Sound and Vision Summer 1968

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COLOUR SYNCHRONIZATION AND GENLOCKING FOR PAL AND NTSC

INTRODUCTION

A DESCRIPTION has already appeared in this journal[1] of the B3605 Synchronizing Generator in its basic form, which provides a source of precisely timed and stable pulses for black-and-white television systems. Further units have now been designed, to complete the B3605 range, which, added to the basic synchronizing generator, provide full synchronization facilities for the PAL and NTSC colour standards. The complete equipment in the form of plug-in modules, occupies a 13·3cm (5¼in) high rack-mounting frame.

The new units, Colour Synchronizing, Colour Lock and a new edition of the Genlock, include a number of special design features aimed at a high standard of performance coupled with reliability in operation. Some of these features are described in this article, in particular a new solution to the problem of colour synchronization in PAL, and genlock refinements that enable generators to be locked 'on air' with so small a disturbance to the received picture that it is barely discernible to a trained observer.

COLOUR SYNCHRONIZATION

In both NTSC and PAL the line and field frequencies and the subcarrier frequency are related in a particular way in order to reduce to a minimum the visibility of the dot pattern produced on the receiver screen by the presence of the subcarrier. This dot pattern is usually most visible on black-and-white receivers.

Now in black-and-white television the starting point in the synchronizing generator for the generation of the output pulses is a signal at twice-line frequency. This is obtained either from a crystal oscillator or from an oscillator locked to mains frequency.

For colour operation, on the other hand, the twice-line frequency signal is obtained, by means of a frequency dividing chain, from the subcarrier frequency crystal oscillator. The correct relationship between the subcarrier frequency and the line and field frequencies is therefore defined by the division ratio of the dividing chain. The subcarrier oscillator and the dividing chain are referred to collectively as the Colour Synchronizing Unit.

NTSC

For the NTSC system, the relationship for minimum dot pattern visibility is that the subcarrier frequency should be an odd harmonic of half the line frequency.

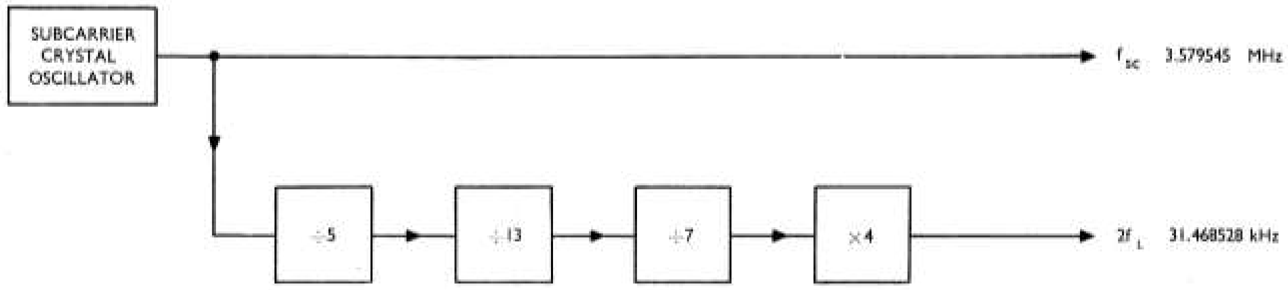

Fig. 1. NTSC Colour Synchronization block diagram.

This may be expressed by:

$$f_{sc} = (n+\tfrac{1}{2})f_L \qquad (1)$$

where f_{sc} is the subcarrier frequency and f_L the line frequency.

For the 525-line standard, $n = 277$, so:

$$f_{sc} = \frac{455}{2} f_L \qquad (2)$$

The division ratio required to obtain twice-line frequency is given by:

$$2f_L = \frac{4}{455} f_{sc} \qquad (3)$$

The number 455 has convenient factors of 5, 7 and 13, so that for NTSC the twice-line frequency signal is fairly easily produced by dividing the subcarrier successively by 5, 13 and 7 and then multiplying by 4, as shown in Fig. 1.

Integrated microcircuits are used in the divider stages, and the multiplying stage employs a locked oscillator to achieve good stability of the twice-line frequency output.

