas in the playback mode the reference signal is obtained from a crystal controlled oscillator (32kHz in our circuit), whose output is 'counted down' by digital circuitry to 25Hz.

The input to the positive input of A1 controls the speed of the motor. It is the input to the negative input which keeps the drum motor locked in phase with each field of the picture.

The output from A1 feeds via amplifier 2 to the MDA (motor drive amplifier), increasing or decreasing the motor drive voltage to keep its speed correct.

The 25Hz pulse from the drum pick-up head (waveform F) is supplied to amplifiers 3 and 4. The 'south pole' magnet generates the top section pulses, for the channel 2 head, and the 'north pole' magnet the bottom section pulses for the channel 1 head.

The signals from amplifiers 3 and 4 now pass via two MMVs (monostable

multivibrators, or 'one-shots') and trigger a flipflop to produce waveform E. (See part 8 of Understanding Colour TV for a description of one type of flipflop.)

The flipflop signal identifies the phase of the video heads — i.e., which head is at that moment reading or writing the video tracks. The square wave output is fed to a trapezoid amplifier, producing waveform D. The width of these pulses changes with speed.

Circuitry in the sample and hold IC compares the trapezoid signal with the incoming 25Hz signal, producing waveform C at the negative input of A1 — which as noted earlier, controls the phase. So in this way the video drum rotation and hence the head scanning of the video tracks is kept 'locked' to the video signal, in both play and record modes.

Most of the circuitry of Fig.11 including SW1, which is controlled by the microcomputer, is contained within a few integrated circuits.

The capstan servo

Fig.12 is a block diagram of a typical capstan motor servo system. As you can

see from Fig.10, the capstan motor drives the capstan by means of a belt.

Secured to the capstan flywheel is a circular magnet. Matching 60 tooth iron gears are fixed on the chassis and flywheel. As the gears cut through lines of magnetic force, voltage is induced in the capstan FG coil. The capstan rotates at about 2.5Hz, so the capstan FG output signal is about 126Hz.

In the record mode this FG signal is amplified by amplifier 5, which contains two op-amps. At the input of this amplifier the signal is a sine wave (waveform J). Amplifier 5 changes this to a squarewave (K). This signal serves two purposes. Firstly it is fed to a frequency to voltage (F/V) converter IC to control the speed of the capstan motor.

If the 126Hz square wave input frequency falls, the voltage output of the F/V converter increases. Conversely if the frequency rises the output drops (waveform L). This signal is supplied to the positive input of op-amp 3.

The second output path for the 126Hz squarewave output from amplifier 5 takes it to circuitry that reduces its frequency by six times, to 21Hz. It is then fed to a pulse generator to produce waveform M.

The output of the 32kHz crystal controlled oscillator (the same oscillator used in the drum control circuitry) is also passed through divider circuitry, which this time reduces its frequency also to 21Hz (waveform X). It then passes through another trapezoid amplifier, to become the phase reference signal (waveform N). This is compared with the pulse signal from the capstan FG, in the sample and hold/amplifier circuitry.

If the phase of the 21Hz signal derived from the capstan FG coil is incorrect, the waveform at point H changes to correct it. This voltage is supplied to the positive

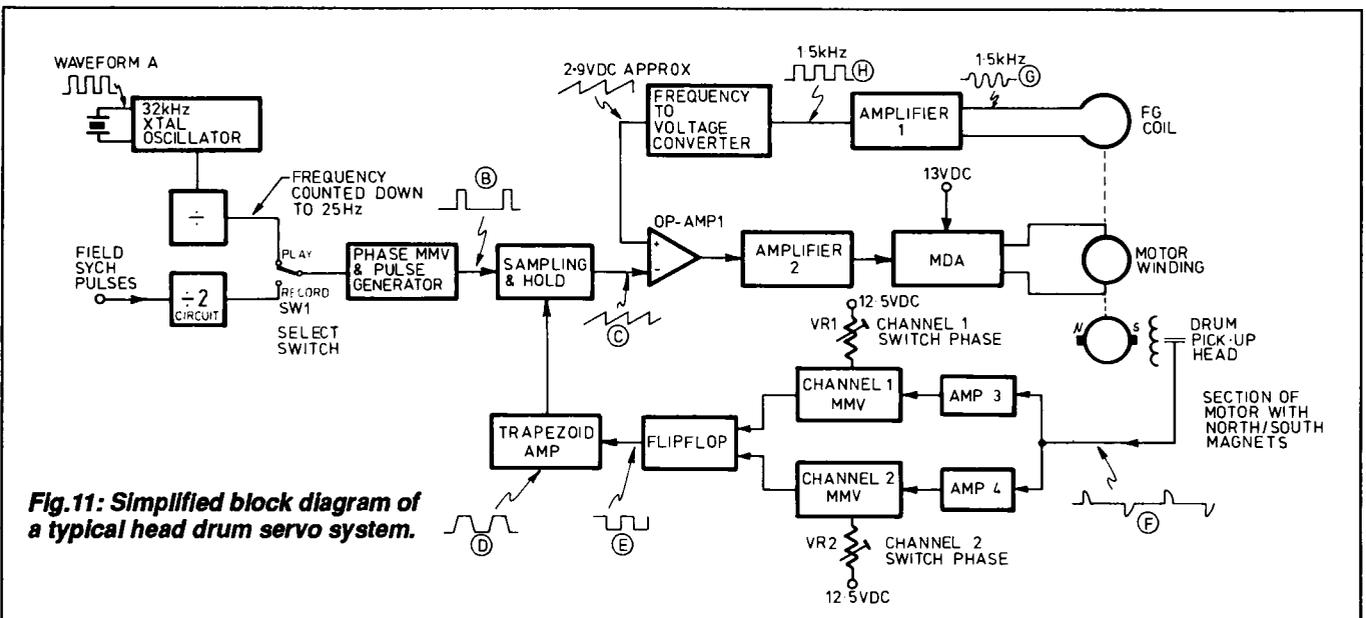


Fig.11: Simplified block diagram of a typical head drum servo system.

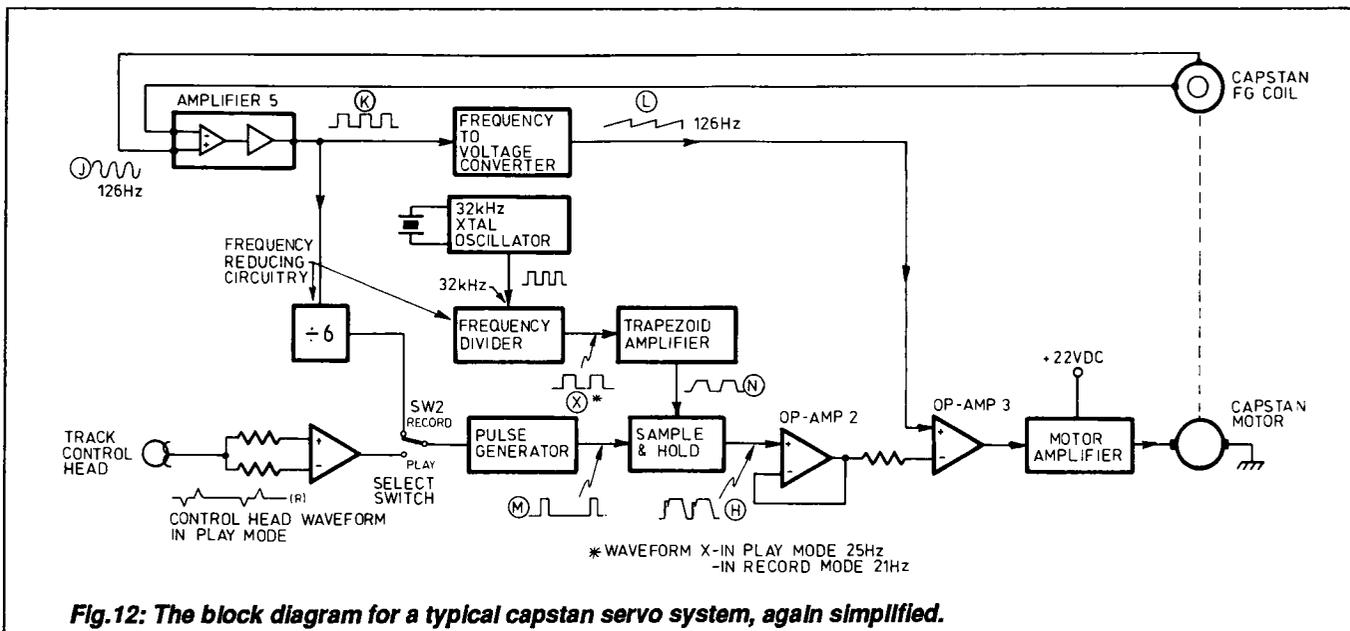


Fig.12: The block diagram for a typical capstan servo system, again simplified.

input of buffer op-amp 2, and then to the negative input of op-amp 3. Thus the signal from the F/V converter controls the speed, whilst the 21Hz signal provides the fine control 'locking' in the phase of the capstan motor correctly. As in the case of the drum motor the output of op-amp 3 controls the voltage output of the drive amplifier supplying the capstan motor.

Play mode

In play mode the capstan servo circuitry operates exactly as in the record mode — with one difference. The speed of the capstan motor is still controlled by the FG signal and frequency to voltage circuitry as before. However, switch SW2 is now in the play position. The playback 25Hz control signal (R) from the tape control track (see again Fig.8) is fed through op-amp 4 to this position of the record/play switch.

In this mode the 32kHz quartz crystal oscillator is now 'counted down' by the

circuitry to form a reference signal of 25Hz instead of 21Hz.

As before both signals are supplied to the sample and hold circuitry, to control the phase of the capstan motor. The tape control track at the bottom of the tape is laid down during the recording process, derived from the 50Hz field syn pulses.

The servo systems we've discussed are typical for a VHS machine. However, you'll appreciate that the same basic principles apply to all machines, although the circuitry of different VCRs can vary considerably.

Reel motor

A reel motor, or motors, winds and rewinds the cassette tape. The reel motor also functions in fast forward and reverse search modes. A typical VCR will use a single motor to drive both reels, and servo control is needed for speed control in FF and REW search modes. We'll discuss this in a later chapter.

The Hall effect

Fig.13 illustrates the basic Hall effect mechanism, using P-type semiconductor material. As a current flows through the material in one direction, magnetic flux from the north pole of the magnet causes the positive holes in the material to be pushed down to the bottom edge. The result is that a Hall-effect voltage appears across the material, between points X and Y.

If the magnet is reversed so that the south pole is nearest to the top of the semiconductor material, the holes collect at the top edge instead. The Hall voltage generated is then reversed. (If N-type semiconductor material is substituted, opposite polarity Hall voltages are produced, but the principle is the same).

The Hall effect is very useful in VCR technology, being used in a lot of motion and position sensors. Hall effect devices are fitted to motors, pulleys, wheels, etc., and the generated Hall voltage is taken

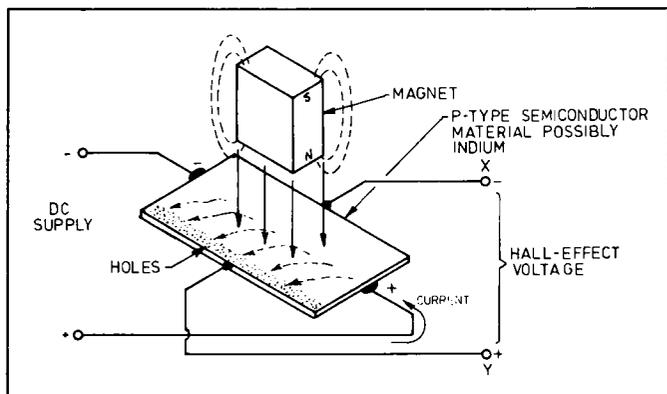
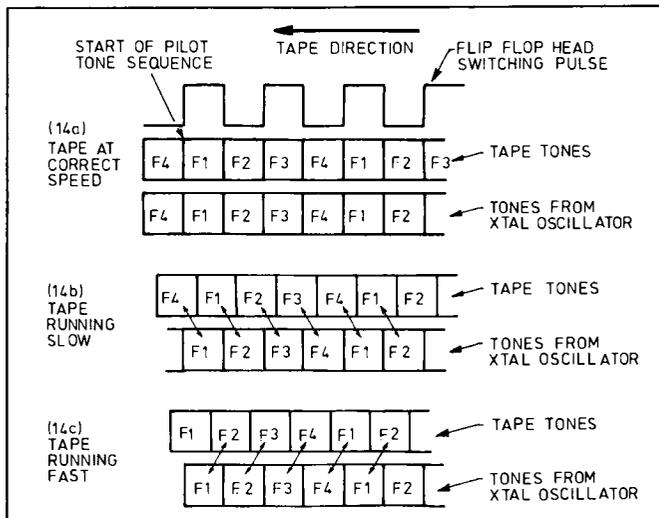


Fig.13 (above): Operation of a Hall-effect sensor, as used in a lot of VCR motion and position sensors.

Fig.14 (right): The function of ATF tones in the Video-8 system, as explained in the text.



through the circuitry to the microcomputer chip.

If a fault occurs and a component with a Hall effect device fitted stops moving, the microcomputer chip senses the absence of one or more the Hall voltages and stops the magnetic tape transport mechanism.

Video-8 ATF system

In the Video-8 system no control track signal is recorded on the lower edge of the tape as in the VHS and Betamax systems. During the record mode a sequence of four different automatic track finding (ATF) pilot tone frequencies are recorded in sequence with the luminance signals, on the helically scanned video tracks.

These pilot tones are generated by a 5.859MHz crystal oscillator and frequency divider contained within the VCR.

Fig.14a shows the order in which the pilot tone frequencies are recorded (compare with Fig.13 in Part 2). F1 is 101.024kHz, F2 is 117.188kHz, F3 is 162.760kHz and F4 is 146.484kHz. The sequence then repeats. The upper sequence in Fig.14 represents the tape, and

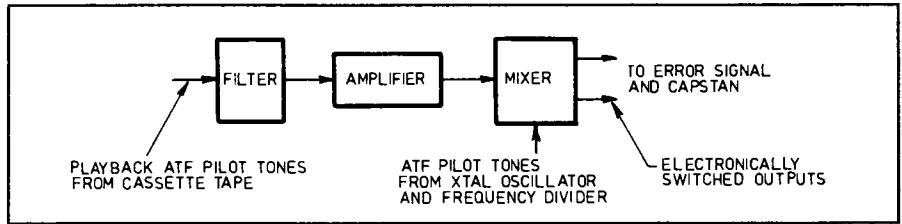


Fig.15: Block diagram of the circuitry used to compare the ATF tones on playback.

the lower sequence the tones from the crystal oscillator and frequency divider.

When the recorded picture is played back, the generated pilot tones within the VCR are compared with the pilot tones recorded on the magnetic tape (Fig.15). At the correct tape speed no output signal is produced.

Fig.14b shows what happens if the magnetic tape is running slow. Some of the F4 signal on the tape will beat with the F1 reference pilot tone signal frequency. Similarly F1 will beat with F2, F2 with F3 and F3 with F4, The resulting frequencies produced will be:

- F4 & F1: 146.484 - 101.024 = 45.46kHz
- F1 & F2: 117.118 - 101.024 = 16.164kHz
- F2 & F3: 162.760 - 117.188

- = 45.572kHz
- F3 & F4: 162.760 - 146.484 = 16.276kHz

These frequencies are usually referred to as '16kHz' and '45kHz'.

If the tape speed is too fast, Fig 14c shows that F1 beats with F2, F3 with F2, F4 with F3, and F1 with F4. Thus for a tape that is too slow a sequence of beat signal frequencies of 45-16-45-16kHz is produced, whereas a too fast tape produces a sequence of beat frequencies of 16-45-16-45kHz. This is from the same sequence of reference tones from the 5.859MHz crystal oscillator.

The output of the mixer is then fed to an op-amp, which produces an error signal to regulate the capstan motor servo circuitry — correcting the speed as necessary.

RECORDING THE PICTURE

Part 4

Now we discuss in greater detail how the luminance and colour signals are handled in the VHS and Betamax systems. We'll also look at a further aspect of the Video-8 system.

Fig.1 is a simplified schematic of the luminance recording section of a typical VHS machine. Compare this schematic with the block diagram of the luminance and chrominance section shown in part 1.

If the input signal at point A is supplied by a standard colour bar generator, then the waveforms in the lettered points in the circuitry will be as shown in the diagrams. To view these waveforms you would need an oscilloscope with at least a 5MHz response and a 10:1 isolating probe.

In modern VCRs these separate sections are all contained within a few large integrated circuits, with the exception of some individual transistors. However, in Fig.1, the schematic is divided into smaller blocks, to make it easier to understand how the circuitry operates.

The complete video signal enters the circuitry at point A (Fig.2). This signal may be supplied via the TV tuner, IF amplifier and demodulator circuitry or by a colour

TV camera. It's usually selected by a customer controlled front panel slider switch.

After passing through the slider switch the complete composite signal is fed to the luminance recording circuitry. It's also supplied to the colour recording circuitry, but more about this later.

The signal at A feeds through capacitor C1 to point B, where transistor Q1 acts as an electronic switch. In the playback mode a positive voltage is supplied to the base of this transistor (point X), turning it hard on and shorting the signal to chassis. This, of course, cuts off the signal input to the luminance recording circuitry. In the record mode Q1 is 'off' and has no effect on the circuitry.

The signal from the keyed AGC amplifier feeds into play/record function select switch SW1 (point C).

Play/record switches in early VCRs were mechanical, usually operated by magnetic relays. However in today's VCR's playback/record select switches

(contained within integrated circuits, together with other semiconductor devices) operate electronically, responding to digitally coded pulses sent by a microcomputer IC (see part 3).

After passing through SW1, the signal is taken to the base of transistor Q2 which operates as an emitter follower. Capacitor C2 and coil L1 form an acceptor trap, tuned to 4.433619MHz. You'll remember that an acceptor trap is a tuned circuit which allows only signals of the frequency to which it is tuned to pass through it (point D). Thus the 4.433619MHz colour subcarrier is removed from the video signal (see part 3).

Next, low pass filter one removes any vestige of the chroma signal information that may have escaped the acceptor trap, leaving only the luminance signal at point E. Fig.4 shows the 'staircase' luminance or Y signal at point E, with the colour information removed. You'll notice that the circuitry has inverted the signal.

