Build Your Own TV Color Converter

Fig. 1. Receiving a color show on a large-size movie screen using the color converter described in this article with a black-and-white set.

By **JAY STANLEY**

Part 1: This color TV converter can be used with three projection units or a three-color picture tube and a second-hand black-and-white chassis.

WHEN black-and-white TV first became a reality, the whole thing was something of a deep, dark mystery to most radio service technicians of the era. But a few brave souls took the plunge, built their own sets, and had the thrill of getting out ahead of most of their competitors and in on the ground floor of a tremendous industry.

Color TV is off to a better start. Many manufacturers are offering courses and a lot of articles have been written about the subject so that the studious can, in a fairly short time, acquire some knowledge of color TV. But, as in all things, there is no substitute for experience with actual equipment on which you have no qualms about experimenting. The cost of present-day color TV sets is high enough to discourage a lot of service technicians (and most consumers) from owning such a receiver.

This article is a practical answer to that problem. Here is step-by-step data for building a color television system. Actually, the original chassis was designed and built by two Denver service engineers; Larry Costa and Paul Dontje.

The unit described in this article is a *color converter* which can simply be hooked onto a conventional (but carefully selected) black-and-white TV set. It can be used to drive a three-unit projection system, or with a bit more circuitry, a three-gun color picture tube.

A look at the block diagram in Fig. 2 and the circuit diagram of the color converter in Fig. 3 will reveal that it is surprisingly simple when compared to many color TV sets. The secret lies in the fact that the set uses a narrow-band system, with .6 megacycle bandpass limiting. This is possible because demodulation is on the *R-Y* and *B-Y* axes instead of the alternative *I* and *Q* axes. The *I* and *Q* system is a wide-band one.

Thanks to the narrow-band system, circuitry is much simpler. Likewise, setup, adjustment, and servicing are also much easier. Don't let the "narrow band" worry you. Color quality is impaired so little that it can only be discerned when a narrow-band and a wide-band set are operated side-by-side—and even then it is difficult to see the difference.

Before covering actual construction of the color chassis, let's trace a signal through this circuit to get an overall idea of how it works. As a starting point, we'll begin with the signal which normally drives the grid of the picture tube in the TV set—a signal which is the composite video output, carrying both the black-and-white and the color information. This signal can be supplied by any really good black-and-white set which has an i.f. bandpass of 4.1 megacycles or more—and maintains this bandpass right through the video amplifier stages. Many of the older TV chassis, built from 1947 to 1949 (split-sound sets), were capable of this bandpass when carefully aligned. The set used here was a *Philco* 1001 chassis, but an *RCA* 630 or an *Admiral* 30A1 (and some others) will work just as well. These are obtainable second hand from many TV dealers.

The composite signal goes to the grid of V_1, the first video amplifier on

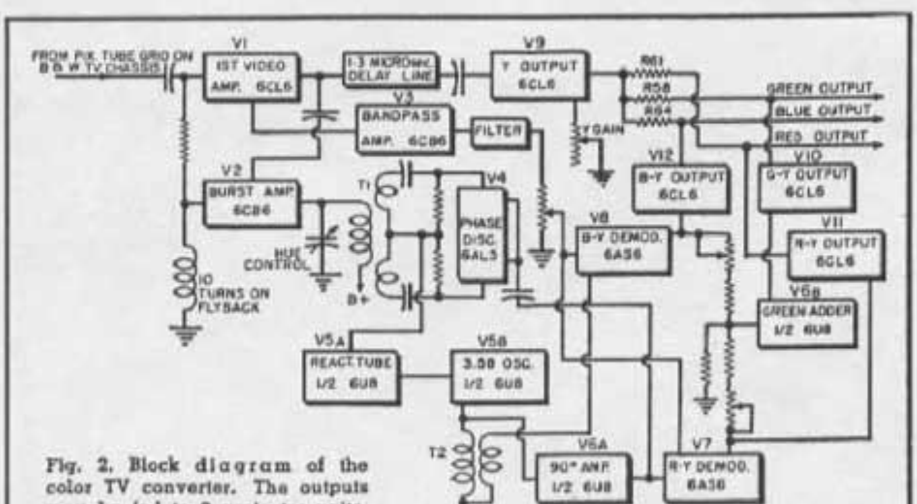
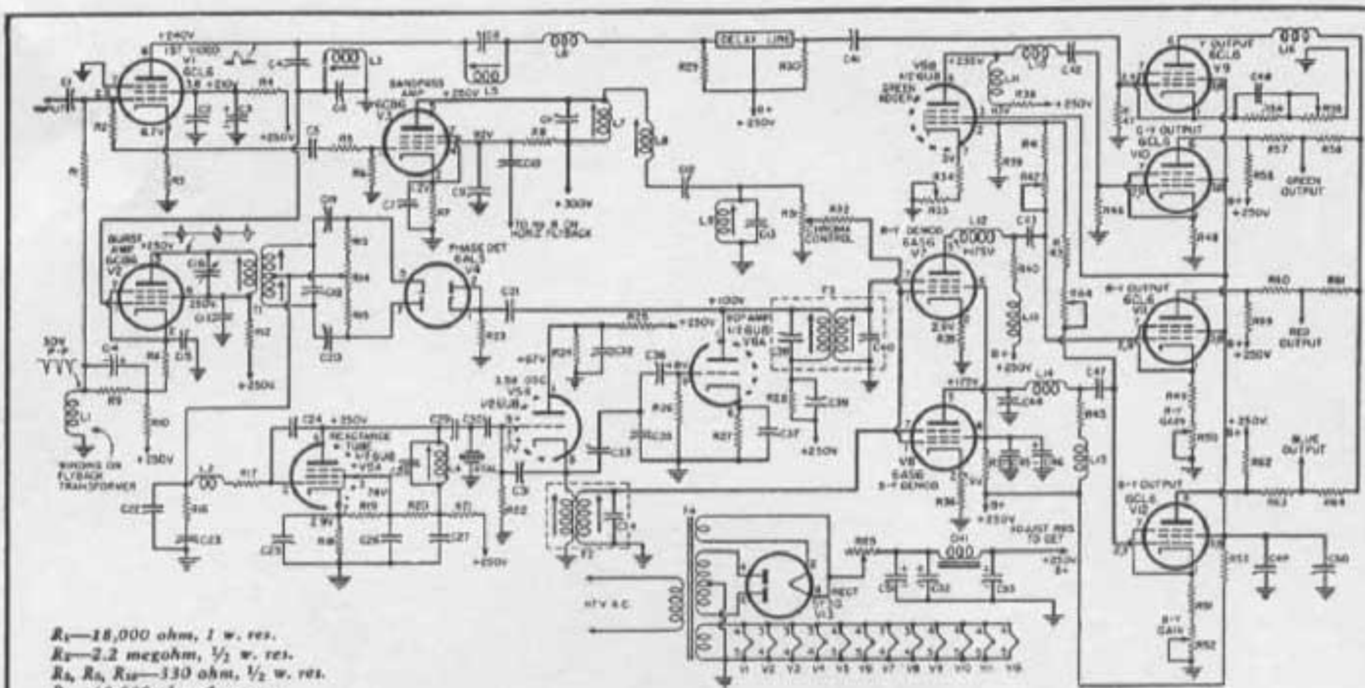


Fig. 2. Block diagram of the color TV converter. The outputs may be fed to 3 projector units.