PAL

In PAL the division ratio presents a more difficult problem. Because of the PAL phase alternation, the subcarrier relationship, for minimum visibility and apparent movement of the dot pattern, has been specified by:

$$f_{sc} = (n-\tfrac{1}{4})f_L + \frac{f_V}{2} \qquad (4)$$

The term $(n-\frac{1}{4})$ times f_L expresses the requirement that the subcarrier frequency shall be an odd harmonic of one-quarter of the line frequency, and the second term, $f_V/2$, that this frequency must then be offset by half the field frequency.

For the 625-line standard, $n = 284$, thus:

$$f_{sc} = \frac{1,135}{4} f_L + \frac{f_V}{2} \qquad (5)$$

so the twice-line frequency is expressed by:

$$2f_L = \frac{8}{1,135}\left(f_{sc} - \frac{f_V}{2}\right) \qquad (6)$$

The factors of 1,135 are 5×227, so to use a dividing and multiplying technique similar to that for the NTSC system would require the rather large division ratio of 227, together with a means of deriving the $[f_{sc} - (f_V/2)]$ frequency. This frequency could be obtained from the subcarrier and $f_V/2$, half-field frequency (derived from the field frequency of the synchronizing generator), using heterodyne mixing techniques, but this would be a difficult process because of the small frequency difference involved, and further problems would exist in dealing with the change of field frequency when genlocking.

To overcome these difficulties, a new method of achieving the required division ratio for PAL[2] is employed in the Marconi B3607 Colour Synchronizing Unit which eliminates the need to use the field frequency component from the synchronizing generator, and furthermore permits the use of dividing and multiplying stages with factors that are achievable in stable and reliable circuits.

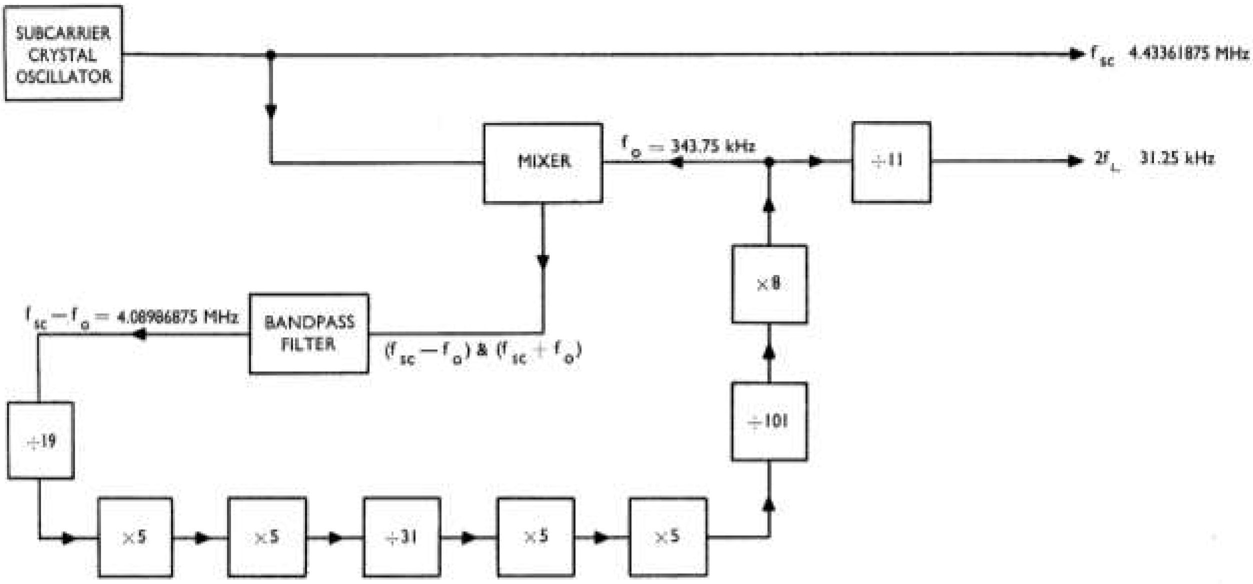

Fig. 2. PAL Colour Synchronization block diagram.