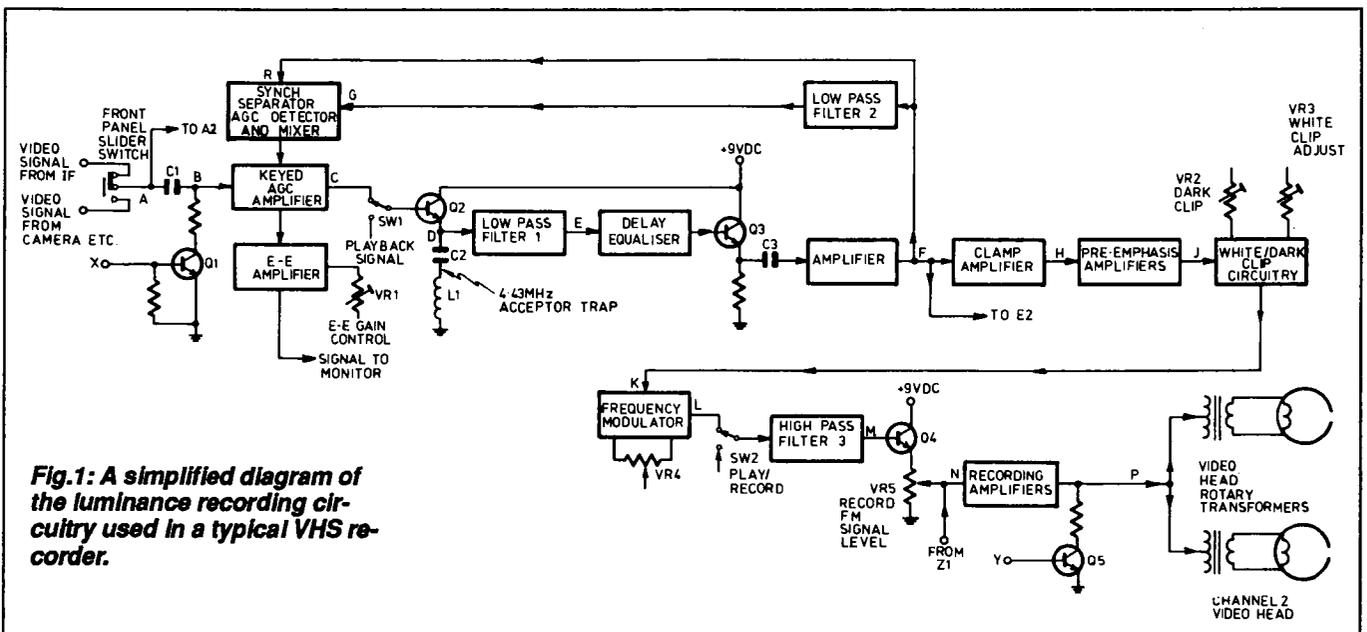


Fig.1: A simplified diagram of the luminance recording circuitry used in a typical VHS recorder.

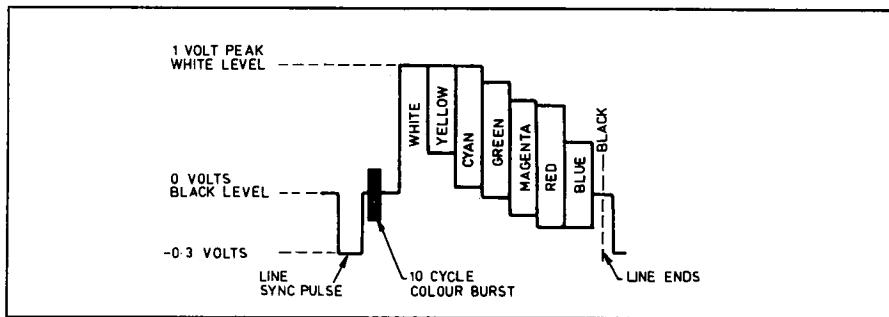


Fig.2: A one line section of an EBU colour bar video signal (75% amplitude, 100% colour saturation), as fed to the circuit discussed.

The luminance signal now enters an equaliser circuit, which delays the signal by about 600 nanoseconds. This is necessary because the colour signal will be slightly delayed by the chroma recording circuitry. The luminance signal must therefore be slowed down, so that both signals arrive together at the video heads to be impressed on the magentic tape of the video cassette.

The signal then continues on its way to the base of emitter follower transistor Q3, to capacitor C3. Next the signal enters an amplifier. The waveform at the output of this amplifier (point F) is again inverted and looks like Fig.5(a), except for the two dotted pulses shown on the back porch of the synchronisation pulses.

Keyed AGC

The signal at point F returns through low pass filter two to point G, where it enters the keyed AGC sync separator circuitry. It also connects via point R to the keyed AGC clamp amplifier.

Since it's important to understand how the AGC (automatic gain control) circuitry works, it is shown in greater detail in Fig.6. The letter and block references are the same as in Fig.1, plus some additional ones.

Because the picture brightness and content is continually varying, the AGC system does not control the total voltage of the signal. If it did, when recording a bright scene the gain of the

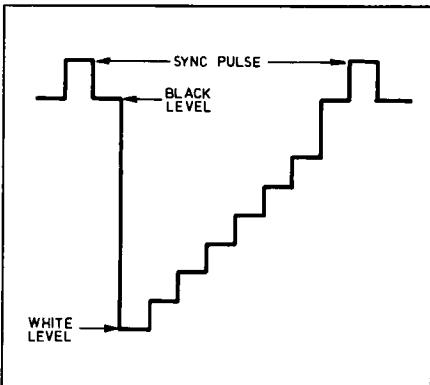


Fig.4: The luminance signal which remains at point E, after LP filtering.

luminance recording stages would drop, and on a dark scene increase — even if the input signal strength at point A (Fig.1) was unchanged.

The complete signal from point B feeds into resistor R1 (Fig.6). The signal from point F enters low pass filter 2 and then the sync separator, which allows only sync pulses to pass — Fig.5(b). Next the signal is amplified, delayed and inverted — appearing as in Fig.5(c). It's then fed into the mixer.

The signal from point F also enters the clamp amplifier (point R), which changes the signal from an AC coupled signal into a DC coupled signal.

The output of this clamp amplifier also feeds into the mixer. The mixer now produces at point 5A the signal shown in Fig.5(a), including the pulses shown in dotted lines.

Finally, the signal is detected or rectified and supplied to the gate of the N-channel JFET (junction field effect transistor). With the gate disconnected, a JFET with a positive voltage connected to its drain acts like a fixed resistor, allowing current to flow through it. Thus the internal impedance of the JFET and resistor R1 act as a voltage divider, reducing the voltage of the incoming video signal from point B.

The positive-going rectified signal from the detector is fed to the gate of the JFET, causing its internal impedance to fall and thus reducing the input voltage of the signal entering the keyed AGC amplifier. The greater the signal at the gate of the JFET, the lower the input to the keyed AGC amplifier.

In this way the keyed AGC signal output at point C is controlled by the amplitude of the sync pulses, and not by the actual picture content. At point C the signal now appears as in Fig.5(a), but without the dotted line pulses and with the voltage of the sync pulse (S) kept constant.

The signal at point F also enters clamp amplifier 2, which clamps the tip of the synchronising pulses to a fixed DC voltage. It then enters the nonlinear pre-emphasis amplifiers (point H). This pre-emphasis circuitry boosts the signal level of the high frequency parts of the

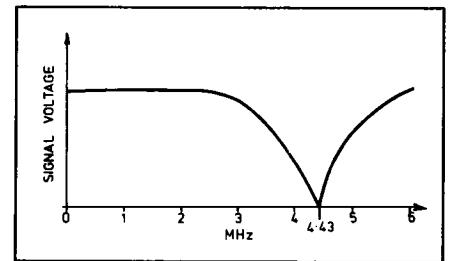


Fig.3: The action of the acceptor trap at point D in Fig.1, effectively removing the 4.43MHz chrominance signal.

video signal, particularly on low level signals. This prevents interference at low signal levels causing picture noise on the recorded signal.

A result of the pre-emphasis process is that hefty waveform spikes are produced on the signal at point J — see Fig.7. Uncorrected, this could cause reversal of black and white shades, and various other problems on the recorded picture. White clip and dark clip circuits remove the spikes above and below certain fixed signal voltage levels (Fig.8).

The signal at point K is next frequency modulated. During this process the tip of the sync pulses produce a signal at 3.8MHz and the white peaks a signal at 4.8MHz (Fig.9).

The FM signal

You will remember from part one of this series that a frequency modulated signal is used to record the luminance signal, so that a bias oscillator is unnecessary. FM

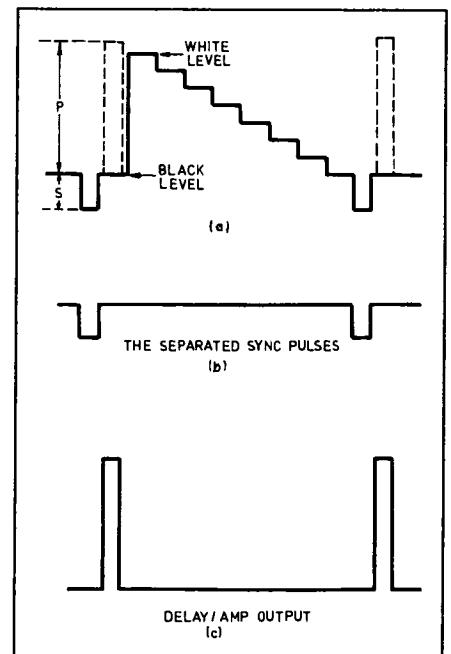


Fig.5: (a) shows the 'staircase' signal at point F; (b) the separate line sync pulses, at point 5b (Fig.6); and (c) the delayed pulses at point 5c (Fig.6).

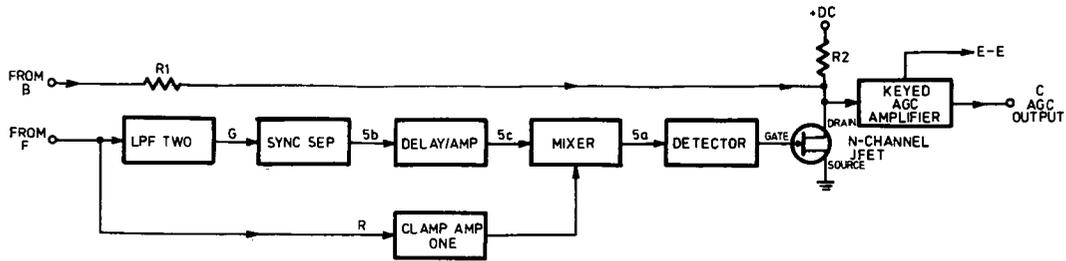


Fig.6: A simplified diagram of the keyed AGC section of Fig.1, used to explain how the AGC works (see text).

signals are far less sensitive to unwanted interference than are AM (amplitude modulated) signals.

With the luminance signal converted to FM (point L), the bandwidth is now only 1MHz (3.8 - 4.8MHz) — see Fig.10.

Next the FM signal passes through play/record switch SW2 and enters high pass filter 3, which attenuates the lower sideband (point M - Fig.11). This leaves room for the down-converted chrominance signal to be fitted in. Keep in mind that the amplitude of an FM carrier remains constant — only the frequency changes as it is modulated (Fig.12).

The FM signal now feeds into the base of emitter follower transistor Q4 (Fig.1). Preset resistor VR5 adjusts the record FM level. Finally the signal is supplied to the recording amplifiers. The output (point P) drives the primary windings of the rotary transformers, energising the two video heads set in the head drum.

The FM recording current signal is shown in Fig.13. The 'cotton reels' shown in the diagram are the down-converted AM (amplitude modulated) 627kHz colour signals, which use the FM envelope as a bias signal.

Transistor Q5 is cut off in the recording mode. In the playback mode 9V DC is fed to point Y via a suitable resistor. Q5 then conducts, effectively shorting the signal to ground at point P.

Recording the colour

At first sight the colour circuitry looks rather complicated. However, it is made up from a number of simple circuits. Old timers will recognise most, if not all of these as originating from the early days of radio and TV.

In order to understanding the processing of the chroma signals, a basic knowledge of colour TV is helpful. Part 1 of this section also described the basic method of 'down-converting' the AM colour signal to 627kHz before recording it, together with a block schematic.

Fig.14 is a block diagram showing in greater detail (although still simplified) how the colour signal is recorded. The complete video signal at point A in Fig.1

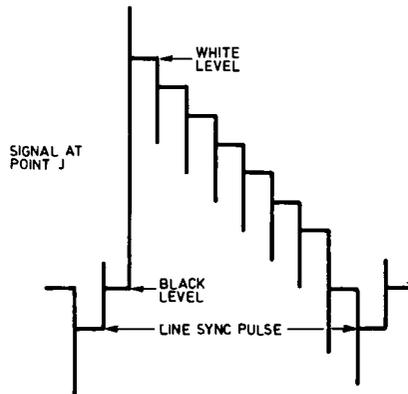


Fig.7: The signal at point J, after pre-emphasis. Note the hefty waveform spikes.

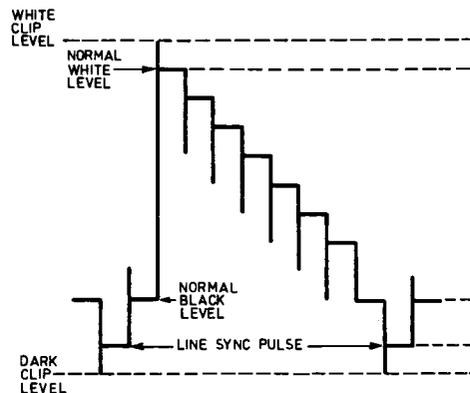


Fig.8: The signal at point K, after white and dark clipping.

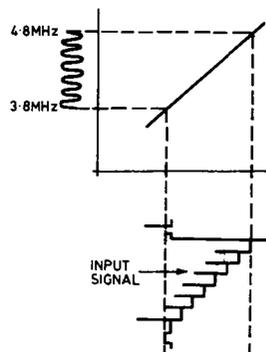


Fig.9: In the frequency modulation process, the luminance signal swings the carrier between 3.8 and 4.8MHz.

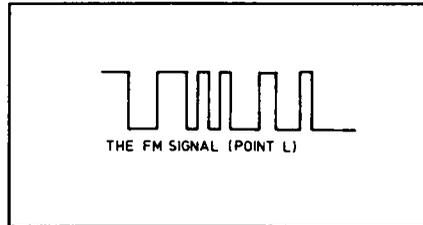
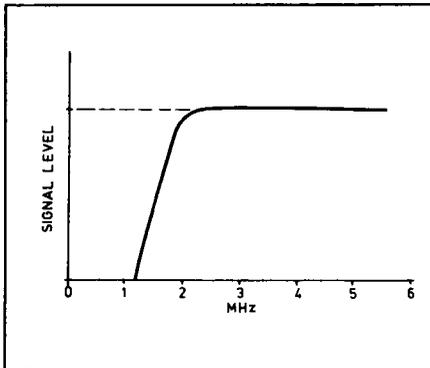
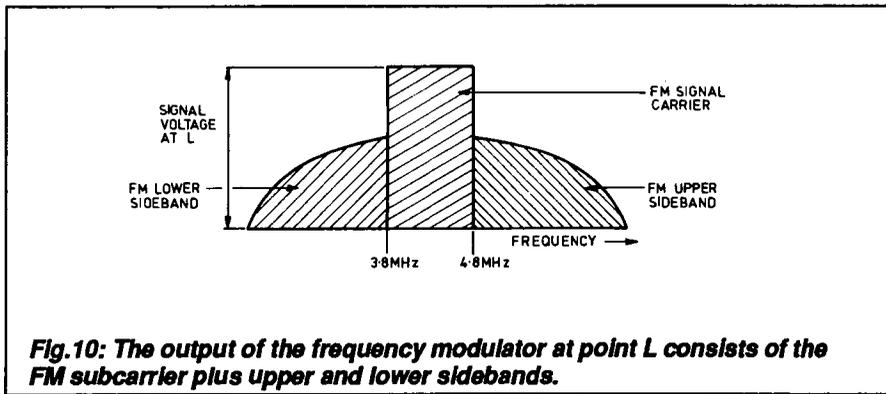


Fig. 11: FM signal bandwidth at point M, with the lower sideband attenuated.

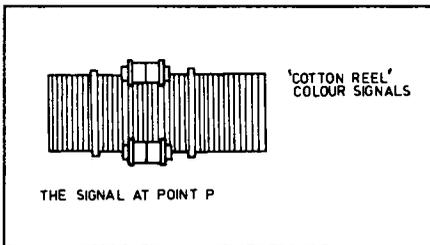


Fig. 13: The 'cotton reel' chrominance components on the recording head signal at point P.

The luminance signal at point F in Fig. 1 is fed into the white clip circuit at point E2 in Fig. 14, and then via capacitor C5 to the sync separator (point F2.) This allows only the sync pulses to pass through, entering the monostable multivibrator at point G2.

Coil L2 and capacitor C5 alter the phase of the horizontal sync signal so that it is timed correctly with reference to the colour burst signal (point H1). This timed horizontal sync pulse is known as the burst gate pulse.

Point H1 goes direct to point J1 into the burst gate. It's then demodulated by the ACC detector, whose output is fed into the ACC mixer (point K1).

In this way, the colour burst amplitude is kept at a constant voltage, controlled by the amplitude of the horizontal sync pulse input at point E2. In appearance it's the same as in Fig. 15, but with the signal voltage of the colour burst kept at a constant level.

The signal from the ACC mixer is also fed via capacitor C4 into the main converter amplifier. A signal frequency of 5.060572MHz (the colour subcarrier frequency + 40 times the line frequency + 1/8 the line frequency) is also fed to the main converter at M1 via bandpass filter 5.

Within the main converter this signal is combined with the colour signal subcarrier input of 4.433619MHz to produce a signal frequency of 626.953kHz, referred to as the 627kHz rotational chroma signal.

You'll remember that how these frequencies are obtained was explained in part 1. (It might be a good idea to refer back to it at this point.)

The 627kHz rotational signal output from the main converter enters low pass filter 6 and then the 627kHz signal

Fig. 12: The actual waveform of the FM signal at point L, of constant amplitude.

is taken to point A2 in Fig. 14 and enters bandpass filter 4. The luminance information is removed, allowing only the 4.433619MHz colour subcarrier to pass and reach electronic play/record mode selection switch SW3 (point B2).

The 'cotton reel' chroma waveform is shown in Fig. 15 and the bandwidth of the signal in Fig. 16. The dotted line shows the luminance signal as it was before passing through filter 4.

Electronic play/record switch SW3 feeds the 4.433619MHz subcarrier signal into the ACC (automatic colour control) circuit. The colour signal from the ACC circuit (point C2) is fed through capacitor C4 and electronic play/record switch SW4 into the burst gate (point D2).