R_1—18,000 ohm, 1 w. res.
R_2—2.2 megohm, ½ w. res.
R_3, R_5, R_{39}—330 ohm, ½ w. res.
R_4—10,000 ohm, 2 w. res.
R_6, R_{20}, R_{24}, R_{40}, R_{50}, R_{51}, R_{64}—15,000 ohm, ½ w. res.
R_7, R_{37}, R_{38}, R_{44}, R_{55}, R_{56}, R_{46}, R_{57}, R_{58}—100 ohm, ½ w. res.
R_8—82,000 ohm, 1 w. res.
R_9—12,000 ohm, 1 w. res.
R_{10}, R_{18}, R_{29}—220,000 ohm, ½ w. res.
R_{11}—220 ohm, 1 w. res.
R_{12}—2200 ohm, ½ w. res.
R_{14}, R_{42}—100,000 ohm pot
R_{17}, R_{28}, R_{30}, R_{49}—1000 ohm, ½ w. res.
R_{19}—10,000 ohm, 1 w. res.
R_{22}—22,000 ohm, 2 w. res.
R_{23}—2200 ohm, 1 w. res.
R_{25}—150,000 ohm, ½ w. res.
R_{26}—10,000 ohm, ½ w. res.
R_{27}—18,000 ohm, 2 w. res.
R_{31}—100,000 ohm, ½ w. res.
R_{32}—500 ohm pot
R_{33}, R_{34}, R_{52}—2000 ohm pot
R_{35}, R_{54}—10,000 ohm, 5 w. res.
R_{36}, R_{58}—4700 ohm, ½ w. res.
R_{38}—22,000 ohm, ½ w. res.
R_{41}—39,000 ohm, ½ w. res.
R_{43}—33,000 ohm, ½ w. res.
R_{45}—500,000 ohm pot
R_{46}—15,000 ohm, 1 w. res.
R_{46}, R_{47}—1 megohm, ½ w. res.
R_{48}—150 ohm, ½ w. res.
R_{50}—1500 ohm pot
R_{53}—8200 ohm, 1 w. res.
R_{59}, R_{62}—4700 ohm, 1 w. res.
R_{60}, R_{63}—8200 ohm, ½ w. res.
R_{65}—550 ohm, 25 w. adj. res. (Adjust to give 250 v. from power supply "B+" output.)
C_1, C_{41}, C_{42}—.1 µfd., 400 v. cond.
C_2, C_{28}—.01 µfd. button ceramic cond.
C_3, C_{34}, C_{35}—20/20/60 µfd., 350/350/450 v. elec. cond. (Sprague TVL 3725)
C_4—4.7 µµfd. ceramic cond.
C_5—150 µµfd. ceramic cond.
C_6—22 µµfd. silver mica cond.
C_7, C_{16}, C_{21}, C_{26}, C_{27}, C_{28}, C_{37}, C_{38}, C_{40}, C_{45}, C_{49}—.01 µfd. disc ceramic cond.
C_8, C_{44}—47 µµfd. silver mica cond.
C_9—470 µµfd. mica cond.
C_{10}—.001 µfd., 1600 v. paper cond.
C_{11}, C_{13}—250 µµfd. silver mica cond.
C_{12}—14.7 µµfd., made up of two condensers: a 10 µµfd. and a 4.7 µµfd. ± 5% ceramic cond.
C_{14}—2 µfd., 150 v. elec. cond.
C_{15}—3.3 to 20 µµfd. midget-type variable cond (Phase control)
C_{18}—10 µµfd. silver mica cond. (In trans. can)
C_{19}, C_{30}—.01 µfd., 400 v. cond.
C_{21}—10 µµfd. silver mica cond.
C_{22}—.02 µfd. paper cond.
C_{23}—.22 µfd., 400 v. paper cond.
C_{24}—2.2 µµfd. ceramic NPO cond. ±5%
C_{25}—5 µµfd. NPO cond. ±5%
C_{26}, C_{29}—100 µµfd. silver mica cond.
C_{31}—47 µµfd. ceramic NPO cond. ±5%
C_{32}—500 µµfd. silver mica cond. ±10%
C_{33}—27 µµfd. silver mica cond. (In trans. can)
C_{36}—.002 µfd., 600 v. cond.
C_{38}—100 µµfd. silver mica cond. ±10%
C_{39}—100 µµfd. silver mica cond. (In trans. can)
C_{40}—390 µµfd. silver mica cond. (In trans. can)
C_{46}, C_{47}—.1 µfd., 400 v. paper cond.
C_{50}, C_{51}, C_{52}—40/10/80 µfd., 450 v. elec. cond. (Sprague TVL 3792)
Xtal—3579.5 kc. crystal (Peterson PR Z-2)
L_1—See text
L_2—20 µhy. r.f. choke
L_3—90 t. #36 en. closewound on Miller 1470A form (Cromco L-6)
L_4—105 t. #36 en. closewound on Cambridge Thermionic ½ x 2" form (Cromco L-1)
L_5—4.5 mc. trap, 75 t. #36 en. closewound on Miller 1470A form (Cromco L-5)
L_6, L_{16}—120 µhy. peaking coil
L_7—29 t. #30 en. scramblewound 3/16" on ¼" Cambridge Thermionic form (Cromco L-2)
L_8, L_9—78 t. # 36 en. scramblewound 3/16" on Cambridge Thermionic ⅜" x 1" form (Cromco L-3)
L_{10}, L_{12}, L_{14}—1000 µhy. peaking coil (Cromco P-1000)
L_{11}, L_{13}, L_{15}—500 µhy. peaking coil (Cromco P-500)
CH_1—1 hy., 300 ma. filter choke
T_1—90 t. #40 d.s.c universal wound, ⁵⁄₃₂" wide (pri.); 60 t., each, universal wound, ⁵⁄₃₂" wide (sec.) wound on coil form from Miller 1466 i.f. trans. (Cromco T-1)
T_2—18 t. #30 en. closewound (pri.); 90 t. #36 en. closewound (sec.) wound on form from Miller 1466 i.f. trans. (Cromco T-3)
T_3—60 t. #30 en. closewound (pri.); 26 t. #26 d.c.c. and en. closewound (sec.) wound on form from Miller 1466 i.f. trans. (Cromco T-4)
T_4—Power trans. 370-0-370 v. @ 275 ma.; 6.3 v. @ 7 amps.; 5 v. @ 3 amps. (Stancor P-6315 or equiv.)
Delay Line—See text
V_1, V_9, V_{10}, V_{11}, V_{12}—6CL6 tube
V_2, V_3—6CB6 tube
V_4—6AL5 tube
V_5, V_6—6U8 tube
V_7, V_8—6AS6 tube
V_{13}—5Y3G tube

Fig. 3. Complete schematic diagram and parts list for the TV color converter designed to be used with a black-and-white set.

the color chassis. See Fig. 3. The luminance or Y signal is picked up at the plate of the first video amplifier in the color chassis, passes through a 3.58 megacycle trap (L_3-C_6), and is fed to a 1.3 microsecond delay line, which insures that the luminance information and the color signals arrive at the output at the same time. From the delay line, the signal goes to the grid of the Y output tube (V_9). From the plate of this tube, the signal goes through the matrix resistors, R_{56}, R_{61}, and R_{66}, where the Y signal and the color-minus-Y signals are mixed to provide green, red, and blue output.

The color-burst signal is also obtained from the plate of V_1 and is fed to the grid of the burst amplifier, V_2. This tube is keyed on only during retrace, the keying being accomplished by means of a 10-turn coil wound on the flyback transformer in the black-and-white TV set chassis. (See Fig. 4.) By this means, the color burst, which is on the back porch of the horizontal sync pulse, is amplified—but no other 3.58 megacycle signals get through.