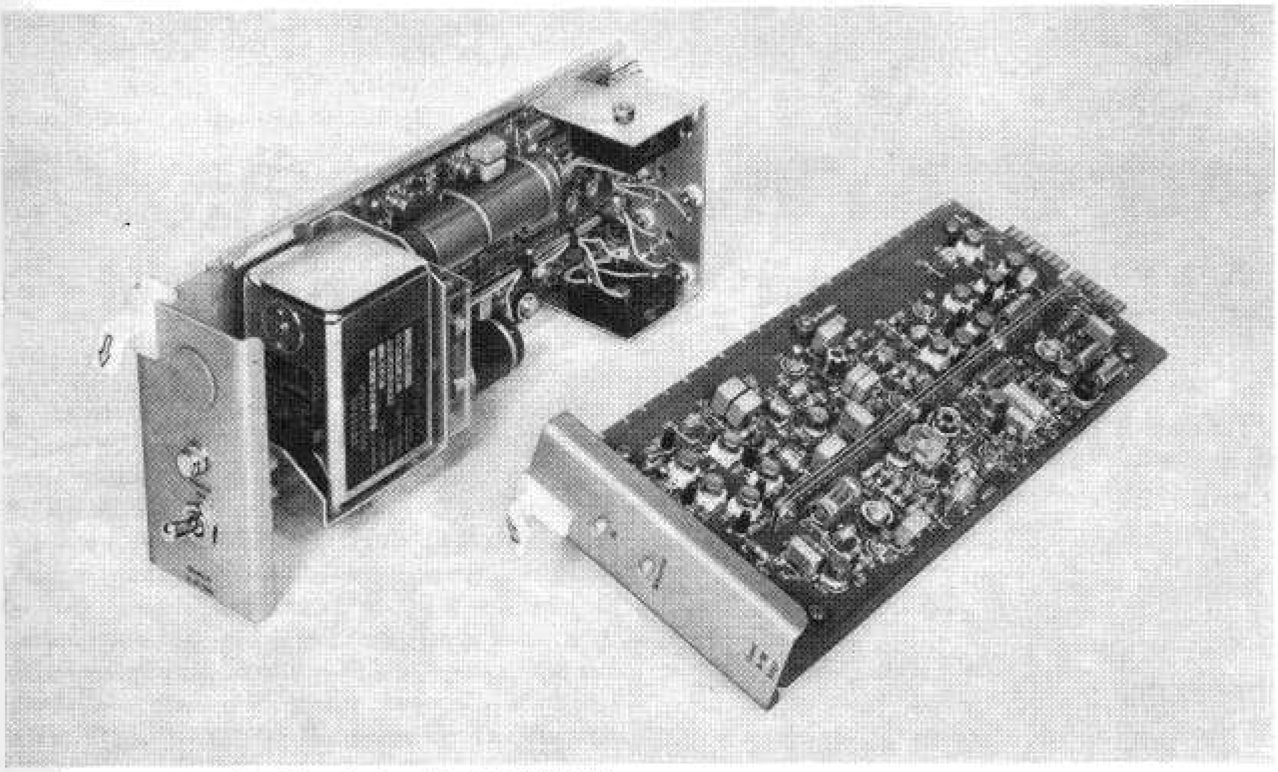

Fig. 3. The two modules of the Colour Synchronizing Unit, NTSC edition.

If the half-field frequency term $f_F/2$ in Eq. (5) above is expressed as a fraction of the line frequency, we get:

$$f_{sc} = \left(\frac{1{,}135}{4} + \frac{1}{625}\right) f_L \quad (7)$$

which can be put in the form of a single fraction:

$$f_{sc} = \frac{709{,}379}{2{,}500} f_L \quad (8)$$

and reducing the numerator to its factors:

$$f_{sc} = \frac{11 \times 64{,}489}{2{,}500} f_L \quad (9)$$

The large prime number 64,489 prevents the direct method which is employed for NTSC being used to derive twice-line frequency directly from the subcarrier, because the very large differences in frequency that would occur between the multiplying and dividing stages would lead to severe stability problems.

The new method stems from the idea of forming this large prime number as the sum of two smaller numbers, each of which can be conveniently factorized. Thus Eq. (9) may be written:

$$f_{sc} = 11\left(\frac{a+b}{5{,}000}\right) \times 2f_L \quad (10)$$

where $a+b = 64{,}489$.