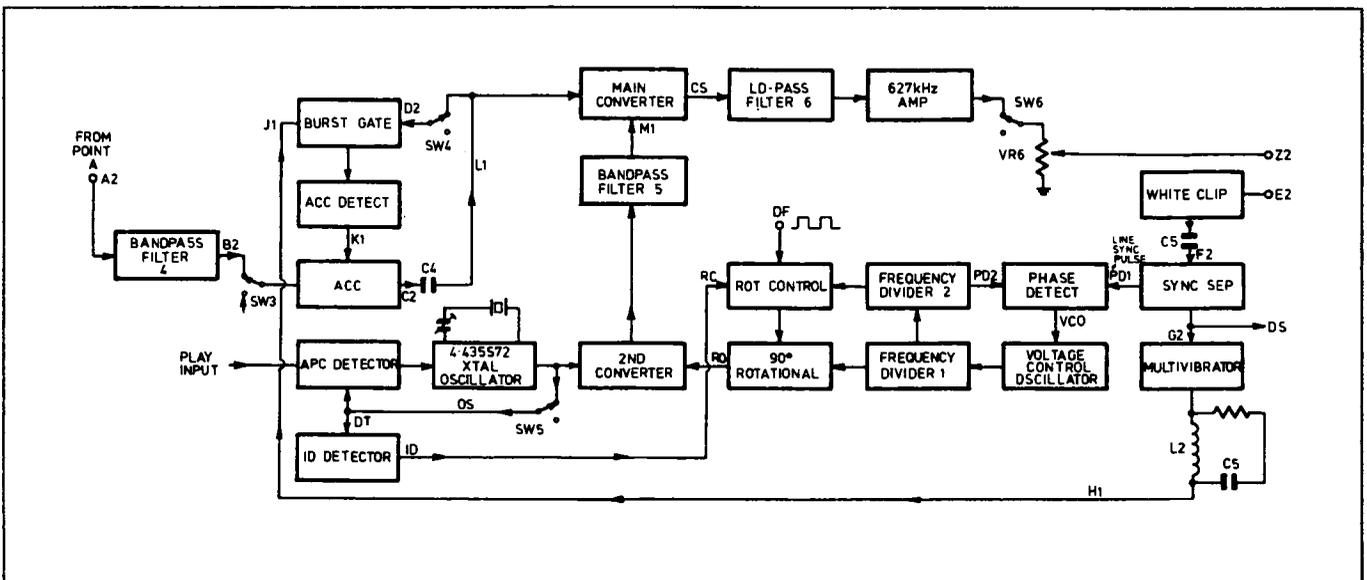


Fig. 14: Block diagram of the colour recording circuitry of a typical VHS recorder.

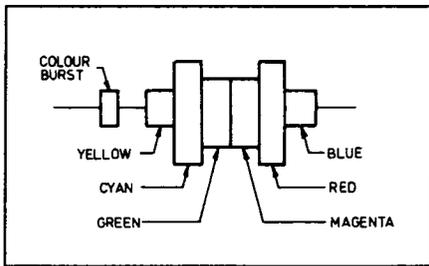


Fig. 15: The 'cotton reel' colour bar signal at point B2 of Fig. 14.

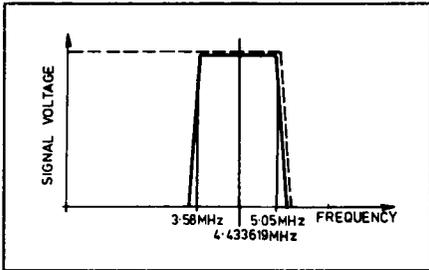


Fig. 16: The bandwidth of the incoming colour signal at point B2.

amplifier. The amplifier output passes through switch SW6 to preset pot VR6 (record colour level control).

Point Z2 connects to point Z1 in Fig. 1. The down-converted cotton reel colour signal then modulates the luminance FM signal as shown in Fig. 13. Fig. 17 shows the bandwidth of the combined signals.

Record drum servo

One output from the sync separator (Fig. 14) is taken to point DS and connects to the recording drum servo circuitry.

You'll remember that a TV signal sync separator stage output consists of 15.625kHz line pulses and 50Hz field sync pulses. The 50Hz pulses divided by two become 25Hz reference signals, which are then recorded on the video tape control track.

When the video cassette tape is played back, they serve as synchronising pulses for the video head drum servo circuitry. (Refer to part 3).

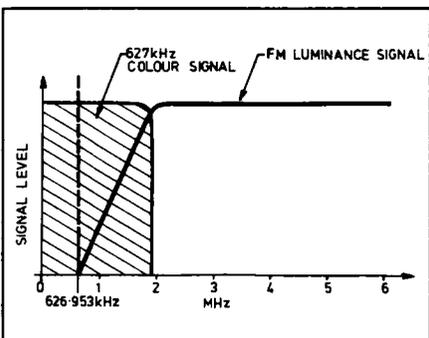
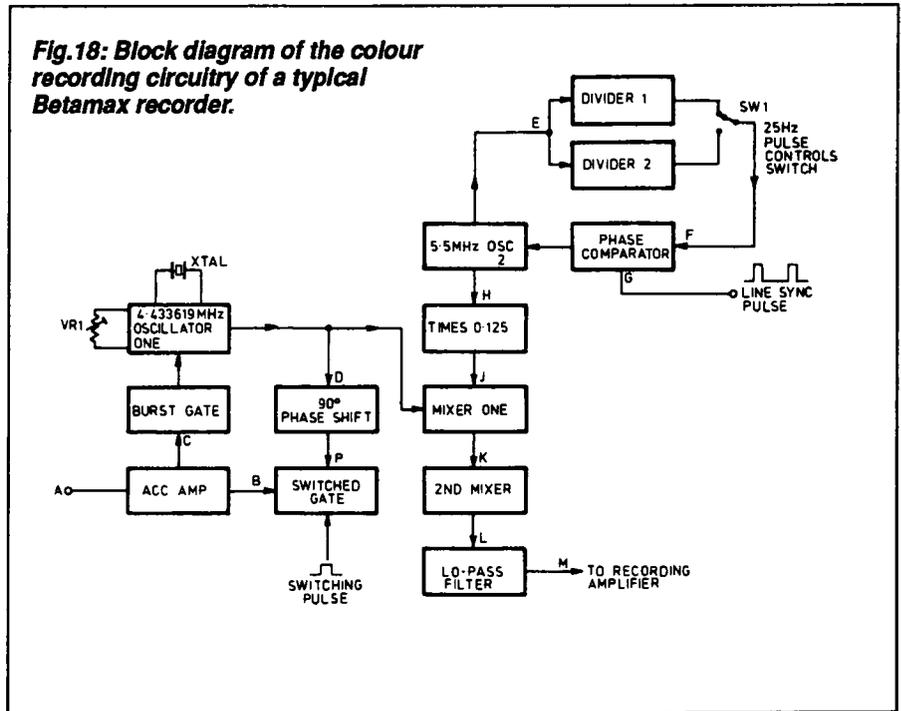


Fig. 17: The bandwidth of the combined luminance and rotational chroma recording signals.

Fig. 18: Block diagram of the colour recording circuitry of a typical Betamax recorder.



The AFC loop

The 627kHz amplitude modulated colour signal is phase shifted in steps of 90°, through 360°. An AFC (automatic frequency control) loop is necessary in order that the various signal frequencies used to produce the 627kHz rotational signal are exactly correct and in phase.

The line sync pulses from the sync separator also feed to the input of the phase detector (point PD1), the output of which connects (point VCO) to a voltage controlled oscillator whose frequency is 160 times the line sync frequency ($15.625 \times 160 = 2500\text{kHz}$, or 2.5MHz).

Digital frequency divider 1 accepts this signal and produces an output of 1/4 of 2500kHz, or 625kHz, which is forty times the line frequency. The 625kHz signal is supplied to digital frequency divider 2, and also to the 90° rotation circuit.

Digital frequency divider 2 now reduces the signal frequency by 40 times ($625,000/40 = 15,625\text{Hz}$) and feeds it back into the phase detector (point PD2). The internal circuitry of the phase detector compares this 15.625Hz signal with the 15.625Hz frequency of the TV line sync pulses at point PD1.

Provided that the two signals exactly match in frequency and phase, the phase detector output is zero.

However, if the output frequency of digital divider 2 rises above, or falls below the line sync pulse frequency, a corrective voltage is sent by the phase detector to the voltage controlled oscillator. In this way, the frequency of the 2500kHz signal is controlled by the line pulse frequency.

Besides the 625kHz signal from digital

divider 2 the rotational control circuitry receives (point DF) a 25Hz control signal from the servo circuits. The output of the 90° rotation control circuitry (point RO) is fed to the second converter.

The output at point RO is phase shifted 90° with each succeeding line of the TV picture, and kept in step with the video head rotation by the 25Hz pulse from point DF.

The second converter down-converts the signal to 627kHz and feeds it via high-pass filter 5 into the main converter (point M1), where it combines with the colour subcarrier to form the 627kHz chroma signal at point CS. (How this is done was explained in part 1).

The 4.435572MHz signal at point OS via electronic play/record switch SW5 is supplied first to the ID (identification) pulse detector (point DT). The output at point ID feeds into the rotational control circuit at point RC, synchronising the 90° rotation control circuitry.

The result of this control is that the signal sent to the channel one video head does not change in phase. However the signal sent to the channel two video head does change phase by 90° for each line of TV picture recorded. We'll see the reason for this when we discuss the colour playback process.

The signal at point OS is also taken via switch SW5 into the APC (automatic picture control) detector. The APC circuitry only operates in the play mode.

The Betamax system

The Betamax system uses similar principles to the VHS system. Some basic

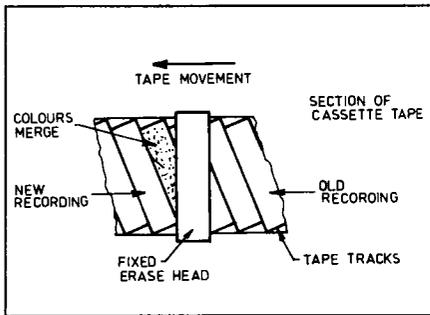
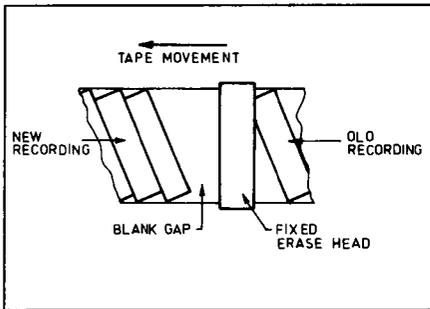


Fig.19(a) above: A fixed erase head causes overlapping of recordings.

Fig.19(b) below: A fixed erase head also produces a gap at the end of a recording.



information was given in part two of this series.

As in the VHS system, the luminance signal is FM modulated. However two frequency modulators may be used, with the signal fed to the second FM modulator delayed by one line. The frequency modulated signal is then passed through pre-emphasis amplifiers and black and white clip circuits just as in the VHS system.

The FM signal carrier frequency is 5.2MHz for a peak white signal, and 3.8MHz at black level. (Compare with Fig.9 and Fig.10).

Fig.18 shows the basic system used in the Betamax format colour recording circuitry. The colour signal with the luminance information removed enters at point A. The waveform is as Fig.15. It passes through the ACC circuit and into a gate circuit at point B. This gate alternate-

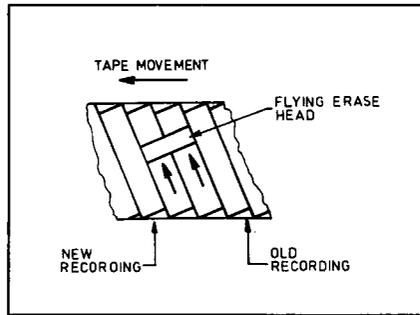
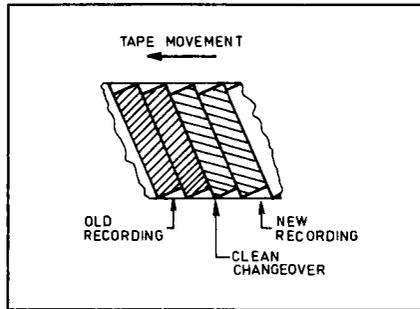


Fig.19(c) above: A flying erase head straddles both field tracks.

Fig.19(d) below: The flying erase head gives clean changeovers between recordings.



ly accepts the signals from points B and P, under the control of a pulse.

The signal from the ACC amplifier is also fed to a burst gate (point C) which keeps oscillator 1 (4.433619MHz), accurately locked to the colour burst frequency. The output from oscillator 1 enters a 90° phase shift circuit (point D), producing what is known as the *pilot tone* signal, which is recorded on the magnetic tape.

Oscillator 2's output (free running 5.5MHz) is supplied to digital dividers 1 and 2 (point E). SW1 is an electronic switch controlled by the 25Hz pulse from the video head drum.

You'll remember that each complete frame of a TV picture consists of two interlaced fields. As each field succeeds the previous one, SW1 is electronically switched between the outputs of the two digital divider circuits.

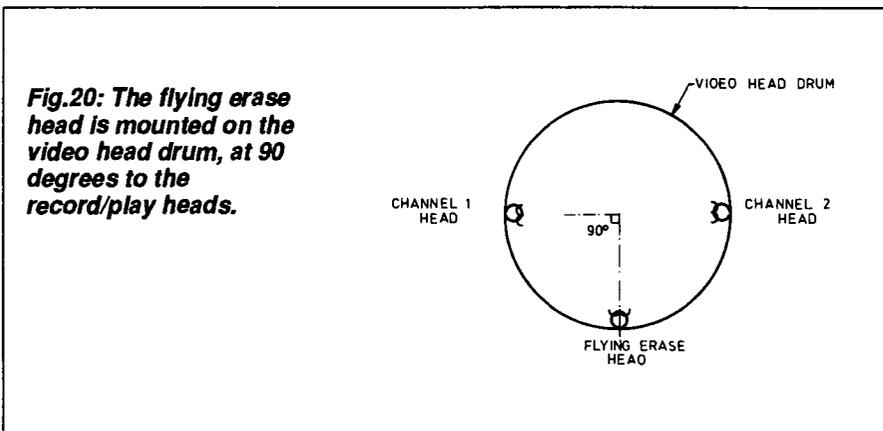


Fig.20: The flying erase head is mounted on the video head drum, at 90 degrees to the record/play heads.

These outputs are supplied to the phase comparator (point F) which also receives line sync pulses from the sync separator (point G). The phase comparator controls the frequency of oscillator 2.

In switch SW1's position 1 the signal from digital divider 1 causes the line frequency signal from the line sync pulse generator to be multiplied by 351 ($351 \times 15,625 = 5.484375\text{MHz}$). In position 2, the line pulse frequency is multiplied by 353 ($353 \times 15,625 = 5.515625\text{MHz}$). Thus oscillator two is alternately locked to one of these two frequencies as the picture fields change.

Oscillator 2's output (point H) now passes through a multiply by 0.125 (divide by 8) digital counter to point J, at one input of mixer 1. The output from oscillator 1 (4.433619MHz) is fed to the other input of this mixer, so that the output at point K is 5.1230721MHz ($0.68945313\text{MHz} + 4.433619\text{MHz}$) for one field and 5.1191659MHz ($0.6855469\text{MHz} + 4.433619\text{MHz}$) for the other.

In the second mixer the incoming colour subcarrier frequency is subtracted from these two frequencies, so that two different down-converted signals of 689.45313kHz and 685.5469kHz are fed (point L) through filter 1 into the recording amplifier (point M).

Channel 1 video head is supplied with the down-converted colour signal of 685.546kHz and channel 2 video head with the 689.453kHz colour signal. This two-frequency signal system prevents colour crosstalk when the cassette tape is played back.

Erasing the picture

In both the VHS and Betamax systems, before the tape reaches the video head drum it first passes over the full erase head (see part 2). In the record mode a bias oscillator energises this head, wiping out all previous recordings.

Suppose we wish to make a new recording and insert it in the middle of an existing one? Using a fixed head erase system overlapping will occur — see Fig.19(a) — and the colours of the new recording at this point merge with the colours of the old recording. At the end of the new recording there will also be a gap, as shown in Fig.19(b).

This problem is overcome in the Video 8 system by the use of a *flying erase head*, set at 90° to the video heads (See Fig.20). Since each video track records one field of the picture, two tracks make up one picture frame.

The flying erase head covers two tracks (Fig.19(c)), and removes one complete frame of picture. When the new recording is made the change is noiseless and free from colour splash.

PLAYBACK CIRCUITRY

Part 5

Here we examine the playback circuitry of a typical video cassette recorder. We also look at picture 'drop out' correction and noise cancelling circuitry, together with long play operation in the newer VCRs.

In practice, most of the circuitry shown as small sections in this part is contained in a few large scale integrated circuits. Also it should be understood that circuitry can vary in different VCRs. However, the schematics shown will serve to illustrate the basic principles of the playback circuitry. Fig.1 is a simplified block schematic showing how the recorded magnetic information on the video cassette tape is supplied to the early stages of the circuitry. As the head drum rotates each video head in turn 'scans' a single tape 'track'. Each track, you'll recall, contains one field of picture information.

On playback this induces a signal voltage in each head as that head detects one 'field' of picture. From channel 1's head the first field of picture data is fed first to

rotary transformer T1, and then to the channel 1 preamplifier. Channel 2's head scans the next picture field, feeding the signal via rotary transformer T2 to the channel 2 preamplifier.

Transistors Q1 and Q2 are cut off in the playback mode. In the record mode 9V DC+ is applied to point X, switching Q1 and Q2 on and effectively shorting points A and B to chassis. Electronic switch SW1 is closed in the playback mode, open in the record mode.

At point C in Fig.1, the signal waveform from the channel 1 pre-amplifier — as viewed on a suitable oscilloscope — appears as in Fig.2(a). At point D, the signal appears as in Fig.2(b). The two signals now enter the switching amplifier. Fig.2(c) shows the 25Hz signal, obtained from the

head drum, that enters this amplifier at point E.

You'll remember that the video head drum speed and phase is accurately controlled by the servo circuitry. (See part 3). This ensures that the 25Hz signal generated by the head drum will correctly control the switching amplifier so that each two recorded fields of the picture are properly synchronised.

The 25Hz signal controls the internal circuitry of the switching amplifier so that it amplifies the signals from the channel 1 and channel 2 preamplifiers in turn. The output signal from electronic play/record switch SW2 at point F appears as in Fig.2(d). Notice that the ends of the waveforms in Fig.2(a) and Fig.2(b) have been slightly clipped.

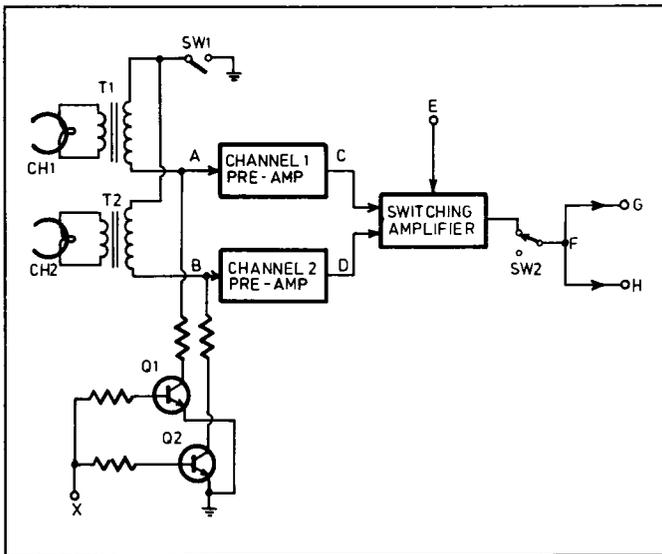
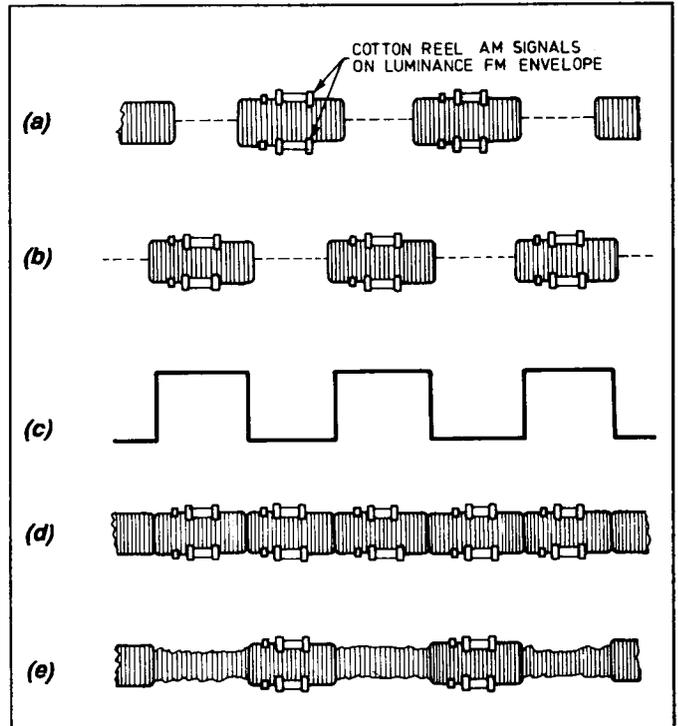


Fig.1 (above): A simplified block diagram of the video replay input circuitry of a typical VCR.

