CBS-Columbia — First Commercial Color Plus Black-and-White Set

Fig. 1—New receiver looks like standard set, has only one more control. Wheel is invisible and inaudible.

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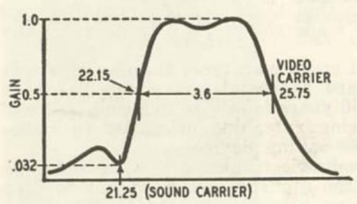

Fig. 2—Video detector output response. Sound carrier is maintained at a level approximately 30 db below video carrier.

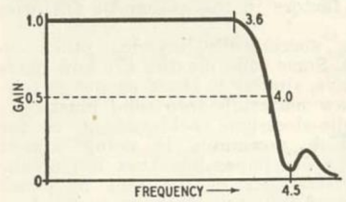

Fig. 3—Response of the combined outputs of video detector and amplifier. Half-power points are near 4 mc on the highs and 30 cycles at the lower end.

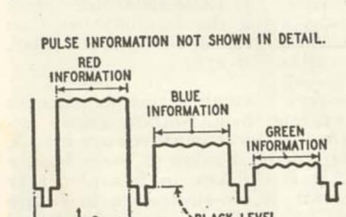

Fig. 4—Signal at video amplifier grid. The amplification of each color must be equal regardless of frequency or level.

A COMPLETELY self-contained television receiver which can receive both black-and-white transmission and CBS color transmission is an important advance in the television field. The console unit shown in Fig. 1 contains—within an exterior no larger than most current black-and-white television models—what the viewing public looks at as a somewhat magical device which reproduces either color or monochrome pictures with the flick of one simple switch.

The dealer and service technician may fear its supposed complexity and wonder about its reliability and serviceability. It should be made quite clear, therefore, that with the exception of the scanning mechanism and its associated 3-tube disc control circuit, the fundamental circuitry in every section of this receiver is already well known to the television industry. Unlike rival color television systems, the CBS color-monochrome receiver uses circuits which have been production- and field-tested for many years. Special consideration has been given in the design of the various sections to bring out the full potentialities of the CBS color system; however, these special considerations represent only refinements of currently "known art."

It might be suspected that the quality of the monochrome picture produced by this dual-type receiver would be neglected in concentrating upon reproducing a good color picture. As will be shown later in this article, design requirements for a good color picture are more stringent than for a good monochrome picture. Since the same basic circuits are used for both color and monochrome, however, the natural consequence is not only good color, but also very good black-and-white reproduction.

The design and operation of the complete color-monochrome receiver will be discussed under the following headings:

1. Tuner and i.f. amplifier.
2. Video amplifier, d.c. restorer, and intercarrier sound system.
3. Synchronization, sweep, and high-voltage circuits.
4. Disc-control circuit.
5. Scanning disc and motor assembly.

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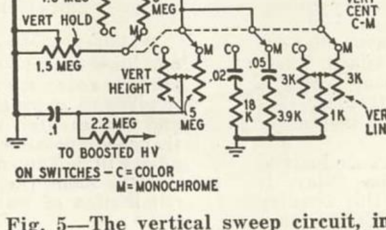


Fig. 5—The vertical sweep circuit, including color-monochrome switching.

Receives black-and-white at 525 lines or full color at 405 lines, at the flick of a switch, and is completely self-contained. Its design features are described in the article below.

Items 1 and 2 are the same in both the color and monochrome positions; switching of circuit elements between color and monochrome operation is necessary only in 3; 4, and 5 operate only during color reception.

Tuner and i.f. amplifier

Since the r.f. tuner or "front end" is not called upon to perform any unusual function in the color-monochrome receiver, almost any well-designed tuner is suitable. The usual considerations of noise factor, gain, oscillator radiation, spurious responses, etc., are applicable.

In the CBS color system, both the vertical and horizontal scanning frequencies are increased over current standard monochrome scanning frequencies. To retain as much picture information as possible in the color position, a minimum over-all r.f. and i.f. 6-db bandwidth of 3.6 mc is employed. A high-Q accompanying sound trap is capacitively-coupled to the first i.f. amplifier tube grid, so that at the output of the video detector, the sound carrier is attenuated 30 db relative to the pass-band. The over-all relative response at the video-detector output is shown in Fig. 2. Two staggered pairs,[1] with CCB6 amplifier tubes, are used because of simplicity and cost considerations. Almost any i.f. amplifier interstage coupling arrangement may be used as long as the response obtained is as shown. Overloading and departures from linearity must be avoided.