First of all the factor 11 can be disposed of by establishing a frequency f_0 from which twice-line frequency can be obtained simply by dividing by 11. It follows that this frequency f_0 is related to the subcarrier by:

$$f_{sc} = \frac{a+b}{5{,}000} f_0 \quad (11)$$

Now, it proves to be convenient to make a equal to the denominator, 5000. This makes b equal to 59,489, which has the factors 19, 31 and 101. Since 5000 has the factors 5^4 and 2^3, the resulting relationship between f_0 and the subcarrier frequency is:

$$f_0 = (f_{sc} - f_0)\,\frac{5^4 \times 2^3}{19 \times 31 \times 101} \quad (12)$$

The block diagram of the PAL Colour Synchronizing Unit, Fig. 2, shows how the method can be put into effect. The subcarrier is fed to one input of the mixer and the frequency f_0, derived from the counter chain, to the other. From the mixer output the difference frequency component $(f_{sc} - f_0)$ is selected and fed to the divider chain. The twice-line frequency output is obtained by dividing frequency f_0 by 11. The key frequencies are indicated, and it can be seen that the wanted frequency at the mixer output is comfortably spaced from the subcarrier frequency, by

340kHz in fact, and of course, by twice as much from the other sideband ($f_{sc}+f_0$). The selectivity of the bandpass filter is therefore not at all critical.

The block shown as the mixer actually takes the form of a balanced modulator, giving a useful suppression of the subcarrier frequency without critical adjustment being required.

The ×8 multiplying stage employs a phase-locked oscillator to achieve good stability of the twice-line frequency output, and to provide a means of starting the closed-loop system. The numerical factors in the divider chain and the actual sequence used are such that the highest frequency occurring is 5·4MHz and the lowest 43kHz. Over this range reliable and stable operation can be achieved without excessive circuit complication. It also permits integrated microcircuits of reasonable cost to be used with advantage in the divider stages.

Subcarrier Oscillator

The subcarrier crystal oscillator is, of course, designed to meet the stringent requirements of stability and accuracy of the PAL or NTSC standards. A temperature-controlled oven is used, operating at about the point at which the temperature coefficient of the crystal is at a minimum.

Fig. 3 shows the three modules making up the PAL Colour Synchronizing Unit. The module on the left contains the crystal oscillator and power supply and the two smaller modules the counter chains. For NTSC the crystal oscillator module is similar, but the counter chain is contained in one module.

COLOUR GENLOCK

Before dealing with the subject of genlocking for colour it might be as well to review briefly the two principal methods that can be used to lock one generator to another. The need to lock generators arises when it is necessary to combine, by mixing, cutting or special effects, signals from picture sources which are driven by separate synchronizing generators. To pull two generators into phase means that the frequency of one or the other must be changed temporarily. Since in most cases the locking operation has to be carried out whilst the local generator is on transmission, it must be done in such a way as to avoid an objectionable disturbance to receivers. Operationally it is advantageous for locking to take place rapidly, since in network working, in particular, the remote signal to which it is necessary to lock may not be available until a matter of seconds before the locked condition is required.

For PAL there is the special requirement of ensuring that the line-by-line alternation, or in other words, the half-line frequency signal produced by the generators, is in step. Since 625, the number of lines in two fields, is an odd number, it follows that the half-line frequency pattern requires four fields to complete. Thus synchronizing generators must be locked correctly in a four-field cycle, instead of a two-field cycle as for monochrome television or NTSC colour.

Two principal locking methods are available, and these can be classified as Constant Line-number and Variable Line-number.

Constant Line-number Locking (Drift Lock)

In Constant Line-number Locking the relationship between line and field frequencies is maintained so that the standard number of lines occurs in each field, and the generator is made to move into synchronism