The output of the burst amplifier goes to the phase discriminator transformer T_1, the secondary of which is also supplied with a comparison signal from the plate of the 90-degree amplifier, V_{6A}. The output of the phase detector is a d.c. correction voltage which is fed to the reactance tube, V_{5A}; this tube, in turn, controls the frequency and phase of the 3.58-megacycle oscillator, V_{5B}. In this way, the local 3.58 mc. oscillator is locked in exact phase and frequency with the transmitted color burst to supply the synchronous demodulators with the missing color subcarrier, the sidebands of which only are transmitted—the carrier being suppressed at the transmitter.

From the cathode of the 3.58 megacycle oscillator, the signal takes two paths. A signal directly from the cathode goes to the 90-degree amplifier which shifts its phase 90 degrees for proper demodulation in the R-Y demodulator. The secondary winding of transformer T_2, however, feeds the

B-Y demodulator directly with no phase shift.

The *B-Y* demodulator and the *R-Y* demodulator receive their color signals from the bandpass amplifier (V_4) and filter, which has a bandpass of 1.2 megacycles (from 2.9 mc. to 4.1 mc.) and passes *only* the color subcarrier sidebands. This automatically drops out the low-frequency *Y* signal.

In the *R-Y* and *B-Y* demodulators, the missing carrier is restored and demodulated to produce the *R-Y* and *B-Y* signals. The *B-Y* signal, taken directly from the plate of V_8, goes to the grid of the *B-Y* output tube, V_{13}. The output of this tube, in combination with some of the *Y* signal, supplies blue.

The *R-Y* signal from the plate of the *R-Y* demodulator goes to the grid of V_{11}, which, in similar fashion to that of the *B-Y* output stage, supplies the red output signal.

The output of the *R-Y* and *B-Y* demodulators is fed to the grid of the green adder, V_{8B}, through a set of resistors. This tube is simply a phase inverter at which the negative signals from the demodulators combine in proper proportion and invert to form the positive *green-Y* signal. This is fed to the *G-Y* output for addition with the luminance signal as described previously for the other two colors.

The outputs terminate in jacks along the end of the chassis, making the three color signals and the *Y* signal readily available for different experimental hookups. Most of the controls are inserted on the rear of the chassis since many of them are setup controls which are left alone once adjusted. Two controls, chroma and phase, are used for minor adjustment during reception, and it is desirable to make them readily available. No "color killer" controls or circuits are needed—simply turning down the chroma control puts the set in shape to receive black-and-white.

In actual construction of the converter, the first step is to round up the needed parts. The careful builder can, by following the data given in the parts list, "roll his own" coils. A real help in doing this is the setup shown in Fig. 5 which provides approximately the same loading as the converter circuits. This allows the coils to be wound with considerable accuracy without actually inserting them in the circuit. The signal generator should preferably be a 3.58-mc. crystal oscillator. A standard d.c. voltmeter will give a clear-cut indication of resonance. This circuit, however, will indicate when the signal generator is tuned to one-quarter or one-half of the resonant frequency, so if a variable frequency oscillator is used, always switch to the next higher band to make certain that you are actually on the fundamental. The physical layout for the windings of T_1 is shown in Fig. 6.

For those who want to buy coils already wound, the designers of the color converter, Costa and Dontje, will supply coils, and their part numbers are given in the parts list under *Cromco*. Write to *Cromco*, in care of P. Dontje at 7020 W. 38th Ave., Wheatridge, Colo.

The color chassis measures 10 x 14 x 3 inches. The layout is purposely crowded in order to keep leads short and point-to-point. No trouble has been experienced from stray capacity, even though some of the signal carrying leads are longer than were desired.

The chassis illustrated in Figs. 7 and 8 has a cut-out for a *Norelco* video amplifier chassis, to allow use with a single-projection unit and a color wheel. The chassis will eventually be used in this fashion although, at present, three *Norelco* projection units are utilized. There are a couple of other extra holes on the chassis for parts which circuit development later proved unnecessary.

In building, all transformers and tube sockets were mounted first, also terminal strips, filter condensers, and controls. Following usual construction practice, heaters were wired in, and then "B+" voltage leads completed. Finally, the r.f. wiring was put in

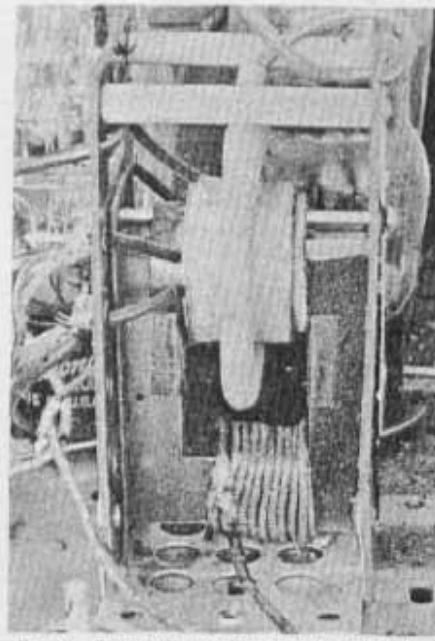


Fig. 4. A ten-turn winding on the flyback transformer keys the burst amplifier on for the proper operation of the 3.58 megacycle color synchronization circuits.

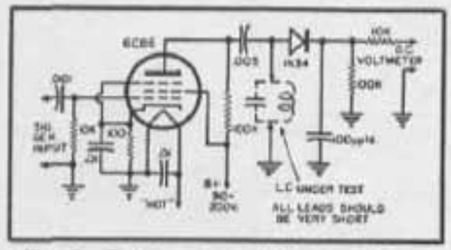


Fig. 5. A test setup which is useful in preparing the coils used in converter.

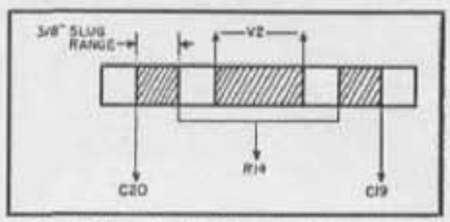


Fig. 6. The physical layout of the phase discriminator transformer windings.

Fig. 7. Top view of the color converter. Note where the crystal is mounted so as to minimize temperature variation effects.

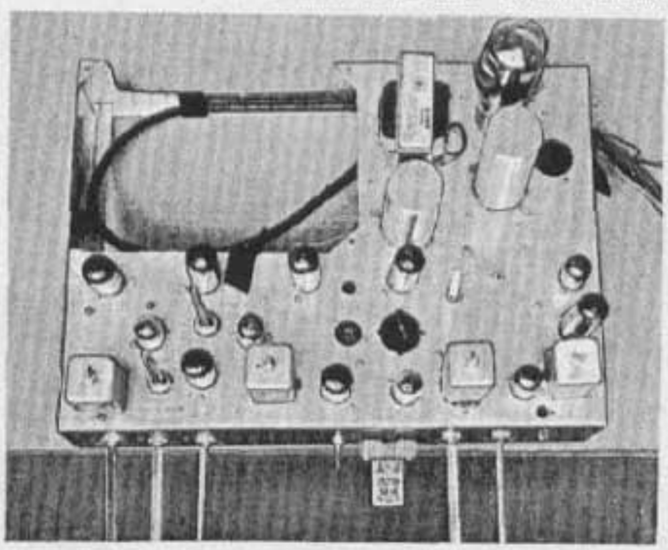
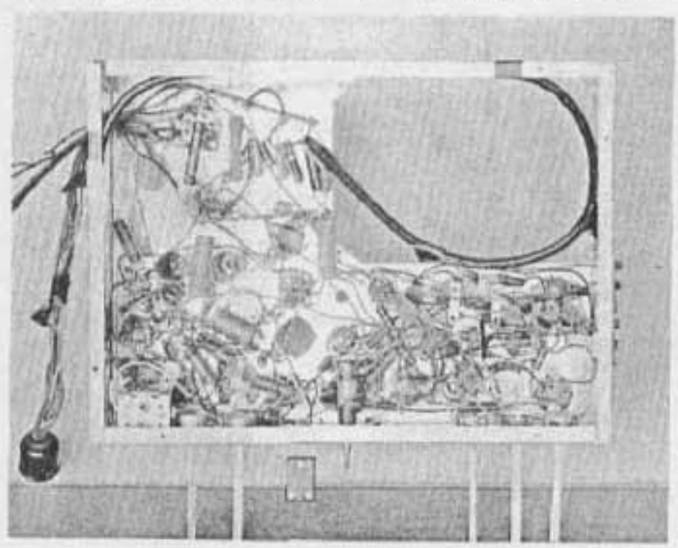