Video amplifier

A combined video amplifier and video detector response flat out to 3.6 mc is used to retain picture information. The response is shown in Fig. 3. A good low-frequency response, down to 30 cycles, is also desirable.

Although high-frequency peaking often is employed in monochrome television receivers to "crispen up" the picture, its desirability is questionable in color reception. To obtain the proper color balance, as transmitted, the detailed color information in the red, blue, and green fields should be amplified equally regardless of frequency.

The output linearity of the video amplifier is particularly important. Consider the highly simplified signal, shown in Fig. 4, arriving at the input grid of the final video-amplifier tube. The scene depicted is a solid color consisting mainly of red, with some blue and less green components. If the tube characteristics are not linear, the relative amplification of the three fields may be considerably different, resulting in poor color reproduction. Furthermore, this color distortion will be a function of over-all signal level. To avoid this difficulty, an output swing of approximately 100 volts with a maximum of 10% departure from linearity has been designed into the receiver.

D.c. restorer

The theoretically desirable type of d.c. restorer, from the point of view of color fidelity, is highly efficient and has a speed of response of the order of a few lines. The instantaneous position of the video amplitude on the kinescope amplification characteristic will, of course, determine the degree of faithfulness of reproduction of the color. Since this position is determined, in great part, by the value of d.c. component present at that instant, one can ap-

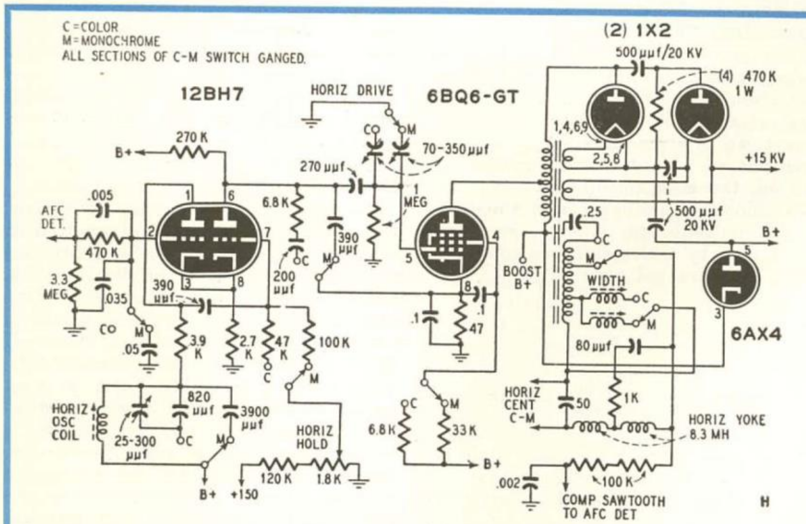


Fig. 6—The receiver's horizontal sweep circuits, with switching for color and monochrome. Note that component values change in the same ratio as sweep rates.

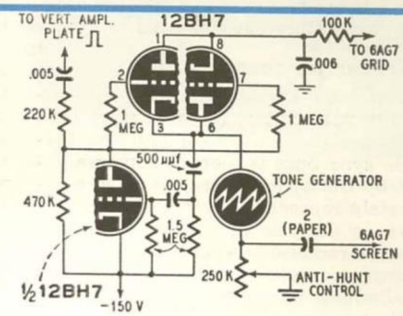
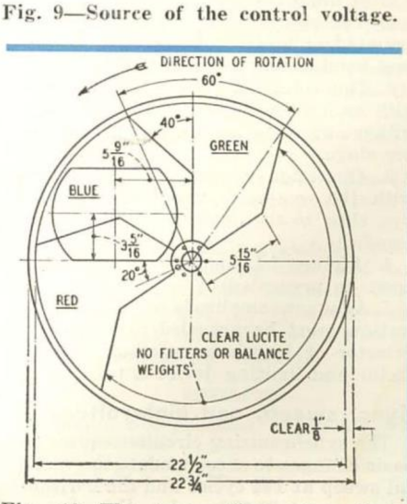


Fig. 9—Source of the control voltage.



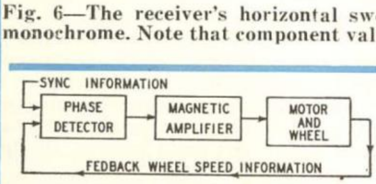


Fig. 7—Disc control circuit diagram. Phase detector and magnetic amplifier schematics appear in Figs. 8 and 9, and the motor photograph in Fig. 13.