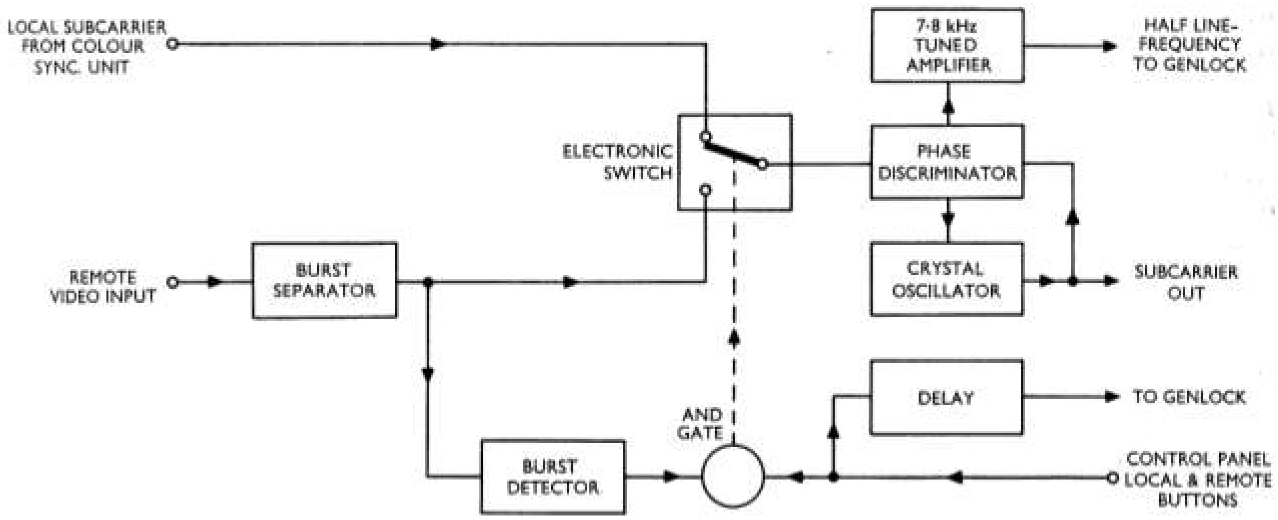

Fig. 4. Block diagram of the Colour Lock unit.

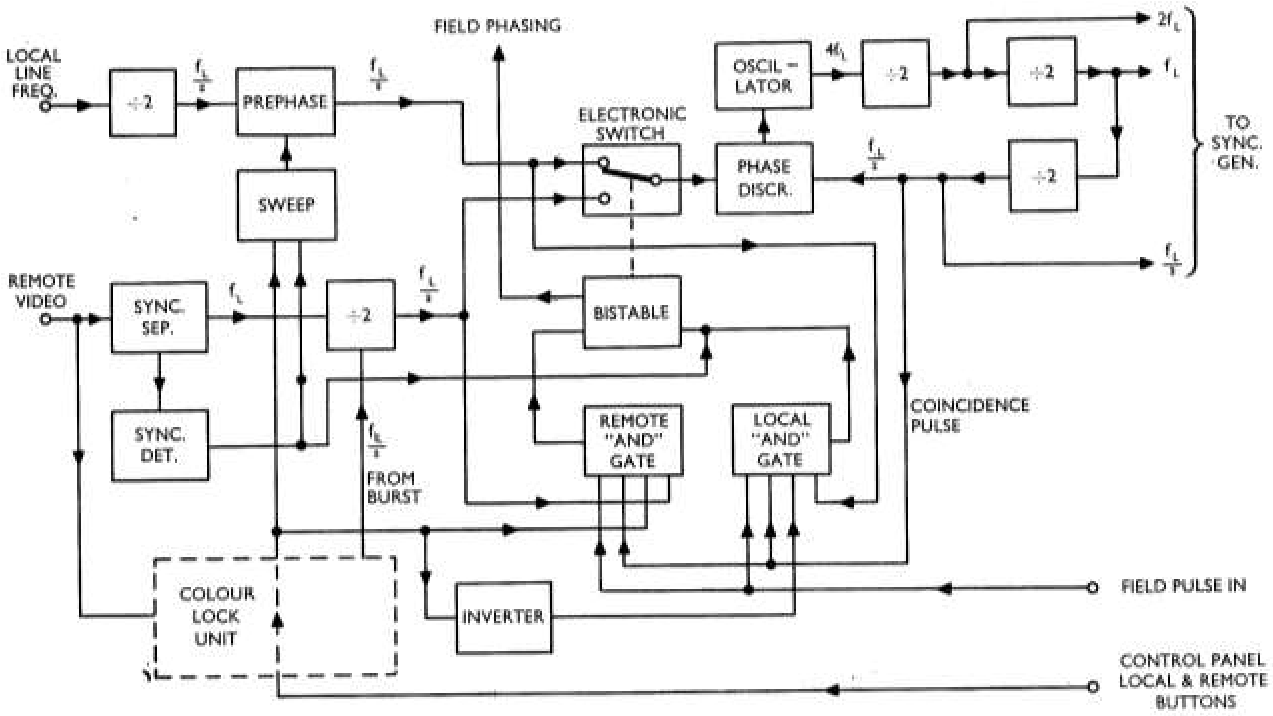

Fig. 5. Block diagram showing the half-line frequency locking circuits of the Genlock Unit.

by temporarily changing the line frequency. This method is sometimes called 'Driftlock' because it has been used with a very small frequency shift so that the generator drifts into synchronism very slowly.