Fig. 8. Bottom view of the converter chassis. The black cable running around the cutout is the delay line in the Y circuit.



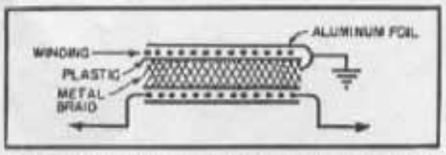


Fig. 9. Details on the construction of the time delay line used in the Y channel. The line is made from a piece of coaxial cable from which the center conductor has been removed and an external winding added.

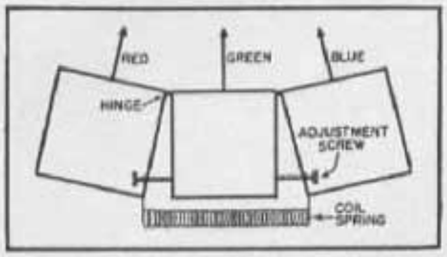


Fig. 10. Three TV projection units can be set up as shown here and used with the converter to give colored TV pictures.

Important: All resistors carrying fairly heavy loads were grouped on terminal strips below the power supply section, as far from tuned circuits as possible, to avoid the possibility of heat causing detuning of circuits. This is a vital matter in a color set because detuning and accompanying shift will cause color contamination.

The crystal is mounted alongside the chassis where it is out in the open and "runs cool"—again to avoid frequency shift.

The heavy black lead which loops around under the chassis is the delay line. Fig. 9 shows how this component is constructed from a 23-inch piece of RG-59/U coaxial cable. As shown, the center wire lead, and its polyethylene sheath, is pulled from the cable, leaving only the metal braid and its plastic cover. These two pieces serve as the foundation of the delay line. First, they are slipped *temporarily* over a metal rod to provide sufficient stiffness for winding. This winding, which should be put on accurately with a lathe, is made of No. 36 enameled wire. It is wound for a length of 22 inches, 128 turns-per-inch. As shown in the drawing, the leads connect to opposite ends of this coil winding. The winding itself is covered with a layer of *very thin* dielectric paper (pulled from old condensers) and this, in turn, is covered with a layer of aluminum foil. The latter is grounded to the inside braid as shown in the drawing, being careful not to short the winding to the grounding foil. Tape completely.

Wiring a set as complicated as this is a job in which even an expert can go astray. One bit of insurance is to tape a piece of vellum (a kind of semi-transparent drawing paper available at any art store or engineering supply house) over the diagram, and then draw in each lead with a colored pencil as it is done. This process is a little tedious—but not as tedious as trouble-shooting for built-in errors. Once the set is wired, the chassis can be given a rough check by comparing pin voltages with those shown in the diagram of Fig. 3.

When the color chassis is completed, the next step is to tie it to the *Norelco* projection units. These are the standard type, readily available from electronic parts jobbers. The hook-up requires three.

As shown in Figs. 10 and 11, the units are mounted side by side, as close together as possible, with hinges between them. Then the chassis are spring-loaded, as shown in Fig. 10, and adjustment screws provided so that the outer two projection units can be pointed in slightly—so that the images from all three units fall on top of each other on the screen. The fact that the units are some distance from the screen, and that the middle unit (green) carries 59% of the illumination, makes the very slight "keystoning" of the two outer units a theoretical rather than a practical worry.

Each of the units has a colored filter in front of it. (Colored Plexiglas was found to work the best—even better than photo filters.) The vertical and horizontal adjustments on the projection units, plus the mechanical position of the projection housings themselves, are all utilized to get the best possible registration of the projected images.

Both vertical and horizontal sweep voltages for the three projection units are picked up from the black-and-white chassis. The vertical sweep is used to drive the vertical yokes on the *Norelco* units—and the yokes are connected *in series*. The horizontal yokes are driven *in parallel*. Doing this will probably require substituting a different output transformer for that originally in the set. In the receiver described here, an *RCA* 231T1 transformer is used with the proper tap to provide the correct impedance match. The grids of the *Norelco* units are driven by the color output signals from the color converter chassis.

If everything checks out OK, we're ready for the final step—tuning up the chassis.

Fig. 11. Front view of the three projection units set up for use with the color converter described in this article. Color filters made of Plexiglas are mounted directly in front of each projector. Touch-ups are provided for registration.

BUILD YOUR OWN COLOR TV CONVERTER

Adjusting the color converter does not require any special test equipment other than the standard TV test instruments, including a v.t.v.m. as shown.

By
JAY STANLEY

Part 2. Complete step-by-step tune up instructions for the TV color converter described last month, including hints for using a 3-gun tube instead of projectors.

THIS article covers a step-by-step procedure which will enable you to get the color converter described in the preceding article appearing in this book going. Essentially, it is a procedure which will get adjustments so close to the ideal that final, minor adjustments can be made with a color broadcast tuned in.

First, equipment. You'll need a *good* signal generator, one capable of tuning the 3.58 megacycle range with very little drift after the initial warmup. Also needed are a v.t.v.m. fitted with an r.f. probe, a standard service-type scope, and a sweep generator which will sweep from 1 megacycle to 5 megacycles.

To begin with, align the black-and-white TV chassis as close as possible to the ideal i.f. curve shown in Fig. 1A. *Be certain to avoid sharp corners on* the i.f. response curve (Fig. 1B) which can introduce highly undesirable phase shift.

Next, make certain that the set receives black-and-white pictures through the color tubes. This will enable you to determine that the *Y* channel is working, and will allow you to get brightness, focus, and convergence of the three projection tubes in proper *adjustment. Unless the brightness* controls, for example, are at something like the proper level, color alignment is virtually impossible.

Now, we're ready to start.

Connect the signal generator (with a 10-μμfd. capacitor in series with the "hot" lead) to the first video amplifier grid in the black-and-white set. Tune in a black-and-white picture, and make certain that the picture is in proper horizontal sync. Then, pull out an i.f. tube to keep any stray signals from reaching the video detector. Set the signal generator as close to 3.58 megacycles as possible, preferably with crystal calibration. When you get it reasonably close to the proper frequency, you should see some indication of color on the raster—in the form of random streaks and shapes.