Fig.2 (right): Showing the way the replay signals from the two heads (a,b) are combined in the switching amplifier, controlled by switching signal (c), to produce the combined signal (d). Waveform (e) shows the effect of a faulty head.



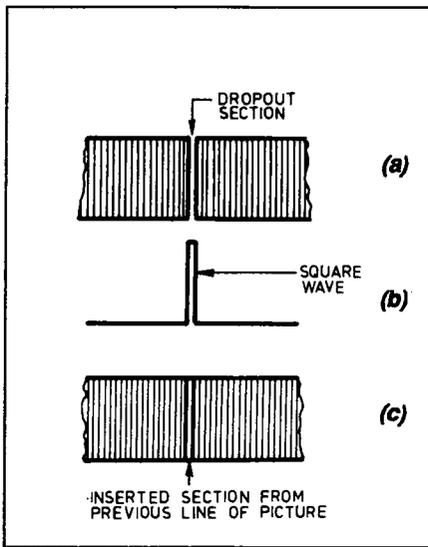


Fig.4: Waveforms for the drop-out correction circuit.

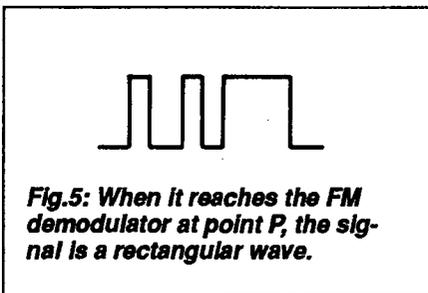


Fig.5: When it reaches the FM demodulator at point P, the signal is a rectangular wave.

period of drop-out only. This pulse appears at point L, with a waveform as in Fig.4(b). When this pulse is present the switching circuit will not accept signals from point K, but only from point N. The signal output from the switching circuit is fed back to the switching amplifier via delay line 1, which delays the signal by exactly one line of picture, and through the feedback amplifier to point N.

The signal at point N cannot re-enter the switching circuit unless the narrow square wave pulse from the drop-out detector appears at point L, during the

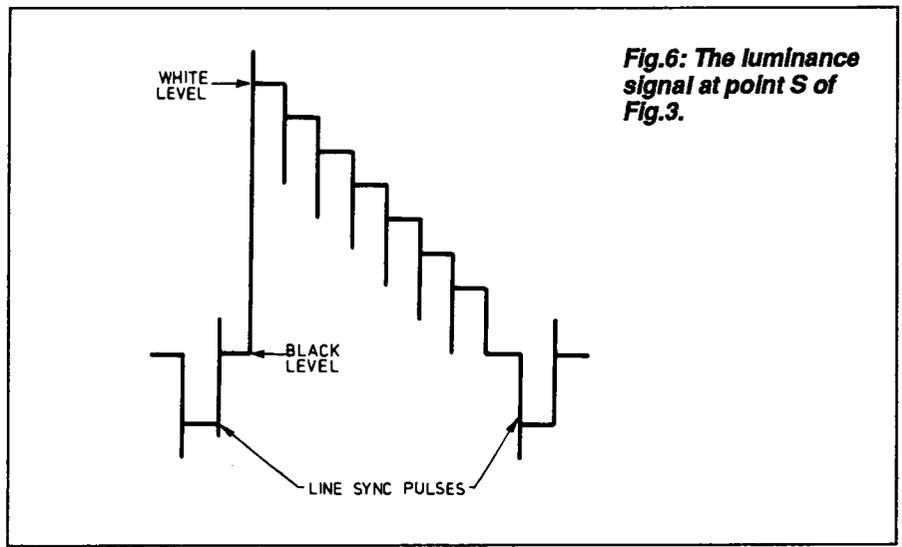


Fig.6: The luminance signal at point S of Fig.3.

drop-out period. The switching circuit now blocks the original signal input from point K so that the signal from the previous line is accepted at point N for as long as the drop-out persists.

The net result is that signal from the previous line is inserted into the missing drop-out section, thus maintaining picture quality — see Fig.4(c).

The FM luminance signal at point M now enters the FM limiter circuit and emerges at point P as a neat FM square wave signal (Fig.5), and is then fed to the FM demodulator. The FM demodulation circuitry will be considered in the last part.

The demodulated luminance signal (point Q of Fig.3) goes via electronic play/record switch SW7 to the base of emitter follower transistor Q3. Capacitor C1 and coil L1 form a 4.433619MHz acceptor trap which prevents stray pickup from the colour circuitry affecting the luminance signal.

The signal at the emitter of Q3 is supplied to the low pass filter (point R) and then to a delaying circuit, which delays

the luminance signal by approximately 600 nanoseconds to ensure that the luminance and colour signals arrive together at the luminance and colour mixer (see Fig.7). The reason for this delay of the luminance is that the colour signal will be slightly delayed by the chroma playback circuitry. At point S (assuming that a colour bar signal is recorded on the magnetic tape) the signal appears as in Fig.6.

Part 4 explained how, during the recording process, the signal levels of the high frequency parts of the video signals are boosted (pre-emphasis), particularly on low level signals. This prevents interference at low signal levels from causing picture noise on the recorded signal.

In the playback process the signal must be de-emphasised. Fig.7 shows a block schematic of the final section of the luminance playback circuitry. Point S1 connects to point S in Fig.3.

The equalising amplifier boosts the signal in the 2MHz region (Fig.8) and then feeds the signal through the de-emphasis amplifiers. The signal emerges at point U

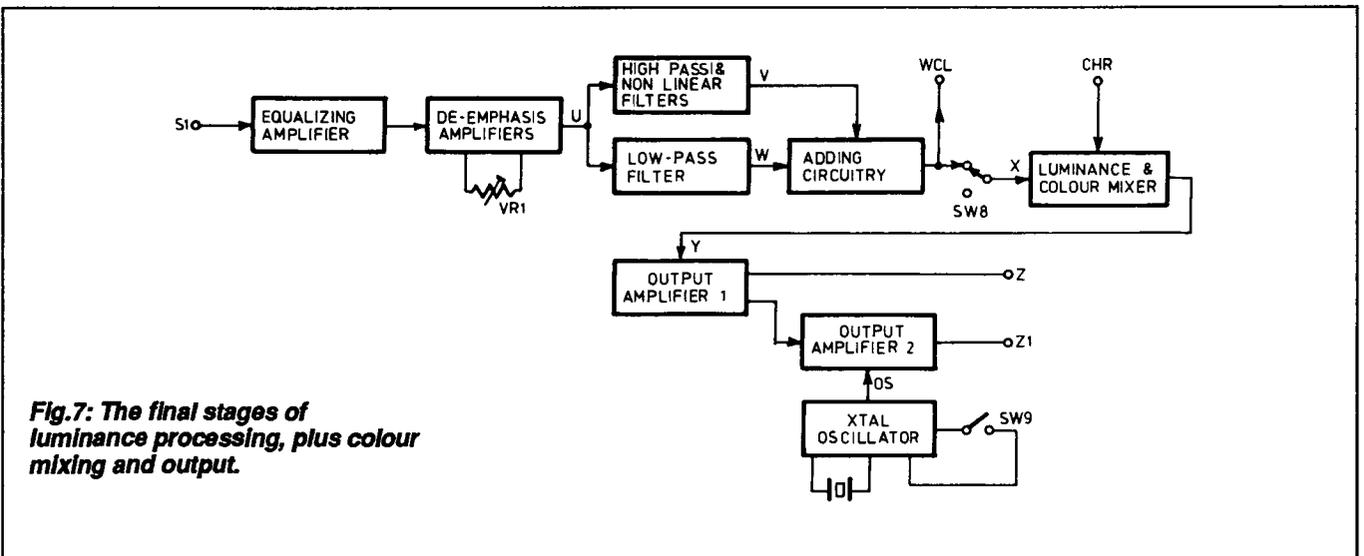


Fig.7: The final stages of luminance processing, plus colour mixing and output.

with the spikes removed, and now appears as a normal 'staircase' luminance waveform (Fig.9) — assuming that the recording is of a colour-bar signal.

Because high frequency noise may be present on the signal at point U (Fig.10(a)), noise cancelling circuitry is included. The circuit shown consists of two filters and an adding/mixing circuit. The signal is fed along one path through high pass and non-linear filters and enters the mixer at point V looking like Fig.10(b). At the same time, it is also fed through the low pass filter, and at point W its waveform is as Fig.10(c).

The signals at points V and W are then added or mixed together to produce an interference free signal - Fig.10(d).

SW8 is an electronic play/record switch, shown in the playback position. In the luminance and colour mixer section, the colour signal (Fig.11) fed in at point CHR is mixed with the luminance signal from point X. Fig.12 shows the resulting signal at point Y.

Output amplifier 1 supplies output to point Z, for direct connection to a video monitor or to another VCR etc. Output amplifier 2 further amplifies the signal supplying the RF (VHF or UHF) modulator that connects to the TV antenna socket of the TV used to view the recorded programme (point Z1).

The crystal oscillator that feeds into output amplifier 2 at point OS is controlled by switch SW9. Closing SW9 produces a monochrome test signal at point Z1 which appears at the RF out socket of the VCR. One channel of a TV receiver is then tuned to receive this pattern. For normal viewing SW9 is switched to its 'open' position.

Colour playback

Block schematic Fig.13 shows the play/record colour circuitry of a typical VHS machine. It's the same diagram shown in the last chapter, but with the playback sections of the circuitry added (shaded areas). Electronic play/record select switches SW3-SW6 and SW10-SW12 are shown switched to the playback position.

Point H in Fig.1 is taken to point CP1 in Fig.13. At this point the signal includes both the luminance signal and the colour signal. The low pass filter circuit removes the luminance signal so that only the down-converted 626.953kHz colour signal (usually referred to as the 627kHz signal) feeds into amplifier P at point CP2. The signal now appears as in Fig.11 (again assuming a colour-bar test signal). You'll recognise this as the standard 'cotton reel' waveform.

The signal then emerges at point CP3 and feeds via electronic play/record

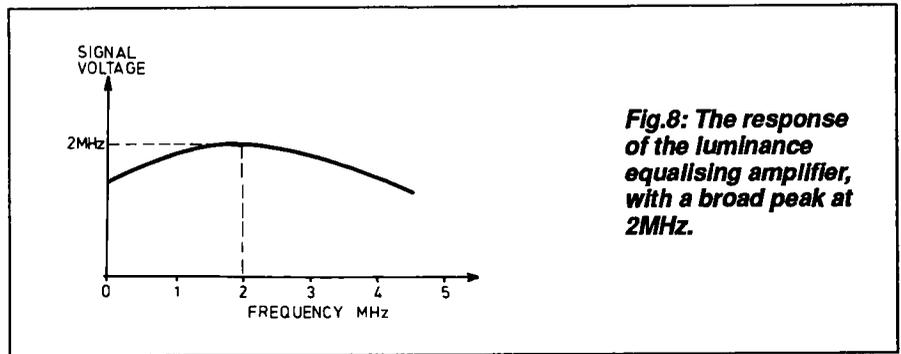


Fig.8: The response of the luminance equalising amplifier, with a broad peak at 2MHz.

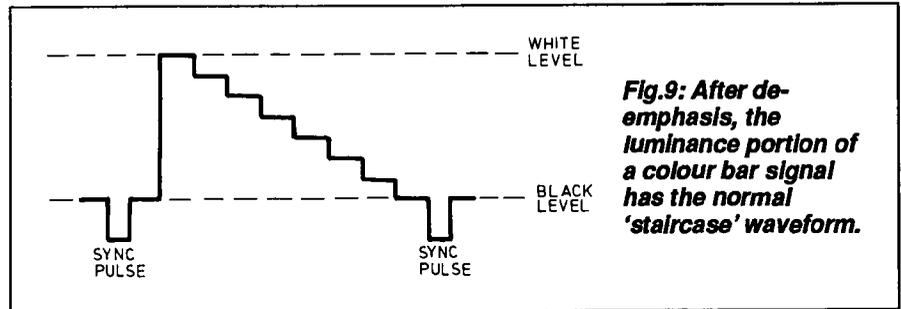


Fig.9: After de-emphasis, the luminance portion of a colour bar signal has the normal 'staircase' waveform.

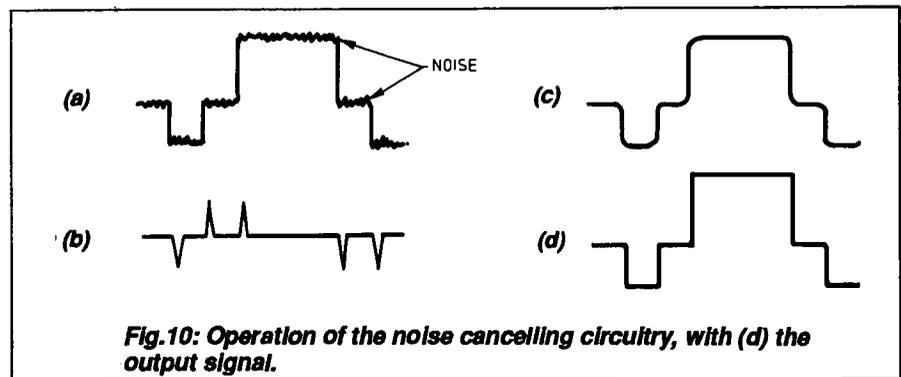


Fig.10: Operation of the noise cancelling circuitry, with (d) the output signal.

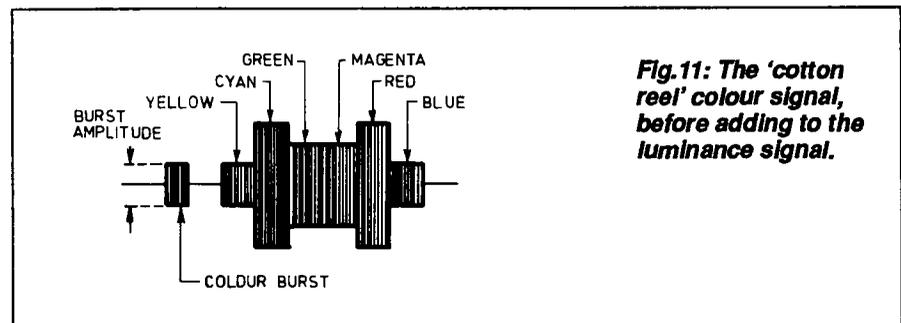


Fig.11: The 'cotton reel' colour signal, before adding to the luminance signal.

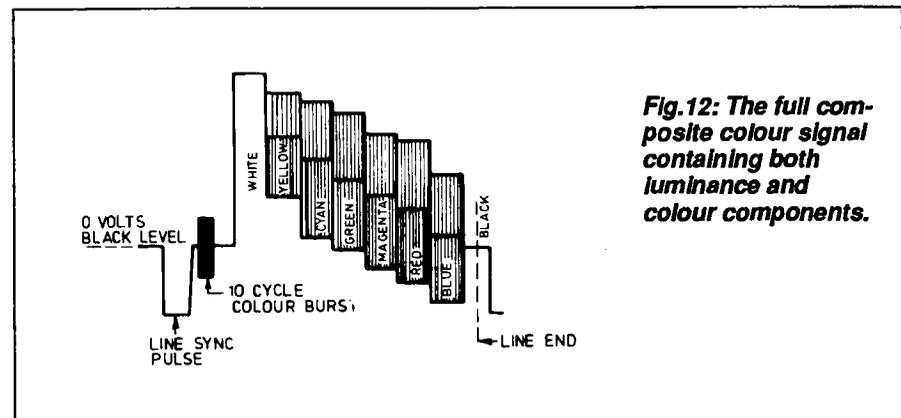


Fig.12: The full composite colour signal containing both luminance and colour components.

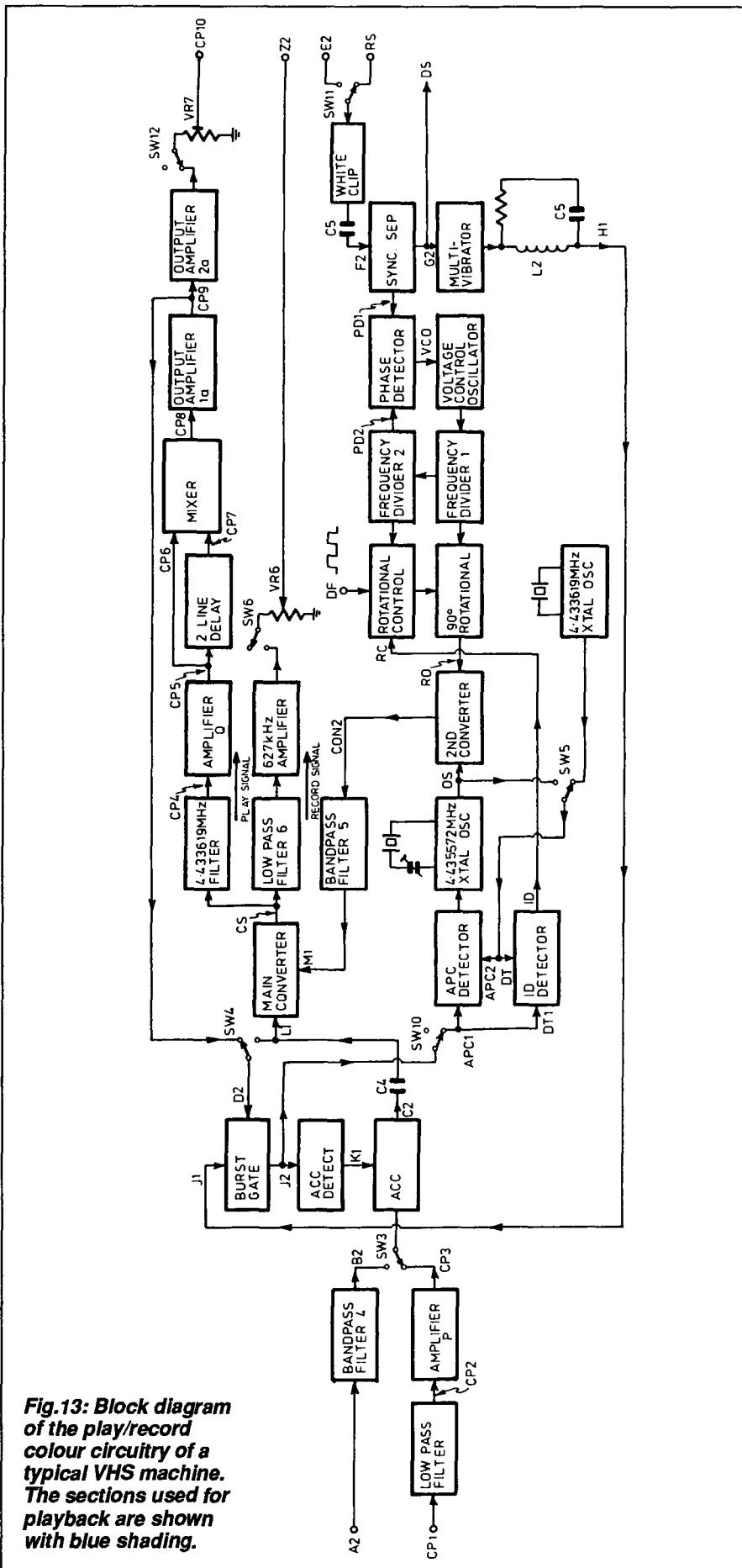


Fig.13: Block diagram of the play/record colour circuitry of a typical VHS machine. The sections used for playback are shown with blue shading.

switch SW3 into the ACC (automatic colour control) circuitry.