Since in colour systems the permissible drift rate is very small, it is necessary for connections for locking purposes to exist between the synchronizing generators for a considerable period in advance of the time that the locked condition is required. Thus methods basically of this type may be used in networks under unified control in which permanent video or control circuits can be maintained between operational centres.

Variable Line-number Locking (Genlock)

The Variable Line-number method of locking is what is normally called 'genlock'. In this, the line frequency remains constant during the locking process, but the number of lines per field is changed by a whole number; usually between 1 and 3. This is done by changing the effective counting rate of the twice-line frequency to field-frequency divider, so changing the field frequency.

When the local field pulses reach coincidence with the remote the count is automatically returned to normal. Phasing of the local and remote line pulses is also necessary and this is carried out by an automatic phase-lock control loop.

THE NEW COLOUR GENLOCK EQUIPMENT

The variable line-number principle has been used in the new genlock equipment, which is suitable for both PAL and NTSC colour systems and for black-and-white operation. Particular design objectives have been to achieve as smooth a transition as possible in going from local to remote lock, and to ensure generally that the equipment is stable and reliable in operation. As many functions as possible are carried out by combinations of simple logic elements, and integrated microcircuits are used in a number of positions.

Pulse-locking functions are carried out in a new edition of the B3606 Genlock Unit, contained in three modules. By means of simple modifications the original edition of the Genlock Unit can be made suitable for colour operation, giving an acceptable performance by previously existing standards. However, the new unit has a superior performance and represents a considerable advance in genlocking technique.

Genlocking in the NTSC and PAL colour systems requires, in addition, the locking of the local system to the remote subcarrier, and this is provided for by the B3608 Colour Lock Unit, occupying two modules. In the sequence of locking operations, that follows automatically on pressing the GENLOCK button on the control panel, the subcarrier is dealt with first.

Subcarrier Locking

Fig. 4 shows the main circuit blocks of the Colour Lock Unit. The local subcarrier from the Colour Synchronizing Unit, instead of being distributed directly, is taken through the Colour Lock Unit. It passes through the electronic switch shown in the local, or non-genlock, position to a phase-locked crystal oscillator. This oscillator provides subcarrier for distribution to the local encoders.

The advantage of including this oscillator is that it ensures a smooth and controlled phase transition when switching between local and remote subcarrier sources. This results from the characteristics of the phase lock loop and the high 'Q' of the crystal oscillator. In the worst case, where the local and remote subcarriers are 180° out of phase, the locked oscillator will pick up the remote phase in approximately 10ms, and the rate of change of phase corresponds to less than 0·2° per line.

The remote phase reference is provided by the burst, separated from the remote video input. In PAL the burst phase swings $\pm 45°$ in alternate lines, and the filtering employed in the crystal oscillator control circuit is designed so as to ensure that the oscillator locks to the mean phase, with a residual phase variation of less than $0{\cdot}25 \times 10^{-3}$ degrees.

In operation, when the GENLOCK button is pressed at the control panel a signal is passed to the AND gate shown (Fig. 4). A burst detector also feeds the AND gate, ensuring that the electronic switch will only operate if burst is present, and will at once return the oscillator to local lock in the event of a subsequent failure of the remote input or the burst. With both signals applied to the AND gate the electronic switch operates, and the subcarrier lock is transferred to the remote burst.

A valuable by-product from the phase discriminator, here, as in the case of PAL receivers, is a 7·8kHz half-line frequency signal. This is passed, via a 7·8kHz tuned amplifier, to the Genlock Unit, where it is used to establish the correct PAL line alternation sequence.

Pulse Locking

The additional requirement of the PAL system in respect of pulse locking, that the half-line frequency sequence be correctly phased, has been met by carrying out the automatic phasing operation at half-line frequency, instead of at line frequency as in conventional genlocks.

The block diagram (Fig. 5) shows the principle of the half-line frequency locking arrangements. The line-frequency signal from the master oscillator of the synchronizing generator, which for colour operation will be derived from the twice-line frequency signal from the Colour Synchronizing Unit, is fed into the Genlock Unit. This is divided by two to produce a half-line frequency square wave which passes via the pre-phasing stage to the electronic switch, shown in the Local Lock position.