Now, pull out the 6U8 oscillator and reactance tube on the color converter chassis, and connect the v.t.v.m. with the r.f. probe to pin 5 of the color burst amplifier, V_8, 6CB6, and tune the burst take-off coil, L_8, for maximum. Remove the probe. (Note: All parts *numbers refer to Fig. 3 in the December article.*)

Next, ground pins 1 and 2 of the 6AL5 phase detector, V_4. Set the v.t.v.m. on the d.c. voltage scale (50-volt scale or higher), connect it to pin 5 of the 6AL5, and tune T_1, the phase discriminator transformer (both slugs), for maximum d.c. voltage. When this is done, remove the ground from the 6AL5 pins 1 and 2.

Replace the 6U8 reactance tube, pull out the burst amplifier, V_8, and connect the voltmeter with probe to pin 7 of the *B-Y* demodulator (V_9, 6AS6). Tune both slugs of the crystal output transformer, T_3, for maximum reading. You will notice that as you tune the primary of this coil (turning the slug clockwise) you will start toward a maximum reading, and then the oscillator will overload and stop oscillating. Back the slug out a few turns from this point, and the oscillator will be stable. The secondary of the crystal output transformer will tune through a normal peak.

Now, connect the v.t.v.m. with probe to pin 7 of the *R-Y* demodulator (V_7, 6AS6) and tune the output transformer of the 90-degree amplifier, T_4, for maximum.

Replace the burst amplifier tube, and once again pull the 6U8 oscillator-reactance tube. *Connect the sweep generator* (sweeping from 1 mc. to 5 mc.) to the grid of the first video amplifier tube in the black-and-white TV chassis. Turn the chroma control, R_{34}, to minimum, and connect the scope through a demodulator probe to the "hot" end of the chroma control. Tune the band-pass amplifier (V_3) plate coils for the resonance curve shown in Fig. 1C. Markers should be provided by the sig*nal generator, still connected* to the grid of the video amplifier in the black-and-white set.

Disconnect the sweep generator, leaving the signal generator attached, and replace the 6U8 oscillator tube. At this point, it is a good idea to recheck for horizontal sync by tuning the black-and-white chassis to a TV broadcast.

For the next step, turn the chroma control full open and the signal generator to maximum output (unmodulated). Carefully tune the signal generator back and forth around 3.5 megacycles, and you will observe a pattern of color bars shifting around on the raster. You will notice that as you approach the crystal oscillator frequency in the converter, this pattern will become a definite series of color bars, lying horizontally. As you get still closer to the exact frequency, you will note that the bars will become fewer and fewer, and finally disappear. The raster will assume an over-all tone of one color, which may even be simply an off-white. This indicates that the signal generator and the crystal oscillator in the set are *locked together*. (If you cannot achieve this effect, that fact is evidence that the color sync section is not working properly.) Carefully note the *exact* dial reading on the signal generator for future reference.

Now comes one of the most critical of all the tuning adjustments, so be very careful to do it exactly as described. *Slowly* tune the signal generator to a *lower* frequency than that of the crystal. "Slowly" cannot be emphasized too much, for there is real danger that you will pass right by the proper frequency. As you do this tuning, you will begin to see a series of color bars which move diagonally into a vertical pattern. If you tune slowly and carefully about this point, the signal generator will lock to the difference frequency between the crystal and the horizontal sweep frequencies.

Note carefully that as you tune below the crystal frequency there are quite a number of these "lock-in" points. Also, that the *lower* the frequency, the greater the number of bars. (The signal generator locks in at even multiples of the horizontal sweep frequency away from the crystal frequency.) Only the *first* lock-in point *below* the crystal frequency is the proper adjustment, and the only one which makes it possible to phase and align the color demodulators.

Keeping the signal generator locked to this point (as mentioned previously, the generator must be stable) the next step is to add the scope. Set the horizontal sweep in the scope to approximately twice horizontal frequency and switch it for external sync. The sync is obtained by clipping a lead to the "hot" deflection yoke wire (*over* the insulation—no direct connection).

Next, establish horizontal sync pulses by holding the lead to the input of the scope's vertical amplifier *close* (again, no connection) to the horizontal output plate lead in the black-and-white TV set chassis. Set the horizontal gain and horizontal centering of the scope to put these "pips" on two of the vertical calibrating marks on the scope face. See Fig. 1D.

Now, clip the input of the scope's vertical amplifier to the blue output. By carefully tuning the phase control, C_{18}, and the secondary slug of transformer T_3, you will be able to position the sine wave as shown in Fig. 1E. Note that the positive peak of the sine wave should fall halfway between the two previously established horizontal sync points (180 degrees) shown in Fig. 1D.

Changing no settings, connect the scope to the red output. Now tune the output of the 90-degree amplifier plate transformer, T_4. *Important*, the positive peak of the red output must fall *exactly* where the blue went through the zero axis, as shown in Fig. 1F. This establishes the all-important 90-degree phase difference between the *R-Y* and *B-Y* signals.

Still changing no scope settings, connect the scope to the green output. Adjust the red, green, and blue add controls (R_{42}, R_{43}, and R_{44}) to position the sine wave so that its zero axis crosses through the point 29 degrees to the right of the point where the blue was maximum positive. (See Fig. 1G.)

Disconnect the scope, leaving the signal generator attached. On the screen you should have bands of color running vertically. You should be able to adjust the phase control to get a pattern which is orange on the far left, blending into red, then blue, and finally green. When you have reached this point, you are ready to try a color broadcast!

With the color signal tuned in, adjust the plate coil, L_1, of the reactance tube to lock in the color signal. At this point, objects will become colored—even though bananas may look blue! Then adjust the phase control, and the color gain controls, for the most natural coloring in the picture. Once the color gain controls are set properly, correct coloring can be obtained by using the phase control only. This is the external color control available in some form on all color TV sets.

The chroma control affects the saturation of color, and is set to the taste of the individual viewer. One caution: if this control is set too high, the picture becomes garish and very grainy.

Just one more thing. The delay line may need some adjustment. This can be done by observing the color picture. If the color information seems to fall to the right-hand side of the black-and-white image, the delay line is too short. However, if you have made it 22" long, the color will probably fall very slightly to the left of the black-and-white image. Trim the line a few turns at a time until the color picture and the black-and-white picture are perfectly superimposed.

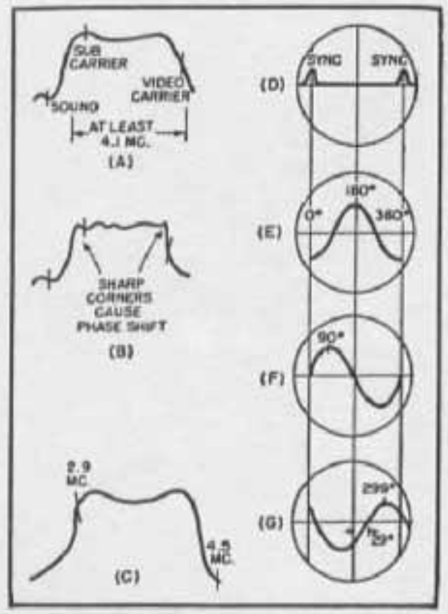


Fig. 1. Oscilloscope waveforms obtained during the various steps of the tune up procedure as described in the text. (B) is an incorrect waveform to be avoided.

3-Gun Tube

Either the 3-unit projection arrangement or a single projection unit with a color wheel provide the simplest way to get going with your color converter. However, if you desire to use a 3-gun tube, the *RCA* tri-color kinescope is available at some parts distributors, and here is the data you'll need.