In the play mode the ACC (automatic colour control) detector operates in exactly the same way as in the record mode — described in part 4 — keeping the colour burst signal at a constant level.

During the recording process the luminance signal input to the white clip circuitry (point E2 of Fig.9) is obtained from the TV signal being recorded, and passed through the sych separator. In the playback process the white clip input (the luminance signal) is obtained from the recorded luminance signal on the magnetic video cassette tape (point RS connects to point WCL in Fig.7).

The waveform at point RS appears as in Fig.9, but is supplied by the recorded luminance signal instead of the received television signal. Except for this the operation of the white clip circuitry — described in part 4 — is exactly the same as in the replay mode.

The output of the ACC amplifier (C2) enters the main converter at L1 via capacitor C4. Viewed on an oscilloscope the 'cotton reel' waveform appears as in Fig.11, but with the colour burst amplitude held at a constant level.

In both the record and the playback modes a 5.060572MHz signal enters the main converter at point M1. How this signal is produced and its purpose was discussed in part 1 and part 4. However, we'll give a brief reminder of how the 5.060572MHz frequency is made up.

Crystal oscillator 1 generates a frequency of 4.435572MHz. This frequency is the sum of the colour subcarrier frequency (4.433619kHz) and 1/8 of the line frequency (15.625kHz divided by 8, or 1953.125Hz). The resultant signal of 4.435572MHz enters the second converter at point OS.

The rotational signal frequency is equal to 40 times the line frequency, or $40 \times 15.625\text{kHz}$ which is 625kHz. This 625kHz signal enters the second converter at point RO.

The 4.435572MHz signal is added to the 625kHz signal within the second converter, so that a resulting signal of 5.060572MHz appears at point CON2. It's then fed via bandpass filter 5 into the main converter (point M1).

You'll recall that in the RECORD mode with switches SW2 and SW4 set to their other positions, the 4.433619MHz received TV colour signal enters the main converter at point L1. Inside the main converter it beats with the 5.060572MHz signal.

The two signals are produced at point CS, one of 626.953kHz (the difference signal) and the other of 9.494191MHz (the sum). Low pass filter 6 allows only

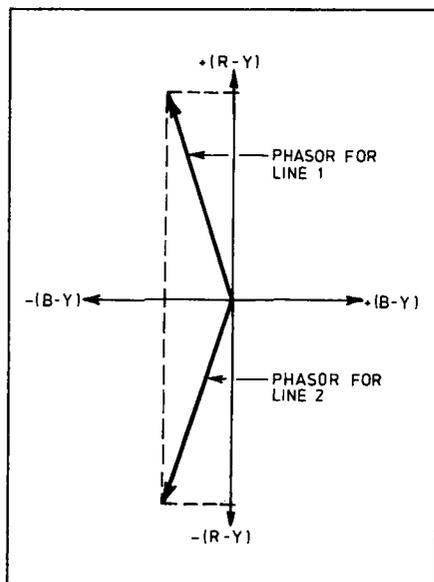


Fig.14: The vector diagram for a red colour, on alternate lines.

the down converted 626.953kHz signal to enter the 627kHz amplifier.

In PLAYBACK mode as shown, the output from the ACC circuitry (point C2) is the off-tape 626.953kHz down-converted colour signal, which enters the main converter at point L1.

This down-converted signal beats with the 5.0605072MHz signal which enters the main converter at M1. This again produces two signals, of 5.060572 - 0.626953MHz = 4.433619MHz (the colour subcarrier frequency) and 5.060572MHz + 0.626953MHz = 5.687525MHz, at point CS. The 4.433619MHz filter allows only the 4.434619MHz colour subcarrier signal to pass to point CP4, supplying the signal to amplifier Q.

Vector restoration

In the transmission of the PAL colour signal the phase of the (R-Y) signal is reversed by 180° as alternate lines of the picture are transmitted. This is done in order to cancel out colour phase errors due to transmission path distortion. Fig.14 shows the vector diagram for a red colour. The upper phasor line we'll call line 1. The lower line represents the phasor for the next line, which we'll call line 2.

Azimuth recording prevents 'crosstalk' - the picking up of unwanted signals by one video head from the track recorded by the other video head, at luminance signal frequencies. However at the lower frequencies used by the colour signals it is not so effective. So the rotational 626.953kHz colour recording system previously described is used.

Fig.15(a) represents the recording of the down-converted rotary colour signals on

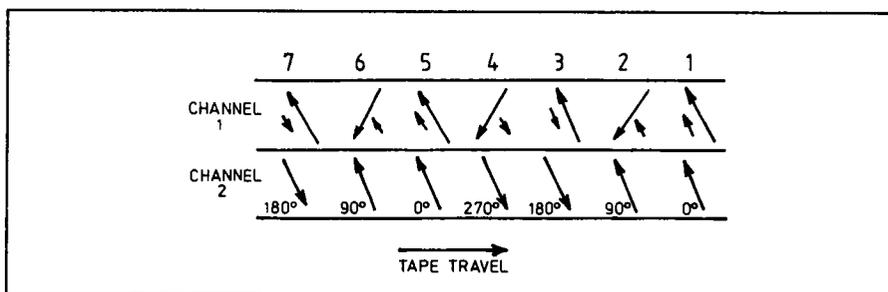


Fig.15(a): The way down-converted rotary colour signals are recorded on the tape — assuming a constant colour, say red. The channel 2 head records the signal with a 90 degree phase delay.

the magnetic tape. We'll assume that each line consists only of a red colour. The channel 1 video head records each line of the picture in the same colour phase as the PAL signal. The channel 2 head records the signal with a 90° phase delay for each line.

In the playback process, the colour signals recorded by the channel 2 head are returned to their correct phase by the rotational circuitry. Otherwise, the colours viewed on the displayed picture would be incorrect. This is known as vector restoration.

When the VCR is in the playback mode each head tends to pick up a little of the colour signal from the other track. For example channel 1's head responds to part of the channel 2 track signal. The small arrows in Fig.15(a) represent the crosstalk interference picked up by channel 1's head from the channel 2 track.

When the signals arrive at point CP5, the colour vectors for the channel 2 signal have been corrected by the rotary circuitry. However, the crosstalk vectors remain on the channel 1 track signal.

This signal appears at the output of amplifier Q, and goes directly to the mixer input at point CP6. The signal also passes through the two-line delay circuit, so that the signal at point CP7 is delayed by two lines. Inside the mixer line 3 (Fig.15(b)), line 4 is combined with delayed line 2, and line 5 with delayed line 3 and so on.

You can see that the small crosstalk vector arrows in Fig.15(b) exactly cancel out those in Fig.15(a), so that the colour signal at point CP8 is free from crosstalk.

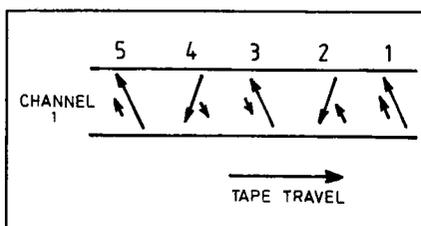


Fig.15(b): Inside the replay colour mixer, delayed signals at CP7 are used to cancel crosstalk.

The signals are then amplified by output amplifiers 1a and 2a and feed via switch SW12 to preset control VR7, the playback colour gain control. The signal at point CP10 is supplied to point CHR on Fig.7. Here the 'cotton reel' colour signal of Fig.11 is combined with the luminance signal (Fig.9) to produce the output signal of Fig.12.

Because of slight variations in the tape and video drum rotation speed, and possible 'stretch' in the magnetic tape, frequency and phase errors occur in the playback colour signal entering the main converter at point L1. We'll call this variation Fv. To compensate for Fv, tiny changes in phase and frequency must be made in the signal entering the converter at point M1.

APC circuitry

The APC (automatic picture control or automatic phase control) circuit operates only in the playback mode. The colour signal (Fig.11) is taken from point CP9 and fed through switch SW4 into the burst gate (D2). The burst gate, controlled by the off-tape line sync pulses fed in at J1, allows only the colour burst signal to pass to point J2.

The 4.433619MHz colour burst signal is taken via electronic switch SW10 to the APC detector (APC1). The signal from the 4.433619MHz crystal oscillator is supplied to the APC detector at point APC2, via switch SW5. Within the APC detector the phase and frequency of the burst and crystal oscillator signals are compared (Fig.16). Any differences in the two signals cause a corrective voltage (APC3) to be sent to the 4.43572MHz oscillator, slightly changing its phase and frequency to compensate for Fv.

The ID detector

In the record mode the ID (identification) pulse detector obtains its input via switch SW5 (other position) from point OS. In the playback mode its input comes from the 4.433619MHz crystal oscillator.

Inside the ID detector the burst signal is compared with the 4.433619MHz crystal oscillator signal. If a difference between

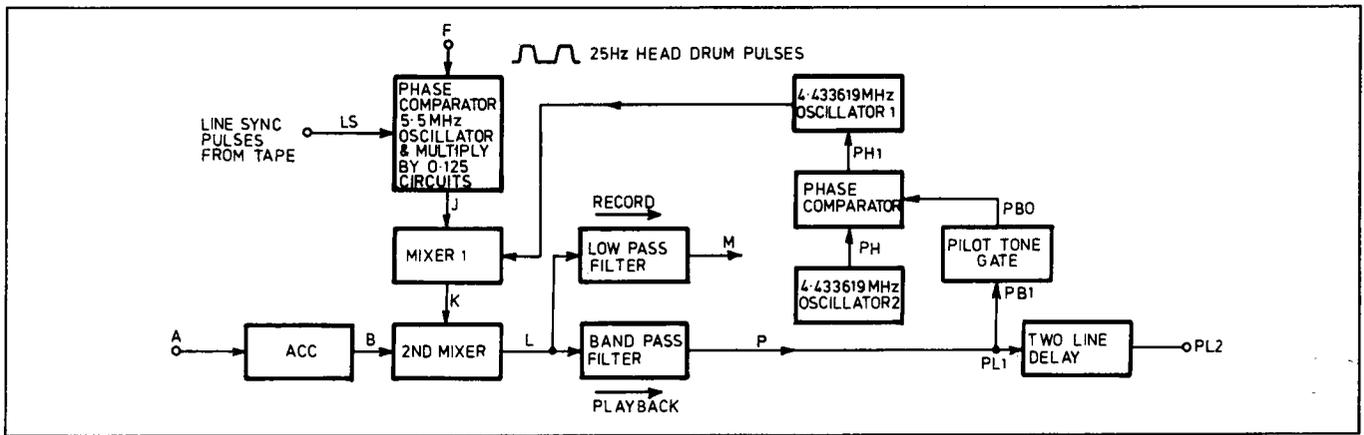


Fig.16: The colour replay circuitry of a Betamax machine.

the two is detected, then the ID detector output (ID to RC) via the rotational control circuitry slightly changes the phase of the output (point RO) of the 90° rotational circuitry. This provides further correction for Fv.

Colour killer

When recording or playing back monochrome pictures, a colour killer circuit may be used. These circuits operate by switching or biasing off the chroma circuitry in the absence of a colour burst. This prevents 'colour splash' spoiling the displayed picture.

However, many TV stations now continue to transmit the colour burst even when the programme is in monochrome. For this reason, instead of colour killer circuitry modern VCRs often have a user operated B/W (black and white) switch which turns off the colour circuitry.

'E to E' facility

During recording or when tuning the VCR to the desired TV channels the *E to E* (electronics to electronics) facility is used. The complete video picture signal and the audio signals being recorded are taken to the RF modulator, which converts these signals into a TV signal that may be viewed on the user's TV receiver.

Betamax colour playback

The Betamax system uses principles basically similar to the VHS system — but with some significant differences which we'll briefly consider. A simplified section of the colour replay arrangement is shown in Fig.16. It's helpful to compare this diagram with the Betamax diagram in part 4.

The signal at point K has a frequency of 5.1230721MHz for one field of the picture. With the succeeding field the signal frequency changes to 5.1191659MHz, returning to 5.1230721MHz for the third field, and so on. The circuitry producing these two frequencies was explained in part 4.

In the replay mode, the two down-converted off-tape colour subcarriers recorded on the cassette magnetic tape (685.5469kHz) for channel 1's video head, and 689.4531kHz for the channel 2 head) feed into point A, through the ACC amplifier into the second mixer at B.

The channel 1 off-tape signal is phase shifted by +45° each line, and the channel 2 signal by -45° for each line. The 685.5469kHz signal beats with the 5.1191659MHz signal, producing sum and difference signals of 4.433619MHz and 5.8047128MHz. The 689.4531kHz signal similarly beats with the 5.1230721MHz signal, to produce 4.433619MHz and 5.8125252MHz. These signals appear at L.

Bandpass filter 1 allows only the 4.433619MHz signals to reach point P. At point PB1 the pilot tone gate allows only the special pilot tone signal that was recorded on the tape to pass to point PB0 into phase comparator B. Here the signal at point PH is compared with the pilot burst signal. The output at point PH1 controls the phase of oscillator 1, compensating for variations in tape and video drum rotation speed and any 'stretch' in the tape.

After reaching point PL1 the chroma signal enters a two-line delay circuit. It's

then taken (PL2) to phase correction circuitry (not shown) and finally arrives at the luminance and colour mixing amplifier.

LP operation

Many of the newer VCRs have a 'long play' mode, involving two speed operation. This makes it possible to have as much as eight hours of recording on a single video cassette.

The normal tape speed of a VHS machine is 23.39mm per second. For long play operation it runs at half speed, or 11.695mm per second. Two additional video heads are incorporated in the head drum.

Fig.17 shows the relative positions of the video heads in a typical head drum. The long play heads are slightly thicker than the standard play heads.

Electronic switching selects the required heads as standard or long-play modes are required. Because luminance crosstalk increases at the lower tape speed, additional circuitry is included to overcome this.

Audio circuitry

In a standard VHS recorder the magnetic audio track or tracks are located at the top edge of the cassette magnetic tape, as explained in part 2.

In the recording process the audio tracks are first 'wiped clean' by the audio erase head, which has a bias oscillator signal supplied to it. Then the audio signals to be recorded (which may be mono or stereo) are applied to the audio record head(s) proper, together with a suitable ultrasonic biasing signal.

The process is the same as in a standard audio tape recorder, which was described in part 1. However some late model VCRs such as the Video 8 system are now using a section of the helical 'video' tracks to contain the audio signals.

The Video 8 PCM method is an extremely sophisticated compression/expansion analog to digital recording process.

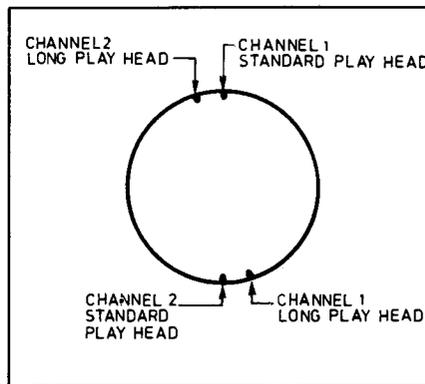


Fig.17: An additional pair of heads are mounted on the head drum, for VCRs offering a 'long play' mode.

THE COMPLETE VHS RECORDER

Part 6

In this final part we begin by considering the complete video cassette recorder. We also discuss some sections of the VCR that were not covered in the earlier parts.

Fig.1 is a simplified block schematic of a typical Video Home System (VHS) format machine. You will remember that during the transmission of a television programme, the energy radiated by the TV station is in the form of an electromagnetic field. When this energy reaches the TV receiving antenna (via the transmission path) an electrical signal is extracted. This signal is then fed down through the antenna cable, entering the Booster/Mixer circuitry at point A in Fig.1.

Fig.2 shows a more detailed block schematic of one type of Booster/Mixer circuitry. The signals at point A enter broad-band amplifier 1 (the 'booster'), which can handle the whole range of TV station frequencies.

From one end of coil L1 the signal passes through the filter circuit formed by RF choke 1, capacitor C2, and RF choke 2, via capacitor C3 to socket A2. A co-ax lead from this socket feeds the signal to the antenna socket of a colour TV receiver. Because of the wide bandwidth

of amplifier 1, the TV set user can still tune the TV receiver to any 'off-air' TV channel.

Through capacitor C1, the opposite end of coil L1 and resistor R2 the received TV signals also arrive at point A3, where they are supplied to the VCR tuner. The VCR tuner can select any TV programme that the viewer may wish to record.

In both the record and playback modes video and audio signals are supplied to points V1 and AU1. The video signal passes through the video buffer amplifier and via resistor R3 to point M1.

The audio signal amplified by the audio amplifier modulates the 5.5MHz oscillator (point OS). This FM (frequency modulated) signal is fed into transformer T1. Via resistor R5, capacitor C4 and RF choke 3 the modulated 5.5MHz signal reaches point M1.

The carrier oscillator generates a TV channel signal frequency — typically channel 1 (VHF) or channel 36 (UHF) — an unused TV channel frequency.

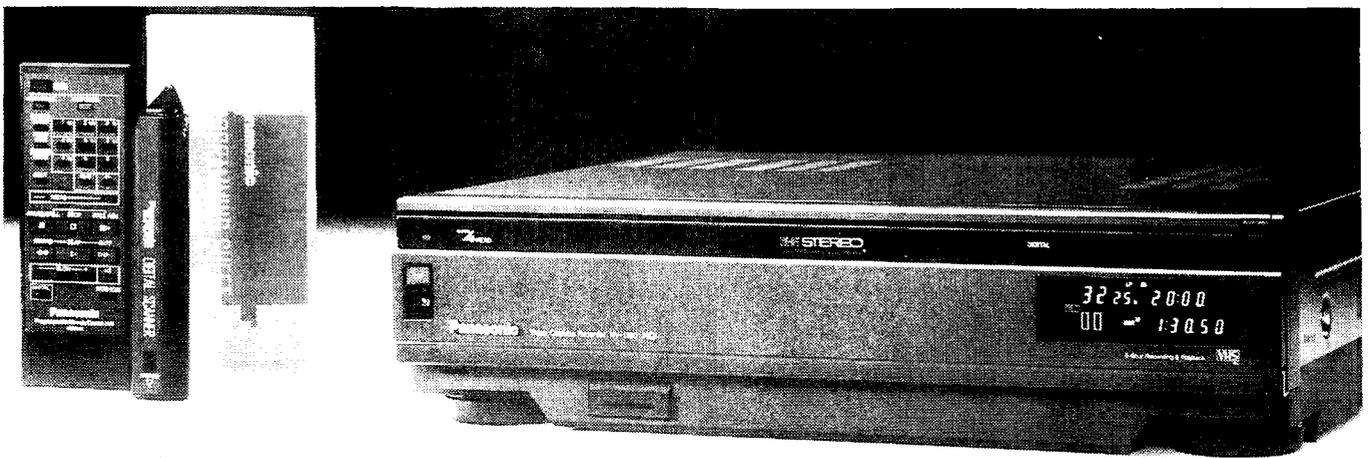
Both the video and audio signals at point M1 modulate the carrier oscillator, producing a composite TV signal carrier. Via capacitor C5, resistor R2, capacitor C2 and capacitor C3 this signal is supplied to socket A2 and through the co-ax lead to the TV set.