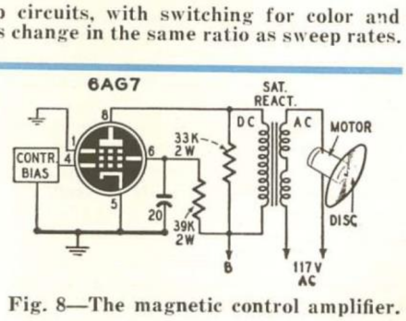


Fig. 8—The magnetic control amplifier.

Fig. 10—The two-section color disc.

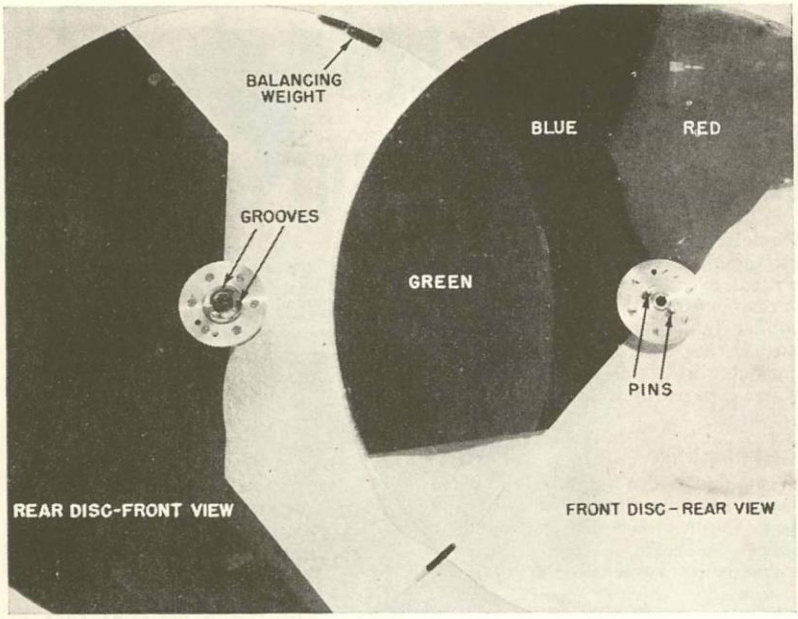


Fig. 11—Some details of the discs and hubs, showing the pins and grooves which reproduce color while in motion but permit black-and-white reception when still.

preciate the reasons for the d.c. restorer requirements stated above.

To meet these requirements at the present time would involve complex and costly circuitry (the simple direct-coupling arrangements employed in current monochrome receivers do not meet these requirements), and so a simple diode d.c. restorer circuit has been used, pending further developments.

Intercarrier sound system

The intercarrier sound system, although not critical, requires more care in its design. In the color position, 144-cycle sync buzz is more readily amplified by the audio system and more accurately reproduced by the loudspeaker than is 60-cycle sync buzz in monochrome reception. Application of well-known principles, however, is sufficient to eliminate any audible buzz.

Most important of these are:

1. The sound carrier should be attenuated at least 26 db relative to the pass-band at the video detector.
2. The video detector should operate with as high a signal level as possible without overloading the last i.f. amplifier stage.
3. Operation of the video amplifier with the composite video signal sync tips close to the cutoff region must be avoided.
4. Picture i.f. amplifier overloading must be prevented.
5. Adequate amplitude modulation rejection must be provided by the ratio detector or by whatever other FM detector and limiting device is used.

Sync, sweep, and high-voltage

The synchronizing circuits require no basic changes to accommodate the vertical sweep at 144 cycles and the horizontal sweep at 29,160 cycles. However, a noteworthy improvement, the double time constant input, is incorporated in the sync circuit of this receiver. This addition to the conventional sync circuit improves the noise immunity of the sync by providing a fast discharge path for the undesirable noise energy stored up in the grid-coupling capacitor, thus preventing the effects of impulse noise bursts from "hanging on."

The problems of converting to color sweep frequencies have been brought to the attention of the public and the industry[2] and still remain a point of interest. To produce the color sweep frequencies of 144 and 29,160 cycles per second, the time constants of the vertical blocking oscillator and the horizontal multivibrator must be switched. The ratios by which the time constants must be decreased are:

$$\text{Vertical: } \frac{144}{60} = 2.4$$

$$\text{Horizontal: } \frac{29{,}160}{15{,}750} = 1.85$$

If the reader checks the circuits shown in Figs. 5 and 6, he will see that the values which are switched are approximately in the ratios of these numbers. It is interesting to note that the higher vertical sweep frequency requires a retrace time of about 40% of that for monochrome, hence the large peaking resistor.

No changes are required in the vertical amplifier stage. Since the vertical output transformer is designed for 60-cycle sweep, it will operate at least as well at 144 cycles. The vertical winding of the yoke will likewise perform well.