First of all, because of the unequal phosphor sensitivity of the 3-gun tubes, it is necessary to make a slight change in the *Y* signal adding matrix to supply the unequal video drive required on the three grids. This is shown in

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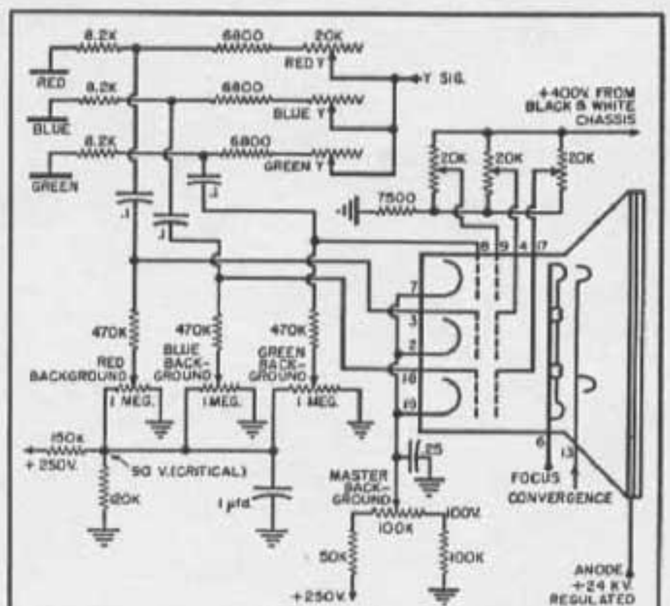

Fig. 2. Additional circuitry that must be included in the converter when it is used with a three-gun color TV tube.

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Fig. 2. It is also necessary to add individual background and master background controls, as well as red, blue, and green screen controls, which control the transfer characteristics of the three guns so that a black-and-white picture may be maintained at any brightness setting.

Set-up procedures for the matrixing and background adjustments are adequately described in instruction bulletins available with the 3-gun tube. *Caution:* before attempting to set up the system for a black-and-white picture, it is necessary to pull the two color demodulators from their sockets in order to avoid any confusion until experience is gained with the various adjustments.

The complications from using the 3-gun tube arise from the need for regulated anode, focus, and dynamic convergence voltages. A practical way to build these stages is to use the standard *RCA* circuitry, specifically that given in the service data for the *RCA* Model CT-100 color receiver. The circuits used include (refer to CT-100 diagram) *V*[illegible], the 6SN7GT horizontal oscillator, *V*[illegible], the 6CD6 horizontal output (with modifications); *V*[illegible], the 3A3 high-voltage rectifier; *V*[illegible], the 1X2B focus rectifier; *V*[illegible], the 6AU4GT damper; *V*[illegible], the 6BD4 shunt regulator; and *V*[illegible], the 12AU7 vertical convergence amplifier.

Of course, if you utilize *RCA* circuits, you must use the standard *RCA* parts, including a tri-color yoke and the matching horizontal flyback transformer. Also needed are a complete set of dynamic convergence components, a purity coil, and the shielding recommended for the tube.

If you are building your system around the black-and-white *Philco* chassis described in the previous article, you will find that the horizontal oscillator has much too long a flyback time to drive the *RCA* transformer properly. It is necessary, then, not only to change the horizontal output stage circuitry, but also, the horizontal oscillator circuit should be modified to conform with the *RCA* circuit. The sync to the horizontal oscillator can still come from the same point in the *Philco* 1001 chassis, however.

When using the *RCA* horizontal output transformer, the keying pulse for the burst amplifier may be taken off terminals "C" and "D." Terminal "E" supplies the horizontal dynamic convergence voltage. Terminal "G" is grounded, as in the original *RCA* circuit. Terminal "F" is left blank, and the rest of the circuitry in the entire dynamic convergence and high-voltage sections should conform with the *RCA* circuit. The 400 volts necessary to drive this set-up may be obtained quite readily from the black-and-white chassis you are using.

The grid circuit for the horizontal output tube (6CD6) is modified in order to eliminate the need for a minus 30 volts. (Refer to CT-100 diagram.) The modification consists of simply changing the grid return resistor, *3R*[illegible], from 47,000 ohms to 470,000 ohms, and grounding the cold end. The cathode resistor, *3R*[illegible], should be changed from 12 ohms to 100 ohms, 2 watt, and bypassed with an 8-μfd., 150-volt capacitor. The screen grid can be supplied from the 250-volt "B+" supply in the converter chassis.

The next requirement will be to obtain the current needed by the purity coil. This can be supplied by paralleling the 20-ohm purity adjustment potentiometer, *2R*[illegible], with the coil, and putting it in series between the output of the choke and the "B+" in the converter chassis.

The vertical convergence voltage can be supplied to the input of the vertical convergence amplifier, *V*[illegible], without making any changes in the vertical output circuit that you already have in your black-and-white chassis. Again referring to the CT-100 diagram, connect one end of the .47-μfd. capacitor, *1C*[illegible], to the red wire on the existing vertical transformer. The end of the .1-μfd. capacitor *1C*[illegible] (in the vertical amplifier shape circuit of the *RCA*) goes to the plate or blue lead of the existing vertical output transformer. The end of *1C*[illegible], .22-μfd. (also in the vertical amplifier shape circuit), goes to the cathode of the vertical output tube.

The remainder of the connections in the vertical convergence circuits should be hooked up exactly as shown in the *RCA* schematic. The green-and-yellow leads from the existing vertical output transformer should be tied directly to the vertical deflection windings on the deflection yoke. This eliminates any need for vertical centering circuits.

Note: terminal 5 of the flyback is not used.

The "B+" 400 volts from the black-and-white chassis goes to the fuse, *3F*[illegible], which feeds the cathode of the shunt regulator, 6BD4, the plus end of *3C*[illegible], 20-μfd. capacitor, and one end of the horizontal centering control. This gets the "B+" voltage into the rather involved circuit.

Two more things. Once the tube is set up for proper black-and-white reception, the color mixing circuits operate exactly the same as for the 3-unit projection system described previously. Adjustments needed to converge the tube are covered in the technical data now widely available.

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Projection Color TV with a Color Wheel

By **JAY STANLEY**

Fig. 1. The complete projection color TV receiver showing the color converter described in the two previous articles in this book, in the upper compartment and the color wheel and switch in the lower. The complete 6-tube keyer chassis mounts in the cut-out section of the converter.

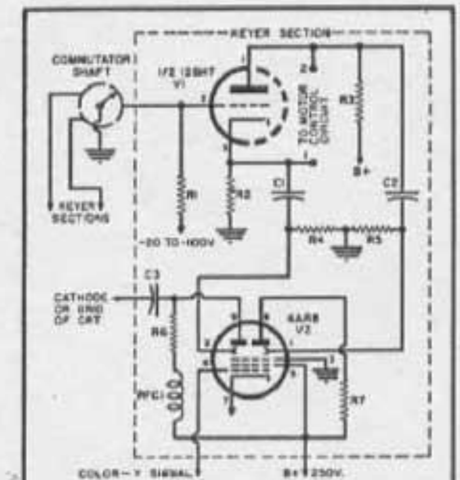
In response to requests from readers — here is how you may use a color wheel and one projection unit with the color TV converter described in the two previous issues.

THE original model of the color converter described in the previous articles in this chapter in this color televisionbook was designed for use with a 3-unit projection system. This is by far the simplest way to get a color set going—but of course it is a somewhat cumbersome way to do the job. For this reason, many readers have asked for data on using one projection unit and obtaining the color with a color wheel.

This article outlines such a system, as shown in Fig. 1. It is *not* intended as a step-by-step construction article but, rather, will present a method that has been developed from experimental work with a color wheel system so that the experienced technician can, in working out his own layout, avoid many of the pitfalls which may otherwise plague him.