One of the selector buttons of the TV is then tuned to channel 1 or 36. Should a 'beat pattern' then be observed on the TV screen, the frequency of the carrier oscillator can be varied by adjusting preset capacitor TC.

By selecting channel 1 or 36 on the TV, the viewer can monitor programmes being recorded by the VCR, or of course, view programmes previously recorded on the video cassette magnetic tape. By selecting a different channel on the TV it's also possible to record one TV programme and at the same time watch a different programme on another channel.

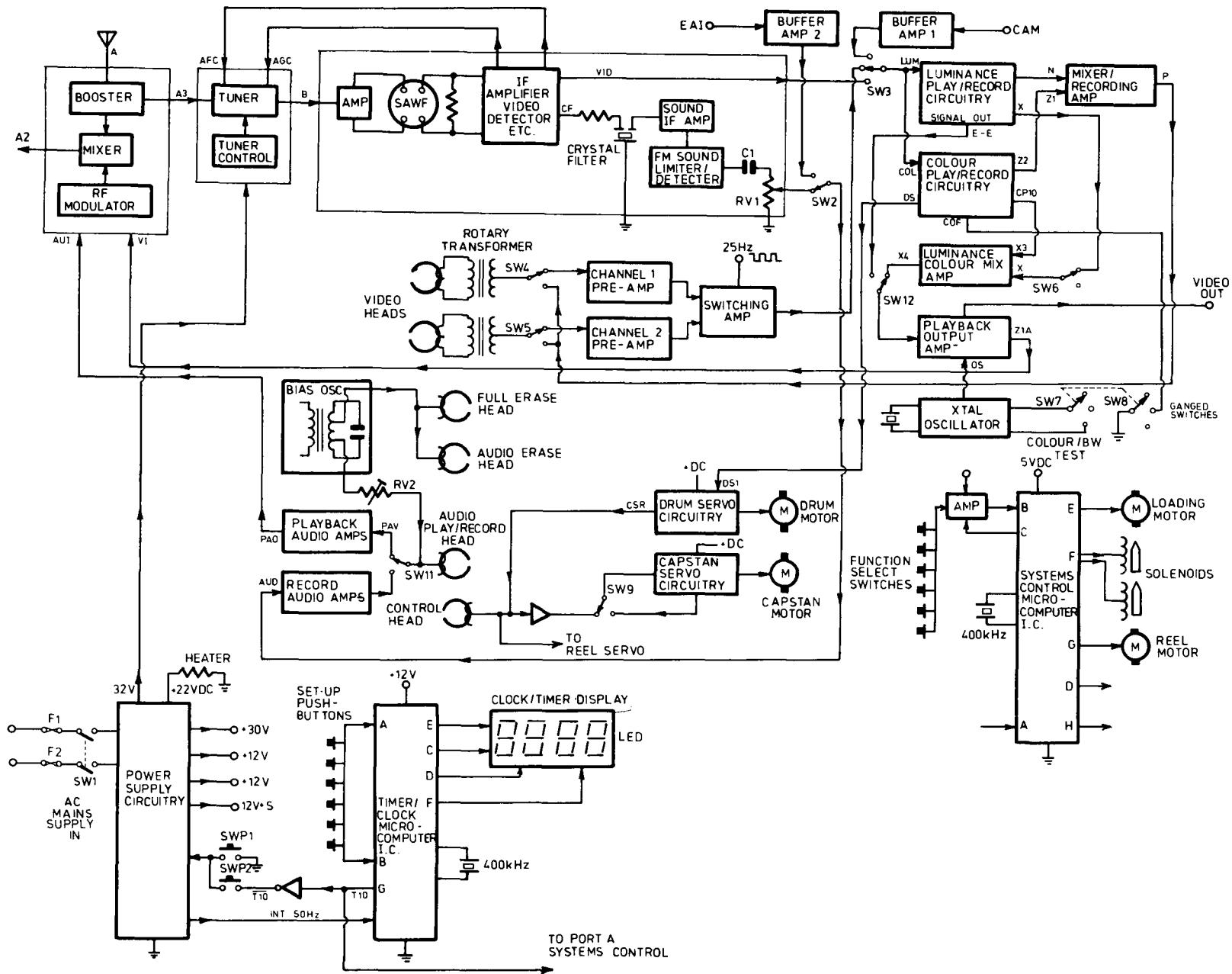
Tuner and IF stages

Because the VCR tuner/IF stages (Fig.1)



The Panasonic model NV-D80 VCR, which features both bar-code programming and digital 'freeze-frame' as well as more common facilities such as high fidelity stereo sound.

Fig. 1: A simplified block diagram for a typical VHS video recorder, used in this article to bring together the concepts explained previously.



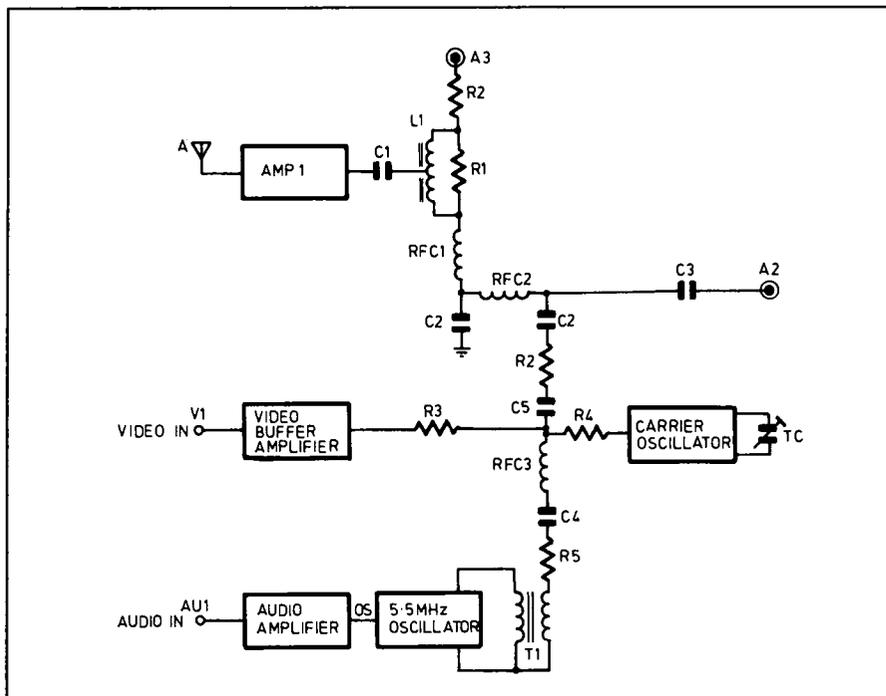


Fig.2: A more detailed look at the RF booster/mixer circuitry of a typical VCR. Amp 1 at the upper left is the broadband RF booster amplifier.

operate as a superheterodyne receiver, the tuner contains a local oscillator which beats with the received amplified station frequency. To tune in the various TV stations varicap diodes are used. (See part 7 of 'Understanding Colour TV'). Control of these may be by selector buttons, an electronic memory system or a remote control unit.

Two intermediate frequency signals are produced at point B. One carries the vision information, the other the sound signal in exactly the same way as in a colour TV receiver.

You'll remember that for Australia the vision IF signal is 36MHz and the sound signal 30.5MHz. The two signals are separated by 5.5MHz (in Britain the vision IF frequency is 39.5MHz and the sound IF frequency is 33.35MHz — a separation of 6MHz).

IF bandpass shaping is performed by a SAW (surface acoustic wave) filter and amplified by the IF amplifier, which is contained within a single IC. Automatic frequency correction (AFC) is used to

'lock' the tuner to the TV station frequency. A voltage is fed back from the IF amplifier to the TV tuner's local oscillator varicap. If any 'drift' occurs the AFC voltage changes slightly to correct it.

Automatic gain control (AGC) voltage is also fed back to the tuner. This is needed to compensate for possible variations in signal strength when changing from one TV station to another. Besides this, in some weak signal areas, fading can occur.

Exactly as in a colour TV receiver, both vision and sound IF signals pass through and are amplified in the vision IF stages. The 5.5MHz (6MHz for Britain) crystal (or ceramic) filter extracts the FM sound signal at point CF. It's then amplified by the sound IF amplifier and passes through into the FM limiter/sound detector stage.

Preset resistor RV1 is used to set the sound signal to the desired level. Switch SW2 is shown in its normal position — the other position is used when it is desired to feed in an external audio signal.

An RF signal modulated with a colour bar signal fed in at point A would produce the standard waveform at point VID, as viewed on an oscilloscope. This waveform was shown in parts 5 and 6.

Switches SW3 to SW6, SW11 and SW12 are the electronic play/record switches controlled by the microcomputer IC via ports D and H.

The solid lines indicate the playback positions, while the dashed lines show the record mode positions of these switches.

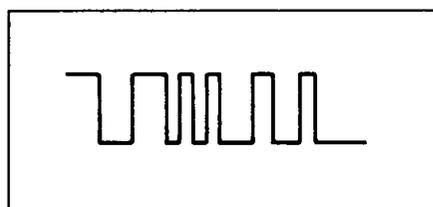


Fig.3: The luminance signal at point N is in the form of an FM carrier centred on 4.3MHz, and deviating by +/-500kHz.

Record mode

In the record mode the signal at point VID passes through switch SW3 (dashed line) into the luminance play/record circuitry at point LUM, where the colour information is removed — allowing only the luminance signal to pass into the circuitry.

The complete signal also enters the colour play/record circuitry at point COL, where it passes through a bandpass filter which removes the luminance information. The operation of the luminance and colour circuits was discussed in parts 4 and 5.

At point N the luminance signal consists of a frequency modulated signal (Fig.3). The colour information at point Z2 — assuming a standard colour bar signal is being recorded — consists of a rotational 627kHz 'cotton reel' AM signal which enters the mixer/recording amp at point Z1. Fig.4 shows the resultant waveform at point P as viewed on an oscilloscope.

The signal from point P is taken through switches SW4/SW5 (dashed line positions) and via the rotary transformer into the video heads. It's then recorded on the magnetic tape.

The E-E signal

From the luminance play/record circuitry the complete colour bar signal (or colour picture signal) is taken from point E-E (electronic to electronic) output to switch SW12 — dashed line position.

It then enters the playback output amplifiers at point Y. At point Z1A the video signal is taken to the V1 input of the RF modulator. In this way, the programme being recorded can be viewed on the TV set.

A direct video signal is available at the VIDEO OUT socket shown. This socket is useful when recording from one VCR to another, or for connecting to a video monitor.

Test signal

The operation of the 'test' signal was briefly considered in part 5. The crystal oscillator (typically 500kHz) feeds

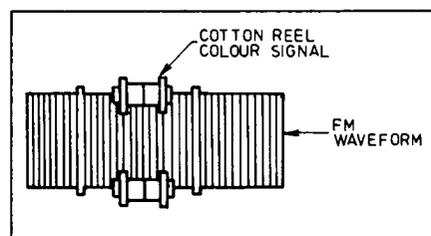
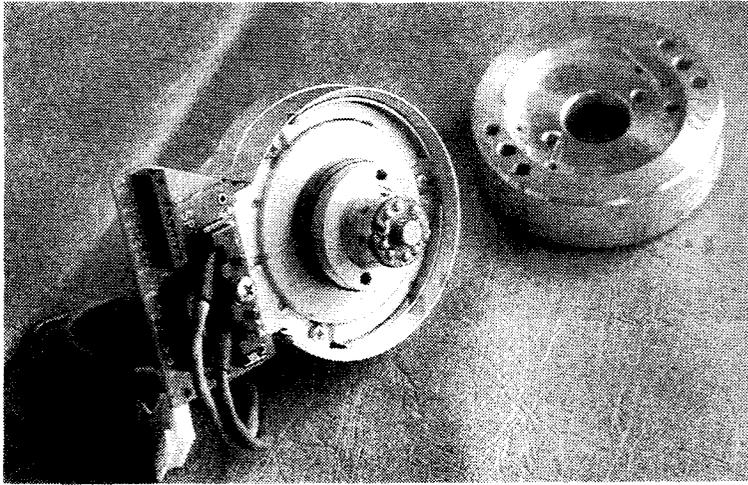
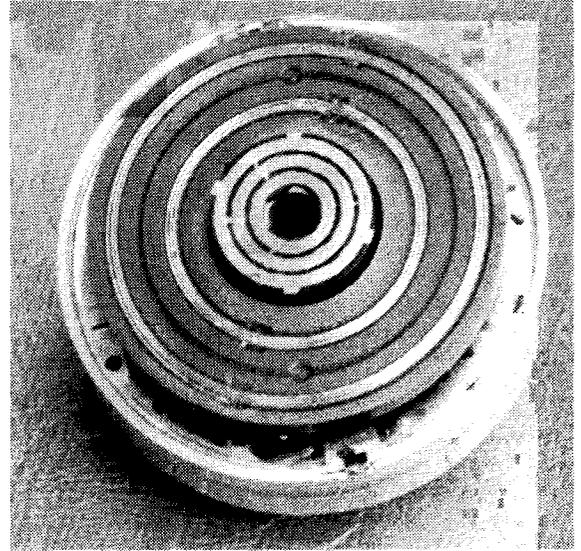


Fig.4: At point P, the waveform shows the FM luminance signal together with the 627kHz 'cotton reel' chroma signal.



Above: Photo A shows the rotary head drum assembly of a VHS machine, with the rotating section lifted off.



Right: Photo B - underneath the upper section of a head drum assembly from a Philips VCR, showing the rotating halves of the rotary transformers for each head. The windings are the lighter rings in the central (annular) grooves.

into the playback output amplifiers at point OS is controlled by ganged switches SW7 and SW8. In the test position a monochrome signal is produced at point Z1A and is used to tune the TV set for best results on channel 1 or 36.

A colour killer circuit is not incorporated in the VCR schematic shown in Fig.1. To prevent patterning when recording or playing back a monochrome picture, SW7/8 are set to the B/W position taking point COF to chassis. Circuitry in the colour play/record section now prevents the colour signal from reaching point Z2. For normal use SW7/8 is set to its COL position.

Recording the sound

From the sound detector, the audio frequency sound signal passes via capacitor C1 and preset sound level control RV1 through SW2 to the record audio amplifiers (point AUD). The output of the audio amplifiers goes via switch SW11 (dashed line position) to the audio play/record head. The bias oscillator signal level is set by preset resistor RV2. The

basic sound recording process was described in part 1 of this section. The bias signal also energises the full erase head and audio erase head, to remove previous recordings from the video cassette tape. You'll notice that an EXTERNAL AUDIO IN socket can be selected by means of switch SW2. When playing back the recorded sound, signal voltage induced in the audio play/record head goes via SW11 (solid line position) into the playback audio amplifier (point PAU).

The output from this amplifier (point PAO) is then fed to the 'Audio In' socket (point AUI) of the RD modulator. In practice the two audio amplifiers are usually combined — we've shown them separately for ease of understanding. (Many VCRs now have provision for stereo sound recording and playback. The playback head contains two audio play/record heads, and stereo record/playback amplifiers are used).

Playback mode

As the head drum rotates a signal voltage is induced in each head. This signal

travels via the rotary transformer through switches SW4 and SW5 (solid line position) to the channel 1 and 2 preamplifiers and switching amplifier (see part 5).

Via switch SW3 (solid line position) the signal enters the luminance and colour play/record circuitry at points LUM and COL. At point X the signal is as in Fig.5 and at point CP10 the standard 'cotton reel' signal is seen.

The luminance signal enters the luminance/colour mixing amplifier via switch SW6 (solid line position) at point X2, and the colour signal from point CP10 enters the luminance/colour mixing amplifier at point X3. At point X4 an oscilloscope would show the standard colour bar signal. Via switch SW12 (solid line position) the signal enters the playback output amplifiers at point Y. The amplified signal (point Z1A) is supplied to the 'Video in' socket of the RF modulator (point V1).

Control head signals

From point DS a 50Hz signal is taken from the synchronisation separator, within the colour play/record circuitry. You will remember from part 3 that the drum servo circuitry divides this by two, to produce a 25Hz pulse (point CSR). In the record mode this signal is recorded on the video tape control track.

In the play mode the recorded 25Hz control track pulse is fed back to the capstan motor servo circuitry, and also to the reel motor servo circuitry.

Rotary transformer

Fig.6 shows a schematic of a standard transformer, with a primary and secondary winding. It is wound on a core made

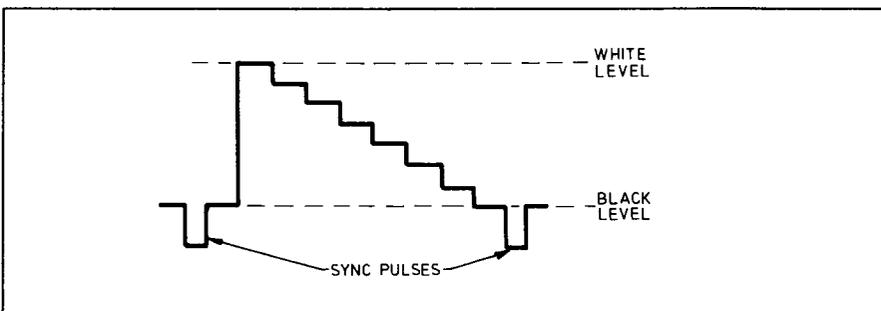


Fig.5: The luminance signal at point X, when a standard colour bar signal is being played back.

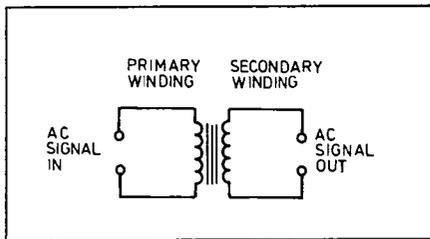


Fig.6: In case you've forgotten, the basic schematic for a standard AC transformer. Bear this in mind when trying to visualise the rotary head transformer.

from laminated iron sheets. As you will know, when an alternating current (AC) signal is supplied to the primary winding a current is induced into the secondary winding, producing a signal across the secondary winding.

To pass the energy from the video heads to the VCR circuitry, a special type of transformer is needed.

Fig.7(a) represents a VHS rotary head drum, viewed sideways. The dashed lines show its internal cut-away sections. This drum pushes down over the rest of the head drum assembly shown in Fig.7(b).