The horizontal output and high-voltage circuits merit some special attention in connection with color. Because of the light reduction, it is necessary to raise the high voltage and average beam current. The energy storage in the 53° deflection yoke for the 10RP4 picture tube is insufficient to produce over 10 kv with a single rectifier without excessive retrace time or excessive 6BG6 cathode current. Therefore, a voltage doubler is used to meet the 14 kv, 250 μa requirements. The high voltage could have been obtained with a single rectifier only at the cost of excessive retrace time, or with a high-current horizontal deflection amplifier.

Obviously, the design of the horizontal output transformer would be a function of the sweep frequency. Nevertheless, the same transformer, in conjunction with a single yoke, is called upon to operate satisfactorily in both color and monochrome performance. This is accomplished by a simple autotransformer design with an extra tap for switching the horizontal yoke.

Since the losses go up as frequency squared, a ferrite yoke must be used. Ferrite yokes give increased width and high voltage at 15,750 cycles, and at 29,160 cycles the advantages gained by using a ferrite yoke are even more significant.

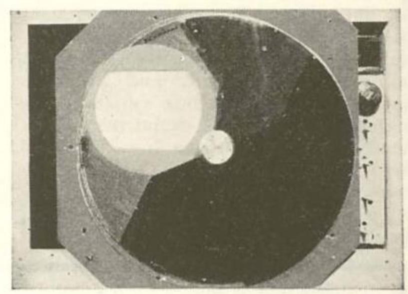


Fig. 12—The black-and-white window.

Disc control circuit

In the CBS field-sequential system the color information is transmitted in the order red-blue-green. To reproduce the color information on the viewer's screen, the color disc must be in exact synchronism with the transmitter. Furthermore, the red field and the red filter on the disc must coincide. The circuit which keeps the disc in step with the transmitter is dubbed the "disc-control circuit."

For the purpose of analysis, the circuit will be divided into several simple circuits whose individual functions are more readily apparent. A block diagram is shown in Fig. 7.

The magnetic amplifier consists of a high-gain pentode whose plate current flows through the d.c. winding of a saturable reactor. The a.c. winding of this reactor is in series with the motor which drives the disc. See Fig. 8. Operation is as follows:

If the control bias becomes less negative, the plate current increases. The increased plate current in the d.c. winding drives the reactor into saturation and hence decreases the a.c. voltage drop across the reactor a.c. winding, thus making a larger share of the line voltage available for the motor. Therefore, a reduction in negative bias at the control tube grid speeds up the motor, and an increase in the negative bias slows down the motor. However, we are *not* interested in varying the speed of the disc; we *are* interested in *keeping its speed constant* at 1,440 r.p.m. This implies that the control bias must be furnished by a circuit which will insure that at every instant the proper control bias is present to keep the motor speed absolutely constant regardless of line voltage or of any line frequency fluctuations.

The phase detector is just such a circuit. Two signals are furnished to the phase detector, one from the vertical output of the receiver which is in sync with the transmitter, and the other one from the disc tone generator. After the two signals are compared by the phase detector, a d.c. output whose magnitude is a function of the relative phase results. A schematic diagram is given in Fig. 9.

By obtaining the proper polarity from the sawtooth tone generator, the phase detector can be made to produce a d.c. correction bias which will keep the color disc exactly in step with the vertical amplifier pulse. Thus the color disc is held in dynamic synchronism by a straightforward electronic control circuit.

Scanning disc and motor

One of the advantages of the field-sequential system for color transmission and reception is that the frequency of color switching is low enough to render it practical to use either electronic, electromechanical, or comparatively simple mechanical devices. The simplest technique thus far used is that of the rotating color disc. The disc is used in the present production receiver. (Other methods have been used or are now in the laboratory stage). The color drum is a mechanical means for obtaining a larger color picture. The tricolor tube is being investigated as a possibility for an electronic field-sequential system. Other mechanical means for converting present 17- and 20-inch black-and-white sets to receive color are under investigation.

To date, the most faithful color reproduction has been obtained with the disc. The discs used in the current receiver are shown in Figs. 10, 11, and 12. The shape of the color segments is determined by:

1. The requirement that the color segment follow the scanning lines vertically down the raster.
2. The position of the center of the disc relative to the raster.

The color-monochrome receiver uses two discs. Each of the discs have three color segments and a 50% clear section. When the selector switch is in *color* position, the color segments of the rotating discs are 180° opposite each other, and the effect is that of a conventional 6-segment disc. When the switch is in *monochrome* position, the discs are indexed (as explained later) so that the clear area of each disc is stationary in front of the raster (Fig. 12).