In theory, a color-wheel system is quite simple. First, there needs to be a switching system between the red, green, and blue outputs and the picture tube, so that the proper output can be switched to the picture tube at the proper time. This must coincide with the time when that section of the color wheel is in front of the tube. For example, when the color converter is delivering a red signal to the projection tube the red segment of the color wheel should be in front of the tube so that a red image is projected.

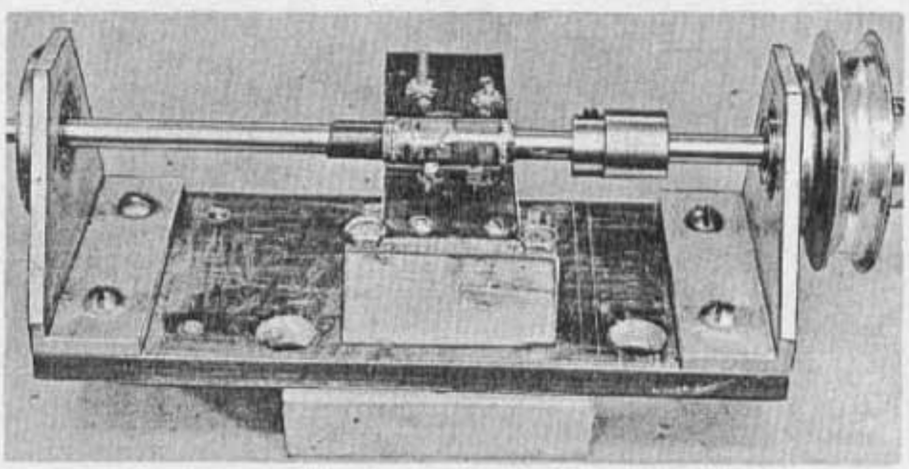
Of course, this switching action can start with a rotary switching device on the shaft of the color wheel, as shown in Fig. 3. But the difficult part of the job comes from the need to sync the color wheel so that it stays exactly in step with the vertical sync frequency of the set. This is necessary to make certain that the "crossover" point (when changing from one color to the other) occurs during retrace, and not



R_1—100,000 ohm, ½ w. res.
R_2, R_3—2700 ohm, 1 w. res.
R_4, R_5—2.2 megohm, ½ w. res.
R_6, R_7—4700 ohm, 1 w. res.
C_1, C_2—.25 µfd. capacitor
C_3—.1 µfd. capacitor
RFC_1—1000 µhy. r.f. choke
V_1—½ 12BH7 tube
V_2—6AR8 tube

← Fig. 2. Schematic diagram and parts list of one of the keyer sections used for selecting the right color signal to go with the color filter in front of the projector. Three keyers are required.

Fig. 3. Commutator-type switch on the shaft of the color wheel used for breaking the color signal into a field sequential one to operate properly with the color wheel. The switch shown here is an example of what may be used, the constructor should use his ingenuity to devise one that is precise and practicable.



during the regular scanning time. If the latter happens, a bar works up and down on the screen, much like a vertical blanking bar.

In an early model of the color-wheel system, it was decided to let the wheel run at random speed, switching the output with commutator contacts on the shaft of the color wheel. But trouble with "crossover" points and noise difficulties led to abandoning the system. However, if the bugs could be worked out, the system would be wonderfully simple in both circuitry and parts.

Subsequent work has been based on the use of a saturable reactor. The vertical sync signal is picked up from the grid of the vertical output stage (or any other convenient point in the vertical system) and applied to a phase detector, driving a d.c. amplifier which, in turn, varies the d.c. potential on a saturable reactor. The reactor controls the speed of the color-wheel motor, with the result that it keeps in sync with the vertical sweep of the TV set, so that the "crossover" occurs during the retrace when it is not visible on the screen.

As shown in Fig. 2, the switching starts with a commutator, the rotary shaft of which is grounded. The "rotating" ground is applied to the grids of three keyer amplifier tubes in turn. Each of the keyer amplifiers feeds the deflector elements of a 6AR8 tube—a wonderful new type developed especially for color work. In effect, this tube is a voltage-controlled single-pole, double-throw switch, and at the same time an amplifier.

Here is how the switching takes place. The commutator segment, as it grounds the grid of the keyer amplifier, removes the bias voltage and allows a pulse of plate current to flow. The output is taken off across R_1 in the cathode circuit and is positive with respect to ground. This positive voltage is used to switch the 6AR8 from one plate, which is idling (no output), to the plate which is driving the CRT cathode.

The color minus Y signal is fed to the control grid of each of the three 6AR8's, one for each color. As the commutator rotates, it will switch the output to the live plate of each tube in turn. The net result is a sequential color signal applied to the CRT that is in step with the segments of the color wheel. The commutator cannot be used directly for switching the inputs to the CRT as the noise level from the sliding contacts is prohibitive, and of course, with a 1 megacycle video signal present at this point, it cannot be bypassed. However, the indirect switching method outlined, makes it possible to bypass the commutator segments with a small capacitor (.001 µfd.) and get rid of the high-frequency noise, the only noise present. Even this small capacity will round the edges of the switching signals somewhat, but these are hidden in retrace anyway.

The symmetrical output from one of the keyer amplifier tubes (points 1 and 2 in Fig. 2) is applied to a shaping network to form a narrow pulse which is fed to the phase detector and compared with the vertical saw-tooth present on the grid of the vertical output tube (see Fig. 4). The resulting correction voltage is then applied to a

R_1, R_2—100,000 ohm, ½ w. res.
R_3, R_4—470,000 ohm, ½ w. res.
R_5—1 megohm, ½ w. res.
R_6—10 megohm, ½ w. res.
R_7—68,000 ohm, ½ w. res.
C_1, C_2—.01 µfd. capacitor
C_3—.25 µfd. capacitor
C_4—.002 µfd. capacitor
C_5—.04 µfd. capacitor
C_6—4 µfd., 450 v. elec. capacitor
V_1—6AL5 tube
V_2—12AU7 tube
V_3—6CU6 tube

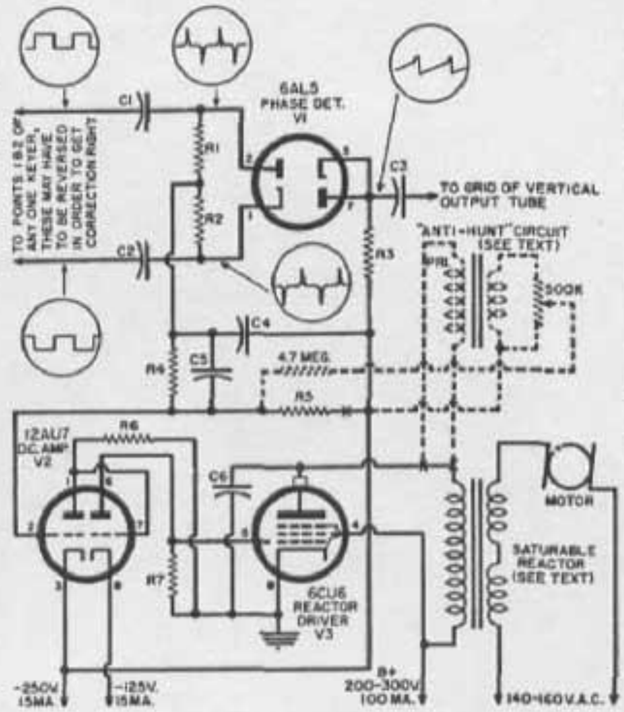


Fig. 4. Schematic diagram and parts list for the color wheel motor speed control circuit. The input is derived from one of the keyer sections, select the one that moves the bar between color wheel filters out of the picture.