Photograph A shows a VHS head drum at the right of the picture, with the rest of the head drum assembly on the left. The drum is secured to the upper section of the assembly by two non-magnetic screws.

The upper rotating ferrite section (driven by the drum motor shaft) rotates and contains two transformer windings. The lower ferrite section (which does not rotate) contains two more (stationary) transformer windings. Between the two ferrite cores is a tiny gap, just sufficient to prevent the two cores touching each other as the upper core rotates. Fig.7(c) shows the schematic.

In Fig.7(b), and photograph A, you can see the little stud connections onto which the colour coded wires from the video heads are soldered. In photograph A the dark rings are the two ferrite cores. Also visible in the photograph are the enamelled copper wires from the non-rotating transformer windings that go to the terminal board.

Photograph B shows the upper section of a Philips head drum assembly. This head is not a VHS head, but it serves to show the basic method of placing the windings within the ferrite cores. (The VHS windings are far more compact).

The two windings are set into slots in the rotating ferrite core. The other two windings are set into identical matching slots in the lower stationary ferrite core.

When a signal is being recorded the

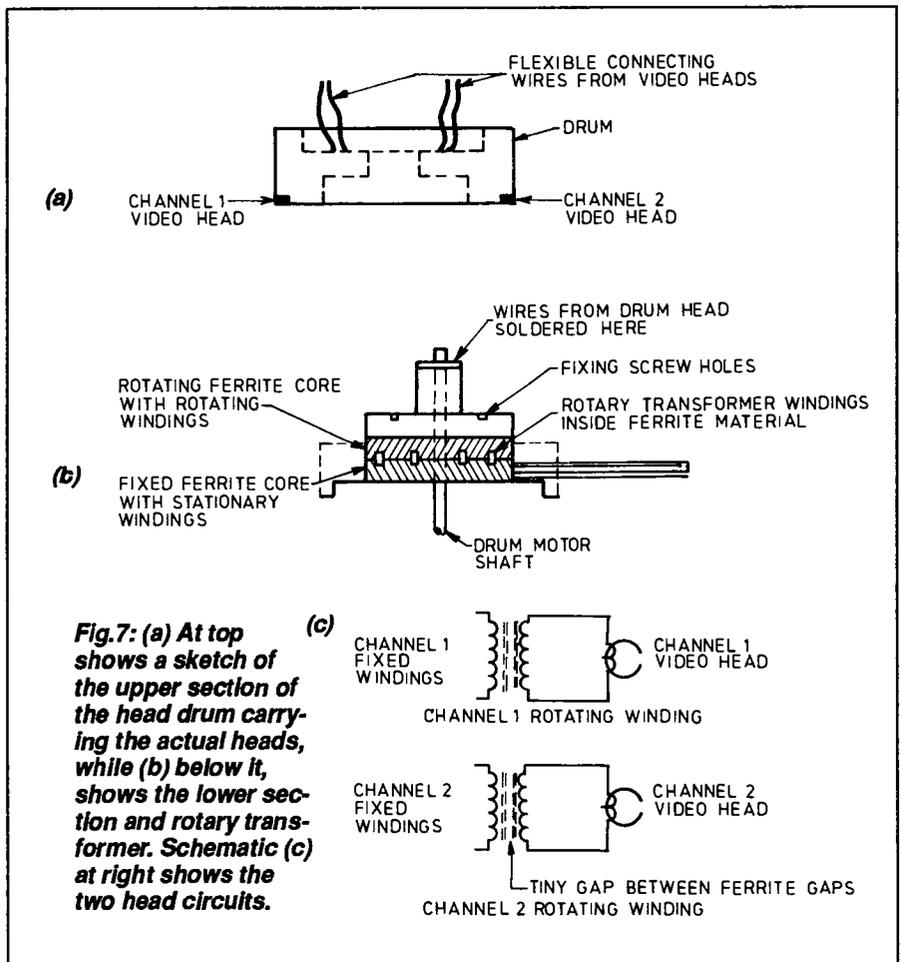


Fig.7: (a) At top shows a sketch of the upper section of the head drum carrying the actual heads, while (b) below it, shows the lower section and rotary transformer. Schematic (c) at right shows the two head circuits.

fixed windings act as the two primary windings and induce signal voltages into the rotating windings, which act as secondaries. The rotating windings energise the two heads and the video information is impressed upon the video cassette magnetic tape tracks.

In the playback mode the magnetic information on the video cassette tape induces a signal voltage into the video heads. The two rotating windings now act as primary windings and induce signal voltages into the fixed windings, which now become the secondaries.

The operation of the systems control microcomputer circuitry was discussed in part 3. However, because the operation of the reel motor and the 'port A' signals were not covered in that article, we'll describe them here.

Reel motor servo

Reel motor forward and reverse control signals are obtained from port G of the systems control microcomputer.

Fig.8 is a block schematic of one type of reel motor servo circuit. The reel servo circuit operates only in forward and reverse picture search modes. The signals from port G are inverted by the inverter circuits 1 to 4. When 'play', 'fast forward'

or 'fast forward picture search' modes are selected by the function switches, points A and C on the motor drive amplifier are at binary 0 (low) and points B and D at binary 1 (high).

The output voltage at point M is positive and at M1 negative, and the motor rotates in the forward direction. If the rewind or reverse fast picture search function is selected then the binary signal outputs at port G are inverted and point M becomes negative and point M1 positive, causing the reel motor to rotate in the reverse direction.

Signals from port D of the systems control microcomputer go via digital switching circuitry to point SPD, controlling the voltage input at the positive input of op-amp 2 and the DC voltage output at point OP1. Notice that op-amps 1 and 2 have a 20V DC power supply.

Point OP1 connects via resistor R4 to point OP2 on the motor drive amplifier, controlling the voltage fed to the reel motor, and thus its speed. When electronic switch SW13 is closed there is no output signal from the frequency to voltage amplifier.

In the fast/forward and fast/reverse picture search modes, the voltage input at point SPD is such that the tape moves at

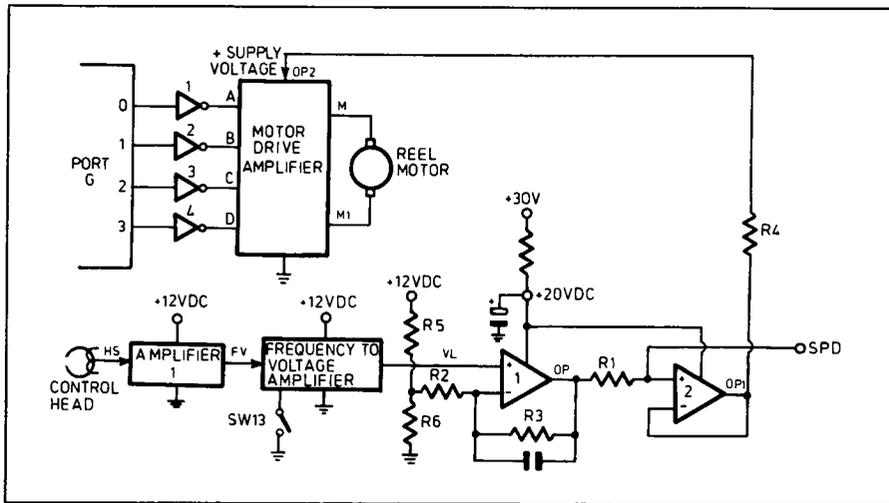


Fig.8: A block schematic of a typical reel motor servo system. Digital signals from port G of the microcomputer are used to control reel motor direction, via the motor drive amplifier.

nine times its normal speed. Switch SW13 is now open.

The signal from the control track of the video cassette tape is picked up by the control head (point HS) and amplified by amplifier 1. Since the tape is travelling at nine times its normal speed, the 25Hz signal recorded on the control track becomes a 225Hz signal ($9 \times 25\text{Hz} = 225\text{Hz}$). This signal frequency is fed into the frequency to voltage conversion amplifier at point FV.

The voltage output at point VL remains steady as long as the speed of the tape is exactly nine times its normal speed. Op-amp 1 drives the positive input of op-amp 2 via resistor R1. If the tape speed increases or decreases, the frequency of the signal from the control head will change. The voltage at point VL will then rise or fall, as will the voltage at point OP1 — by

just the right amount to correct the speed of the reel motor and keep the video cassette tape speed exactly 'locked' to nine times its normal speed.

Port A inputs

Fig.9 shows one possible arrangement of signals that feed to port A of the systems control microcomputer.

W, X, Y and Z are digital multiplexers, controlled by signals from port H. (You'll remember that a digital multiplexer circuit selects and directs any one of a number of input logic signals to a single output). So all the signals fed to each multiplexer can be selected as required and fed to the four inputs of port A. Should the cassette lamp fail, a signal passes through multiplexer W to port A data line 3, and the VCR will not work. When the tape is unloaded this condition also reaches line 3.

The two switches connected to multiplexer X convey first the information that a cassette has been inserted, and then that it is properly loaded. Signals reach port A data line 2, allowing the VCR function switches to operate. Should light strike phototransistors A and B (cassette lamp sensors), signals through multiplexers Y and Z will reach data lines 1 and 0 and halt the movement of the magnetic tape.

If the user selects the timer mode, a signal into multiplexer Y informs the microcomputer via data line 1. When the timer switches on the VCR a signal reaches multiplexer Z and data line 0.

Cassette lamp, sensors

Fig.10 is a sketch of the cassette lamp and sensor arrangement. As the tape from the video cassette passes over phototransistor A (the start sensor) the light from the lamp cannot reach it. This lamp may be a tiny bulb with a filament, or a light emitting diode (LED).

When the magnetic tape returns to the cassette it passes phototransistor B. The current flowing through both phototransistors remains constant.

If the magnetic tape should break, light from the lamp will reach one (or both) of the phototransistors. The current through the phototransistor(s) increases as the light strikes it/them, and a signal is sent to port A of the control microcomputer. The tape transport mechanism then stops and the function select switches will not work.

Time/clock circuitry

The timer/clock shown in Fig.1 is a 4-bit microcomputer. Its internal crystal control oscillator runs at 400kHz. Ports E, C, D, and F drive the clock/timer display.

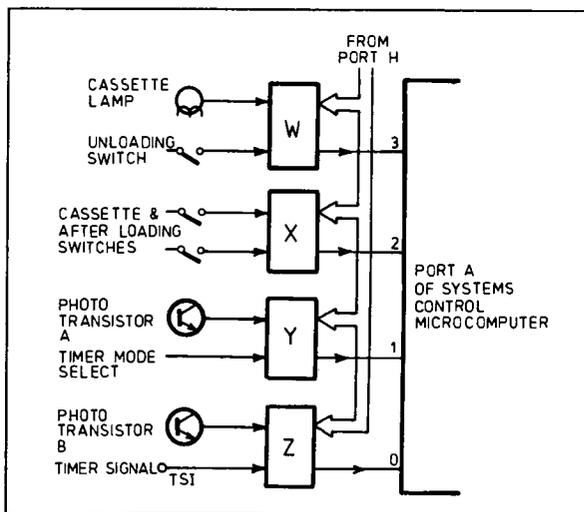


Fig.9: Port A of the microcomputer accepts signals from the cassette lamp, cassette sensing switches and tape loading photodetectors.

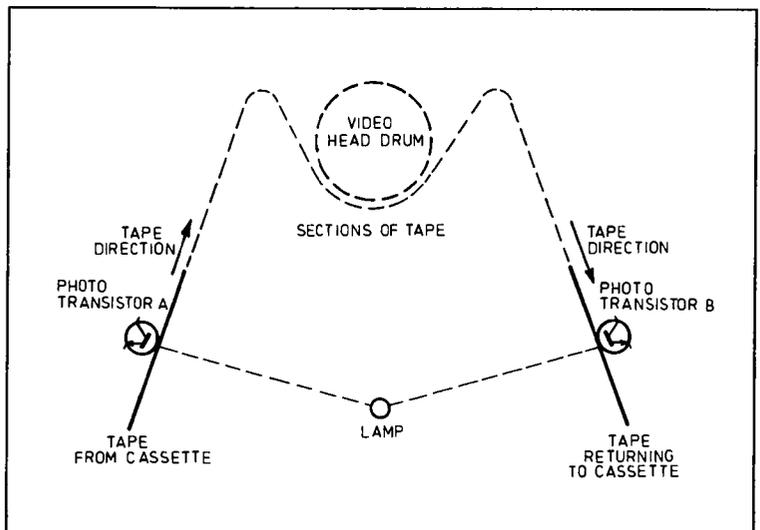


Fig.10: A sketch showing the cassette lamp and photodetector arrangement used to sense correct tape threading.

The IC is 'programmed' by the set-up pushbuttons connected to ports A and B. From port G a signal is supplied to multiplexer Z (see Fig.9, point TSI), which informs the systems control microcomputer that the VCR is in the timer/record mode.

A 50Hz signal from the power supply locks the display clock time to the mains frequency. The clock time 'read-out' is set to show the day and time. It can then be set to turn on the VCR in record mode, at a desired day and time for a selected period of time to record a TV programme. It does this by turning on a section of the power supply. It is not necessary to have the TV set switched on during this recording period.

The power supply

Power supply arrangements in different makes and models of VCRs vary widely. Fig.11 shows a basic schematic of one type of regulated supply.

Regulator 1 produces 32V DC for the tuner varicap voltage supply. The unregulated 30 volt line supplies the capstan and reel motors. Regulator 2 produces 22V DC to power the little heater fitted to the lower section of the head drum assembly. This heater prevents (or removes) condensation (known as 'dew') that might otherwise form on the head drum and prevent smooth running of the tape.

There are three +12V DC supply lines. The 'ever' 12V supplies the timer/clock circuitry, the RF booster mixer, and the systems control circuitry. Lines 12A and 12B power the remainder of the circuitry.

When mains switch SW1 is first switched on, 12V is present on the 'ever 12' line but there is no power at points 12A and 12B.

When the front panel 'on' switch SWP1 (see Fig.1) is pressed, point SV1 is connected to chassis. This causes the electronic switching in the power supply (Fig.11), to operate the closing of SW14 and SW15. 12V DC then appears at both points 12A and 12B, turning the VCR fully on.

When the user desires to select the timer mode, button SWP2 is pressed (switch SWP2 will not operate until switch SWP1 is released). The user now sets the clock/timer display to switch the VCR on (in the record mode) at the desired time — for example at 8pm.

At 8pm port G of the timer/clock microcomputer puts out a binary 1 signal (point TIO).

This signal is inverted (point 'not-TIO') and point SV1 is taken to chassis. DC voltage now appears on supply lines 12A and 12B, and the VCR starts to record the desired TV programme. The on/off and

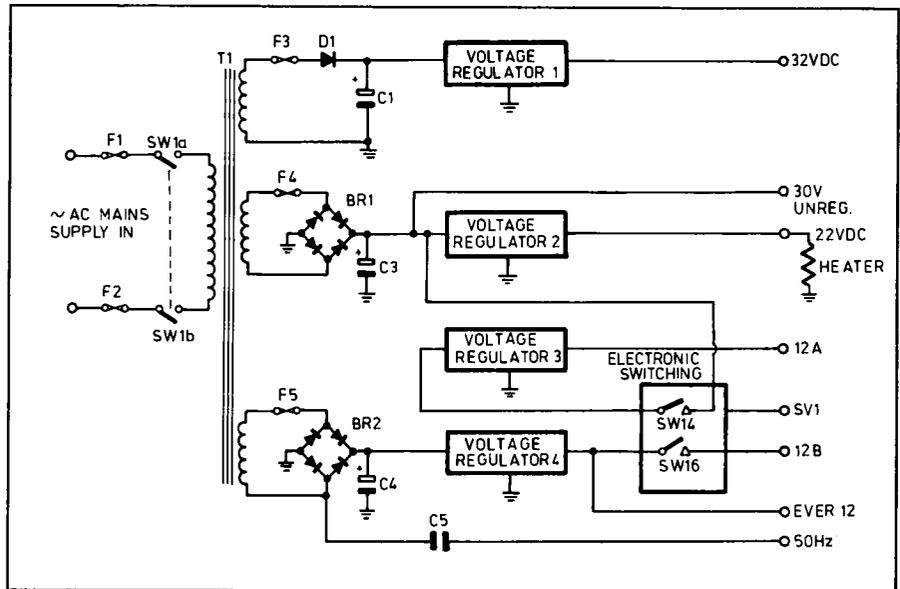


Fig.11: The power supply circuitry of a typical modern VCR. Note electronic switches SW14-15, used for timer recording, etc.

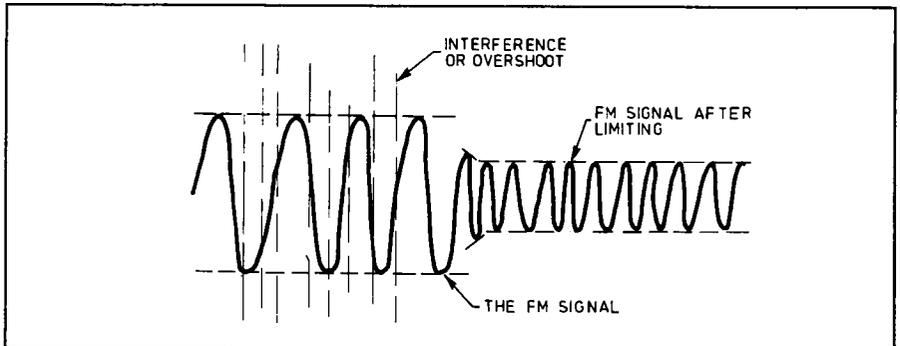


Fig.12: On playback, the FM luminance signal must be passed through a limiter stage to remove unwanted noise.

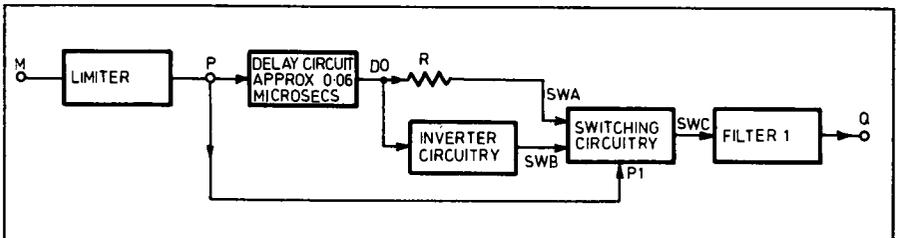


Fig.13: One form of FM luminance demodulator uses a delay/switching circuit which effectively converts the FM signal into a series of fixed-duration pulses, before filtering.

timer mode switches usually have a LED lamp that indicates when 'On' or 'Timer' mode has been selected.

FM demodulator

Before demodulating the luminance FM signal it is necessary to feed it through limiting circuitry. This circuitry clips the amplitude of the FM signal to a value below any unwanted noise pulses (Fig.12).

One type of FM demodulator is shown

in Fig.13. In the playback mode the recorded FM signal enters the limiter at point M. At point P the signal might appear as in Fig.14(a). The signal then feeds into the delay circuit. Fig.13(b) shows the waveform at point DO. It's the same as in (a), but delayed by about 0.06 microseconds.