The function of the pre-phasing stage is to bring the local half-line frequency signal into phase with the remote. Because of the high stability of line frequency in colour systems, incidental differences in remote and local line frequencies cannot be relied upon for this purpose. This stage automatically introduces an increasing phase change to the path, which reaches 360° in approximately three seconds and is activated when the GENLOCK or LOCAL buttons on the Remote Control Panel are operated.

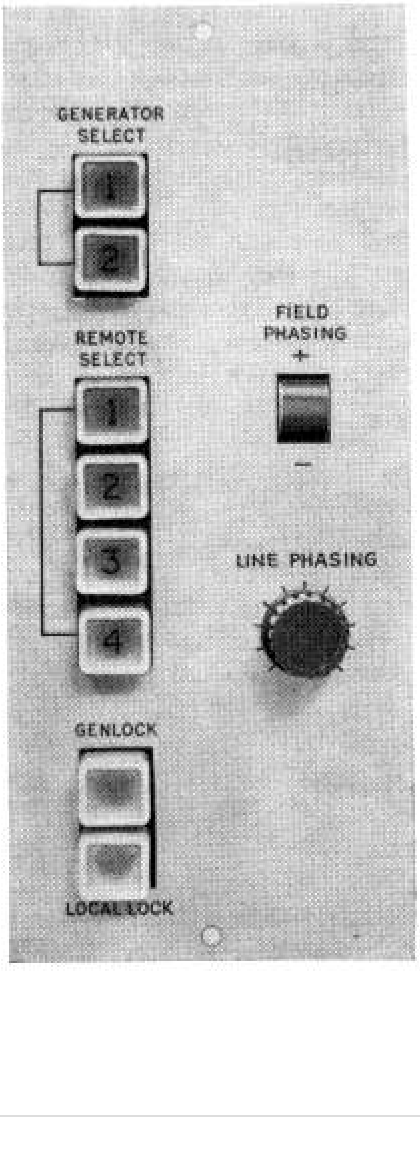

Fig. 6.
Remote Control Panel.

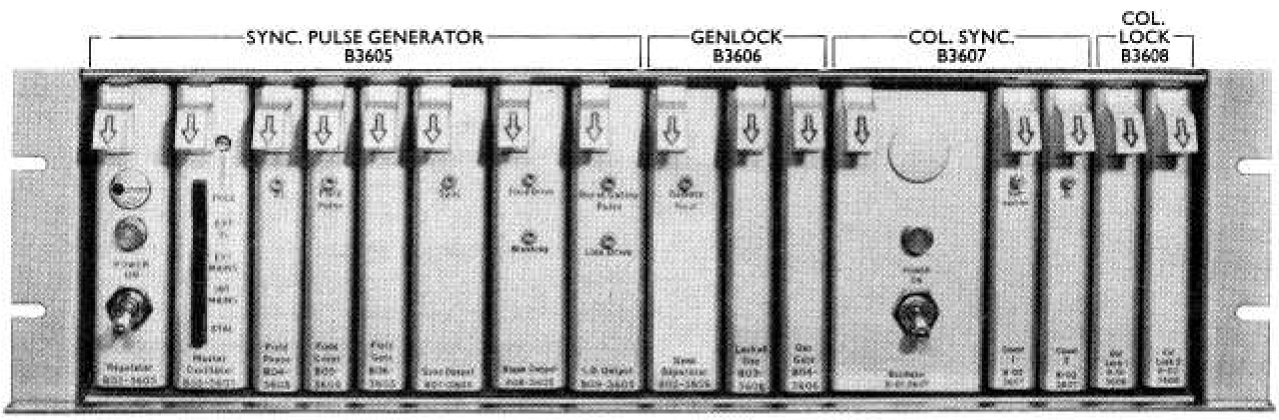

Fig. 7. The complete B3605 Synchronizing Equipment for colour.

From the electronic switch the half-line frequency square wave is applied to a phase discriminator which serves to lock an L–C oscillator, which in turn drives the synchronizing generator via a chain of binary dividers. This oscillator, like the locked oscillator used for the subcarrier, is included so that clean transitions are obtained in switching between local and remote. Abrupt changes in phase are prevented by the properties of the phase-control loop. The phase discriminator locks the oscillator, which operates at four times line frequency, by comparing its output, divided by eight in frequency, with the half-line signal from the electronic switch.