Fig. 5. The four vertical output type transformers are connected as shown here to form a saturable reactor which controls the speed of the color wheel motor in conformity with the signal from the motor control circuit shown in Fig. 4. →

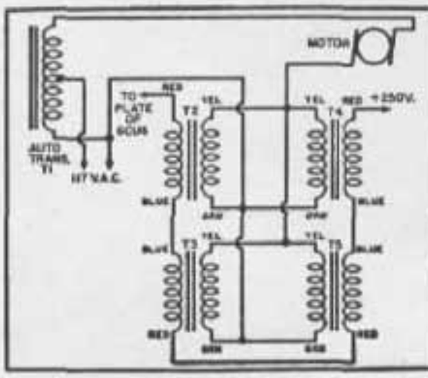
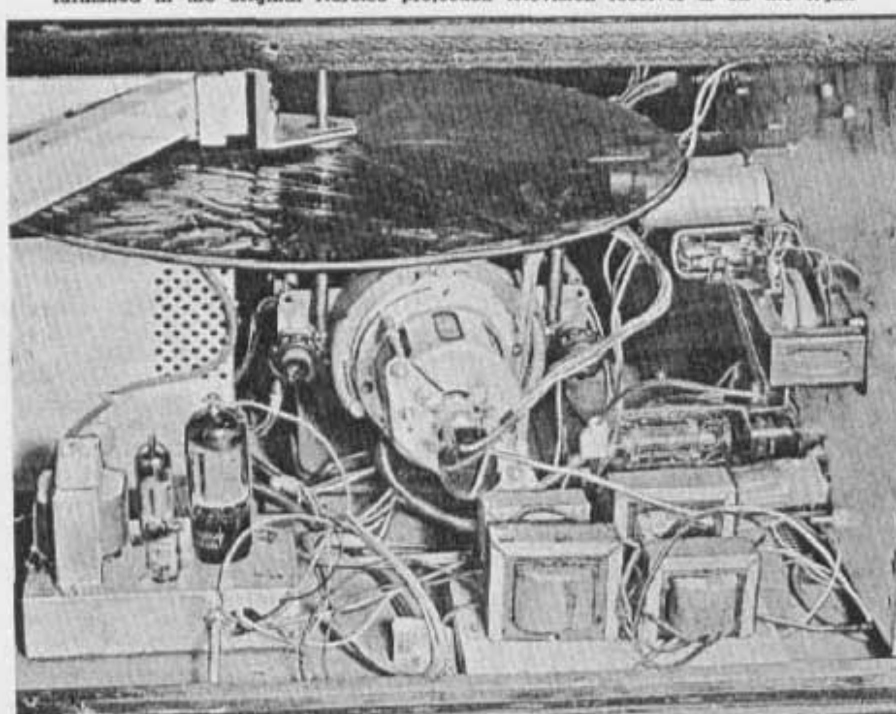


Fig. 6. View of the color wheel and associated circuitry. Note the saturable reactor and motor control chassis in the foreground. The regular deflection chassis furnished in the original Norelco projection television receiver is on the right.



d.c. amplifier system that runs negative with respect to ground in order to have a negative-going bias that will vary between zero and minus 25 volts on the grid of the 6BQ6 (or 6CU6), a husky tube type needed to handle the relatively heavy current required for control of a saturable reactor.

A saturable reactor is a device in which one winding will control the inductance of a second winding. The reactor is placed in series with the motor which drives the color wheel. If the d.c. in the primary increases, the inductance of the secondary decreases, allowing more current to flow, and the motor to speed up, and *vice versa*. The motor itself is fed from an autotransformer which steps up the line voltage 25 volts or so, because even with the minimum inductance of the type reactor to be described in this article, there will still be considerable voltage drop. The circuit used for this portion of the converter is shown in Fig. 5.

The saturable reactor shown in Figs. 5 and 6 uses readily-available transformers. Four TV type (six would be even better) vertical output transformers of the kind which have individual primary and secondary windings work very well. The autotransformer types are not satisfactory. It is of the utmost importance that the transformers used be matched, *i.e.*, of the same manufacturer's part number. The reason is that the a.c. which will be induced in the primary winding (the d.c. control winding in this case) in each transformer must be canceled out by its mate. Connect all of the secondaries in parallel and pay close attention to the winding directions to make certain that all are the same. (For example, for RETMA coded units, connect all green leads to green, and yellow to yellow.) The primaries are all connected so that the pairs are series-opposed to a.c., *i.e.*, connect the red lead of transformer T_1 to its mate's (T_3) red lead, and connect the two blue leads to the next pair of transformer's blue leads. After the paralleled secondaries are connected in series with the motor and a.c. is applied, no, or very little a.c. voltage should appear between the ends of the combined primaries.

Caution: If an a.c. voltage of any magnitude *does* appear, recheck connections. The direction of d.c. to the primaries makes no difference as they are merely connected between "B+" and the plate of the 6CU6 control amplifier.

Incidentally, when using the 6AR8's in the color switching system, it is advisable to do away with the individual color amplifiers in the color chassis described in the color converter article starting on page 123 and extending to page 126 in this book, as the gain of the 6AR8's is rather high and makes the amplifier unnecessary. Too much gain may cause instability.

The output from the *Y* amplifier should be disconnected from the matrix resistors and fed directly to the grid of the CRT. The color signals go to the cathodes and are matrixed within the picture tube.

The color wheel itself should have any multiple of 3 sections (6, 9, etc.) However, for projection use in front of the corrector lens, a 3-section wheel about 16" in diameter is best. Such a wheel gives longer useful projection time for each color without overlap of individual colors. The speed of the wheel is easily determined as a single section should cover the lens during one vertical field time, *i.e.*, a three-section wheel should run 1200 rpm, a six-section wheel 600 rpm, etc. These speeds are a close approximation to those actually required because during a color broadcast, the field frequency is not quite 60 cycles. It may be desirable to drive the color wheel by means of a small V-belt drive, preferably fitted with one variable pitch pulley in order to bring the wheel close enough to the proper speed so that the automatic control system takes over.

It may be necessary to try different keyer amplifier outputs for the phase detector so as to get the "crossover" point into retrace. Try first one and then the other, and settle for the one which moves the "crossover" bar out of the visible portion of the raster.

It is strongly urged that fully saturated color filters *not* be used on this projection system. Doing so may reduce brilliancy. Instead, use ordinary-colored red, green, and blue Cellophane. Fasten these filters to a disc of clear plastic. Also, keep the weight of the wheel as low as possible in order to reduce any tendency for the automatic control system to "hunt." This is a difficult problem to correct and the heavier the wheel the more inertia there is to overcome, with the result that the wheel will overshoot the control, then slow down, then undershoot, then repeat the cycle.

Fortunately, there is an electronic circuit that may be used to correct for this defect. The suggested circuit is shown dotted in Fig. 4. The transformer is a vertical output type. It is important, of course, that the secondary be connected so as to give negative feedback. If it should be hooked up incorrectly, the d.c. amplifier will probably motorboat at a very slow rate that may be varied by turning the "anti-hunt" control (500,000 ohm pot). This circuit works on the idea that the rate of change of the correction voltage must agree with all the variables in the system, including weight of wheel, etc. The transformer only has an output when the current to the reactor is changing, and this output is directly proportional to the rate of change. The 500,000 ohm control taps off the amount of voltage necessary to properly control this change rate. In short, "anti-hunt" is time-controlled inverse feedback.

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