From point DO the signal goes directly through resistor R to one input of the switching circuitry (SWA). It is also fed through the inverter circuitry to the other

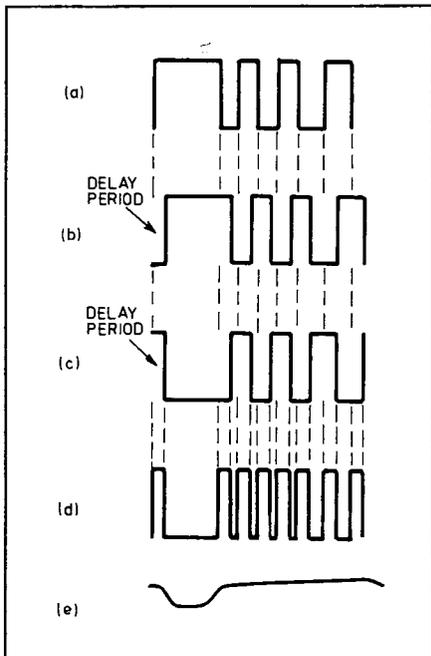


Fig.14: Waveforms found in the FM luminance demodulator of Fig.13. The signal at (a) is converted into pulses 0.06µs wide (d), and then filtered (e).

input connection (SWB) of the switching circuitry.

There is a slight time delay as the signal passes through the inverter, and resistor R ensures that both signals arrive at exactly the same time at the switching circuitry.

The signal from point P also serves as a pulse to operate the switching circuitry at point P1. As the pulse at P1 switches from high to low, the switcher circuitry accepts in turn the signals at points SWA and SWB — Fig.14(b) and 14(c). Fig.14(d) shows the resultant signal at point SWC. Filter 1 then shapes the signal to produce the AM luminance signal shown in Fig.14(e).

System switching

Some VCRs have circuitry that enables them to select and use either the PAL or SECAM system. A special SECAM detector with suitable changeover switching is included in the circuitry.

Also Mullard produce the TDA3952A PAL-to-SECAM transcoder IC. This is useful if you live in Europe where it's possible to receive both TV systems. It's also handy if someone from another country sends you a video cassette tape recorded in SECAM.

However, VCRs are manufactured — for example, by Sony — that can switch between PAL, SECAM and the NTSC system. These machines are specially designed and quite expensive.

More is involved than switching between systems — bandwidths, sound

separation frequencies and many other considerations are involved.

Camera input circuitry

Practically all modern VCRs are equipped with a socket for a video camera. In Fig.1 the upper position of switch SW3 connects via buffer amplifier 1 to point CAM, where the composite signal from the video camera is fed in. The sound detected by the camera's microphone and amplified by its circuitry is supplied to point EAL, through buffer amp 2 to switch SW3 set in its lower position.

The S-VHS system

In the standard VHS system, when the luminance signal is converted to FM the tips of the synchronisation pulse corresponds to a frequency of 3.8MHz and the 100% white peak level to 4.8MHz — a range of 1MHz. This is known as the carrier deviation. (refer back to part 4 and Fig.9 and 10).

In the S-VHS (Super VHS) system, a newly developed video cassette tape is used, surfaced with a special type of ferric oxide material. This tape was developed by the Victor Company of Japan (JVC) — the same company that invented the VHS system.

A top quality VHS tape will have a coercivity of about 730 - 730 Oersteds. However, the new S-VHS tape has a coercivity of 900 Oersteds. (Coercivity refers to the magnetic force needed to reduce the magnetisation of a ferromagnetic material to zero. An Oersted is a unit of magnetic field strength).

An S-VHS video tape cassette has an ID (identification) hole on its case. If a standard tape is inserted in an S-VHS machine, it will not record.

This new video tape makes it possible for the super VHS system to use a luminance signal bandwidth of over 5MHz, instead of the 3.2MHz maximum of the standard VHS system. The FM car-

rier now has a deviation of 1.6MHz, with the sync tip corresponding to 5.4MHz and the peak white signal to 7.0MHz (Fig.15).

This produces an excellent increase in picture definition on the recorded picture and does away with what has been called the 'weaknesses' of the video signal produced by a standard VCR.

Video 8 system

In the Video 8 system the deviation of the FM signal is 1.2MHz (Fig.15). The white peak level corresponds to 5.4MHz and the sync pulse tips to 4.2MHz. This system uses metal tapes (see part 2).

Metal tape in general has a high coercivity — around 1500 Oersteds. The chroma signal, you'll remember, is down-converted from 4.433619MHz to 732,422kHz. Picture definition is very good with the Video 8 system.

VHS-C

The VHS-C compact tape system is used in video cameras and is fully compatible with the standard VHS system. The tape width is the same — 12.65 millimetres. However a VHS-C cassette is far smaller than a standard VHS cassette. It measures approximately 92 x 58 x 22mm. The video head drum is only 41.33mm in diameter instead of the 62mm of a standard VHS drum. In order to produce the same magnetic tape pattern as in a standard VHS machine, four head helical scanning is used as shown in Fig. 16(a).

When a recording is made the video heads signal outputs are switched on and off in sequence as shown in Fig.16(b). The head switching circuitry opens electronic switches SWH1, SWH4, SWH3 and SWH2 in turn so that the signal from each head slightly overlaps the previous signal — see Fig. 16(b) and 16(c).

The recorded VHS-C cassette can be fitted into a special adaptor that is loaded into a standard VHS machine and played back as a normal VHS cassette.

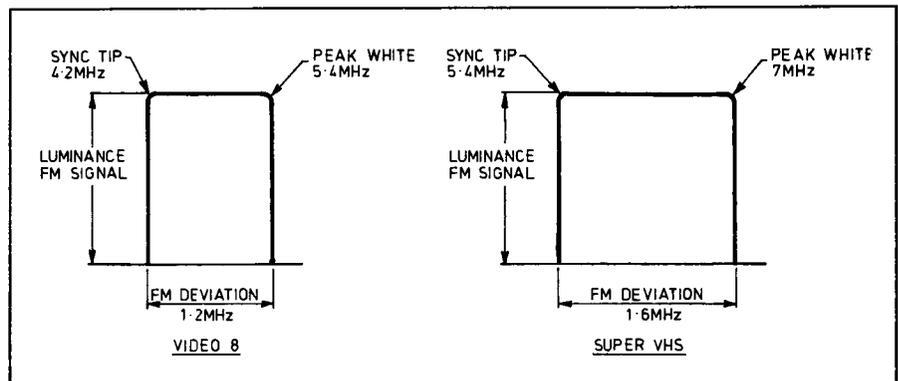


Fig.15: The FM luminance signal frequency deviations used with the Video-8 system (left) and the Super VHS system (right).

Remote control

One basic method of remotely controlling the functions of a VCR was described in part 3. You'll remember that the control signals are transmitted by a handheld unit, in the form of digitally encoded modulated infra-red (IR) light beam signals. An IR receiver unit in the VCR detects the signals and feeds them to the systems control microcomputer circuitry.

The latest handheld control units can not only control the VCR functions, but also program the timer circuitry by means of a bar code.

Panasonic video recorders use this system. A programming card is supplied that holds bar codes — similar in principle to those used on groceries and scanned by a laser at supermarket check-outs. In this case, the bar codes contain sets of codes for all TV channels, on and off times, and dates.

First the card is 'scanned' with the handset. When the handset is pointed at the VCR, and the transmit switch pressed, the machine is set up with the desired TV channel and recording time. Inside the handheld unit is an IR transmitter, a microcomputer IC plus a special optosensor, that can transmit and receive the IR signals used to scan the bar codes. Plus of course, the power supply batteries.

Developments in VCRs

Many brilliantly engineered advancements are now being incorporated into the latest machines. What once were remote possibilities are now realities.

Long play systems using six video heads set in the video drum, high fidelity stereo audio frequency modulated on two carriers, vastly improved circuitry for picture search modes, noise-free still pictures and many other advancements are found in the latest VCRs.

By converting analog picture signals to digital signals, some of the new VCRs can store one complete 'frame' of picture within digital integrated circuitry. When the 'still' function is selected a perfect 'freeze frame' picture is viewed. The development of reasonably priced large

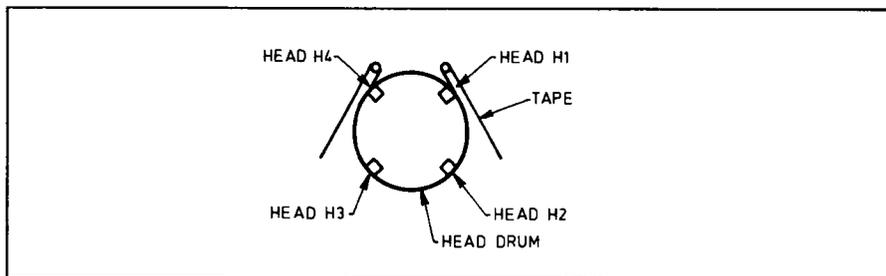


Fig.16(a): With the VHS-C format, a smaller head drum is used but with four heads to retain compatibility with normal VHS machines.

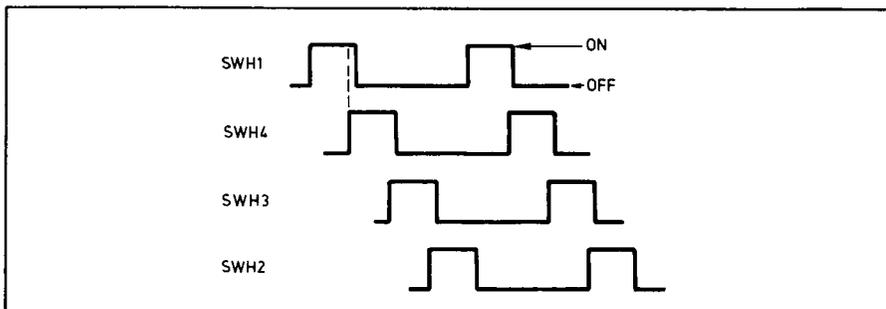


Fig.16(b): The VHS-C head switching signals are gated sequentially as shown, with a small overlap to prevent noise bands.

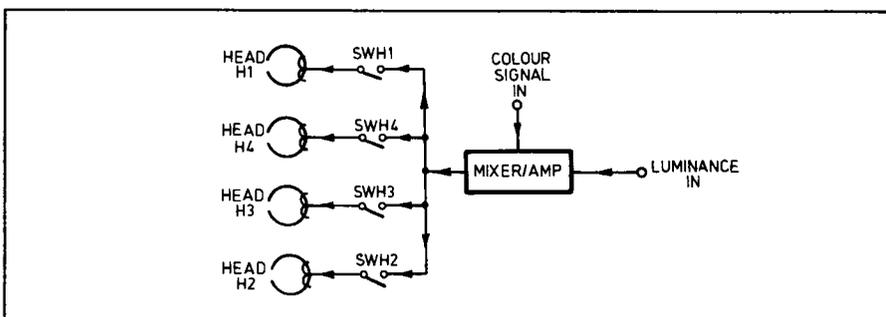


Fig.16(c): The electronic head switches SWH1-4 direct the composite FM luminance/chroma recording signal to the appropriate heads in turn.

storage capacity memory ICs has made this possible.

The photograph at the front of this article shows Panasonic's top of the range model NV-D80 VCR, which features both bar code programming and digital 'freeze-frame' plus many other advanced features. The memory control chip used by this VCR is type uPD65031F175.

Conclusion

In this series we've covered the basic principles of domestic video cassette re-

coders. VCR techniques will continue to improve and advance. You'll find that the basic knowledge of VCR technology gained from this series will help you in the understanding of new developments.

My thanks are due to Mr Henry McAloon, the Technical Training officer of Sony (UK) Limited, for providing technical data on the Video 8 system.

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APPENDIX

1

AUSTRALIAN TERRESTRIAL COLOUR TV: TRANSMISSION STANDARDS

General

The Australian television systems uses 625 lines and a field frequency of 50Hz, with 2:1 interlacing. The colour encoding used is the phase-alternation line (PAL) system.

Condensed Specification

Channel Width:	7MHz
Vision Carrier Frequency:	1.25MHz above lower limit of channel
Vision Modulation:	Vestigial lower sideband AM, negative modulation
Reference Black/blanking:	76% of peak vision carrier amplitude
Reference White level:	20% of peak vision carrier amplitude
Line Frequency:	15,625Hz
Field Frequency:	50Hz
Aspect Ratio:	4:3 (H:V)
Colour Subcarrier Frequency:	4.43361875MHz
Vision to Sound Power Ratio:	10dB (single sound carrier) 13dB (primary sound carrier) 20dB (secondary sound carrier)
Sound Subcarrier Frequency:	Primary 5.5MHz +/-500Hz above Vision carrier frequency Secondary 242.1875kHz +/-1kHz above primary subcarrier
Sound Modulation:	FM
Frequency Deviation:	+/-50kHz
Pre-emphasis Timeconstant:	50us

TIMING INTERVALS OF THE VIDEO SIGNAL

Durations (measured between half amplitude points)	Microseconds
Field period (V)	20,000
Line period (H)	64
Line blanking interval	11.8 - 12.3
Front porch interval	1.3 - 1.8
Line synchronising pulse interval	4.5 - 4.9
Field blanking interval	$25H + 12$
Duration of field synchronising pulse sequence	$2.5H$
Duration of pre-equalising pulse sequence	$2.5H$
Duration of post-equalising pulse sequence	$2.5H$
Equalising pulse interval	2.2 - 2.4
Interval between field synchronising pulses	4.5 - 4.9

Colour sub-carrier burst

- start, from leading edge of line synchronising pulse	5.5 - 5.7
- duration (nominally 10 cycles)	2.0 - 2.5
- duration of burst blanking pulse (per field)	$9H$

Build up time (from 10 to 90 per cent amplitude)

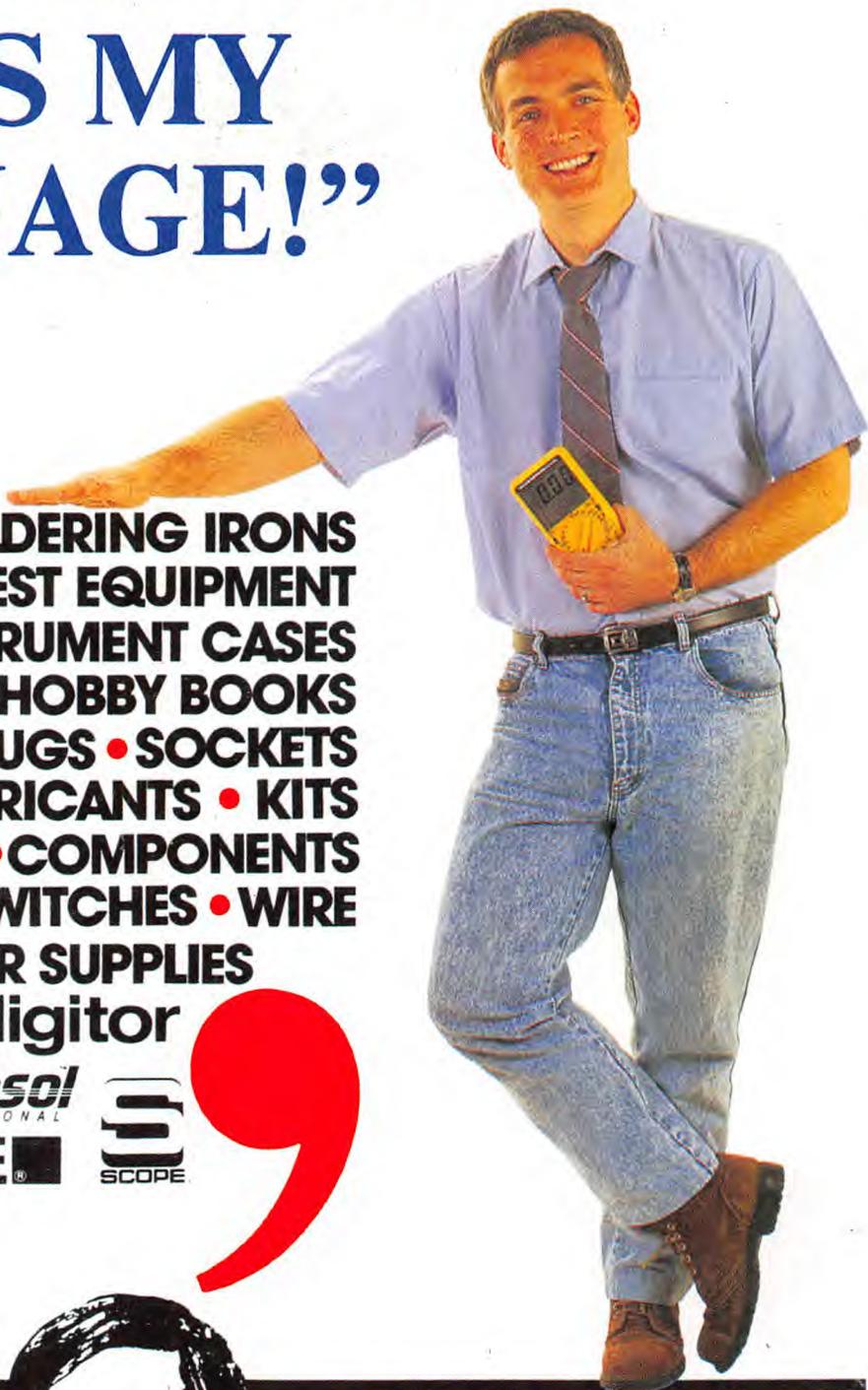
Edges of	
- blanking pulses	0.2 - 0.4
- synchronising signals	0.2 - 0.4

*The build up time is here specified for the radiated signal. Shorter build-up times may be used prior to modulation and in particular at points of interconnection, the limits shall be 0.1 - 0.3.

AUSTRALIAN TELEVISION CHANNELS

	Channel	Vision Carrier (MHz)	Primary Sound Carrier (MHz)
Band I	0	46.25	51.75
	1	57.25	62.75
	2	64.25	69.75
Band II	3	86.25	91.75
	4	95.25	100.75
	5	102.25	107.75
Band III	5A	138.25	143.75
	6	175.25	180.75
	7	182.25	187.75
	8	189.25	194.75
	10	196.25	201.75
	10	209.25	214.75
Band IV	11	216.25	221.75
	28	527.25	532.75
	29	534.25	539.75
	30	541.25	546.75
	31	548.25	553.75
	32	555.25	560.75
	33	562.25	567.75
Band V	34	569.25	574.75
	35	576.25	581.75
	39	604.25	609.75
	40	611.25	616.75
	41	618.25	623.75
	42	625.25	630.75
	43	632.25	637.75
	44	639.25	644.75
	45	646.25	651.75
	46	653.25	658.75
	47	660.25	665.75
	48	667.25	672.75
	49	674.25	679.75
	50	681.25	686.75
	51	688.25	693.75
	52	695.25	700.75
	53	702.25	707.75
	54	709.25	714.75
	55	716.25	721.75
	56	723.25	728.75
	57	730.25	735.75
	58	737.25	742.75
	59	744.25	749.75
	60	751.25	756.75
	61	758.25	763.75
	62	765.25	770.75
	63	772.25	777.75
	64	779.25	784.75
	65	786.25	791.75
	66	793.25	798.75
	67	800.25	805.75
68	807.25	812.75	
69	814.25	819.75	

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