With the electronic switch in the Remote Lock position the half-line frequency square wave is obtained from the remote input. From the remote input terminal, a synchronizing pulse separator produces a line synchronizing signal which in turn drives a divide-by-two stage to give the half-line frequency square wave. To ensure the correct phase of this signal for PAL, the divider is forced into step and maintained so by the half-line signal derived from the burst in the Colour Lock Unit discriminator as described above.

The operation of the electronic switch is controlled by a logic system consisting of a bistable circuit driven by the Remote and Local AND gates. By virtue of the Coincidence Pulse fed to each gate, the electronic switch is prevented from operating until the action of pre-phasing has reduced the phase difference between local and remote signals to a very small amount.

Locking Sequence

The genlocking operation is started when the GENLOCK button on the remote control panel is pushed. First, subcarrier locking takes place as already described, and for PAL the half-line frequency signal derived from the remote synchronizing pulses is brought into phase, as defined by the swinging burst.

Next the Remote AND gate is activated and the local pre-phasing sweep is initiated. When the remote half-line frequency signal and the Coincidence Pulse derived from the locked oscillator are correctly phased, the bistable will receive the signal to transfer the electronic switch to the Remote position. In order to reduce the visibility of any residual disturbance the changeover of the lock condition is made to occur in the field blanking interval by means of a field pulse, also fed to the AND gates.

Reversion from Genlock to Local Lock is achieved in a similar way, the bistable being driven in the other direction by means of the Local AND gate.

The purpose of the synchronizing pulse detector is to return the system automatically to the Local Lock condition in the event of a failure of the remote signal.

The provision of the burst detector in the Colour Lock Unit, the sync detector in the Genlock Unit and a connection from the sync detector to the pre-phasing sweep circuit, permits a remote signal input, and the Genlock condition, to be preselected before the remote signal is present. The system meanwhile remains in the Local Lock condition, and on arrival of the remote signal, the genlocking sequence follows automatically.

The final genlocking operation is that of field phasing, initiated by the transfer of the bistable to the Remote Lock condition.

Field Phasing

Field phasing is achieved by the established method of modifying the count down to field frequency from twice-line frequency, at the rate of one line per field. The maximum field-phase error that has to be corrected is one-half field, as in modern black-and-white genlocks. The odd or even field condition is obtained by a final automatic adjustment of field timing by one half-line duration. The local generator is phased correctly with respect to the PAL four-field sequence by virtue of the lock established first at half-line frequency.

Genlock Performance

Extensive viewing tests on domestic receivers have shown that the care taken in the design, and the refinements introduced, have been fully justified. The subcarrier disturbance, which is very small and of short duration, has no visible effect on colour reproduction, and the accompanying dot pattern movement can only be seen on close examination. The effects of disturbances to the synchronizing pulses are imperceptible except by very careful observation.

The times taken for each stage of the genlocking process are: half a second for subcarrier and PAL sequence identification from burst, three seconds in the worst case for phasing at half-line frequency, and just over three seconds in the worst case for field phasing. The worst cases correspond to the maximum initial phase differences between the local and remote signals.

Remote Control Panel

Control of the synchronizing equipment is from the new Genlock Remote Control Panel, shown in Fig. 6. This provides for selection of local lock, or genlocking to one of four inputs. Lamps behind the buttons light to indicate the remote input selected, and also completion of the selected locking function. Controls are provided for manual line phasing and field prephasing, and buttons for complete generator change-over where a pair are installed.

COMPLETE EQUIPMENT

Fig. 7 shows the complete equipment, comprising the Synchronizing Generator, Genlock, Colour Synchronizing and Colour Lock Units. By means of internal link connections and changing of quartz crystals, the units can be set to operate on the 625-, 525- or 405-line standards. When genlock facilities are not required the Genlock and Colour Lock Units can be omitted.

REFERENCES

1 G. D. Iles: Printed Circuit Synchronizing Pulse Generator, *Sound & Vision broadcasting*, Vol. 7, No. 3, Winter 1966.

2 H. D. Kitchin, The Marconi Company Limited, British and Foreign Patents pending.