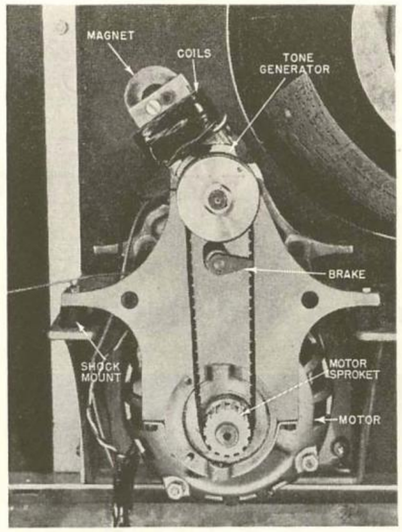


Fig. 13—The motor and motor control.

The filters used in these discs may be the red, green, and blue Monsanto "E" filters or the following Eastman Kodak television filters:

Blue—#451, Green—#610, Red—#260

To avoid flicker, the two discs are paired so that the comparative filters for similar color segment areas do not vary more than ±1% for green, ±2.5% for red, and ±3.5% for blue in their color transmission. The discs are statically balanced to within 0.1 inch-ounce.

The rotating disc and motor are generally not discernible by the viewing audience. It has been the experience of the writers, while demonstrating the receiver to various groups, that invariably the question is raised, "Is there a disc in the cabinet?" The audience (including engineers and service technicians) could neither see nor hear the disc about which they had been hearing and reading.

With the proper motor and shock mounting (Figs. 13 and 14), the operation is essentially noiseless. The motor used in this receiver is a split-phase capacitor type which has a torque of 21 inch-ounces. Its speed is 1,748 r.p.m. and it is geared down with belt and sprockets (Fig. 13) to 1,440 r.p.m. The operating voltage of the motor is approximately 85.

The disc shaft is rigidly connected to the front disc. When this disc rotates it pulls the other, or free, disc along with the indexing pins (Fig. 11) which are engaged in the grooves of the "free" disc hub. It takes the discs approximately 20 seconds to reach the operating speed from the off position.

Mounted on the rear of the disc shaft (Fig. 13) is a tone-generator disc. As each pair of arms of this disc passes under the ends of the horseshoe magnet, a sawtooth voltage is generated in the coils. The spacing, the shape of the arms, and the ends of the horseshoe magnet determine the generated waveshape. The sawtooth voltage is then applied to the disc control circuit for comparison with the vertical sweep pulses as explained previously in the section on disc control.

When the selector switch is thrown to *monochrome* position, a mechanical brake (Fig. 13) is applied. This slows down the forward motion of the discs. At the same time, the current through one of the motor windings is reversed. As the driven disc slows down with respect to the free disc, its relative position with respect to the free disc is allowed to change by 120°, where the free disc is again held in position by the indexing pins which ride in the grooves of the free disc hub (Fig. 11). In this position there is 120° of clear area (Fig. 12). When the reverse current in one of the motor windings reverses the direction of rotation of the disc, a stop latch on the hub of the free disc moves up against a stop on the mounting assembly and both discs are stopped in the correct position (clear sections in front of raster). When the discs are in the correct position, a micro-switch behind the stop latch turns the motor current off. This changeover from color to monochrome takes less than 8 seconds.

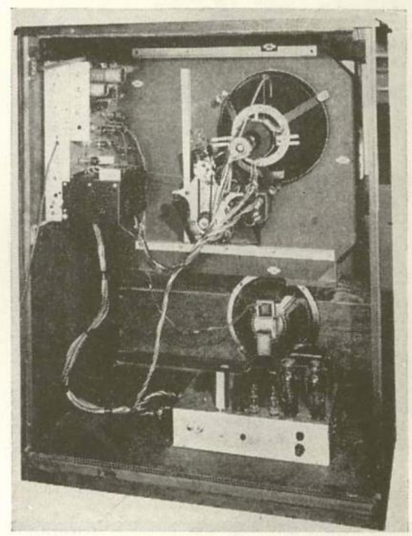


Fig. 14—Rear view, complete receiver.

A magnifying lens enlarges the 10-inch tube image to the equivalent of a 12½-inch tube.

Acknowledgment is gratefully given to the CBS Engineering Staff, and particularly to Dr. Peter Goldmark, John Christianson, and Al Goldberg who worked closely with the authors in the development of this receiver.

REFERENCES

1 "Vacuum Tube Amplifiers," Valley and Wallman; Chapter 4.

2 "Field Sequential Color Companion," Cohen and Easton; *Electronics*, May 1951.

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