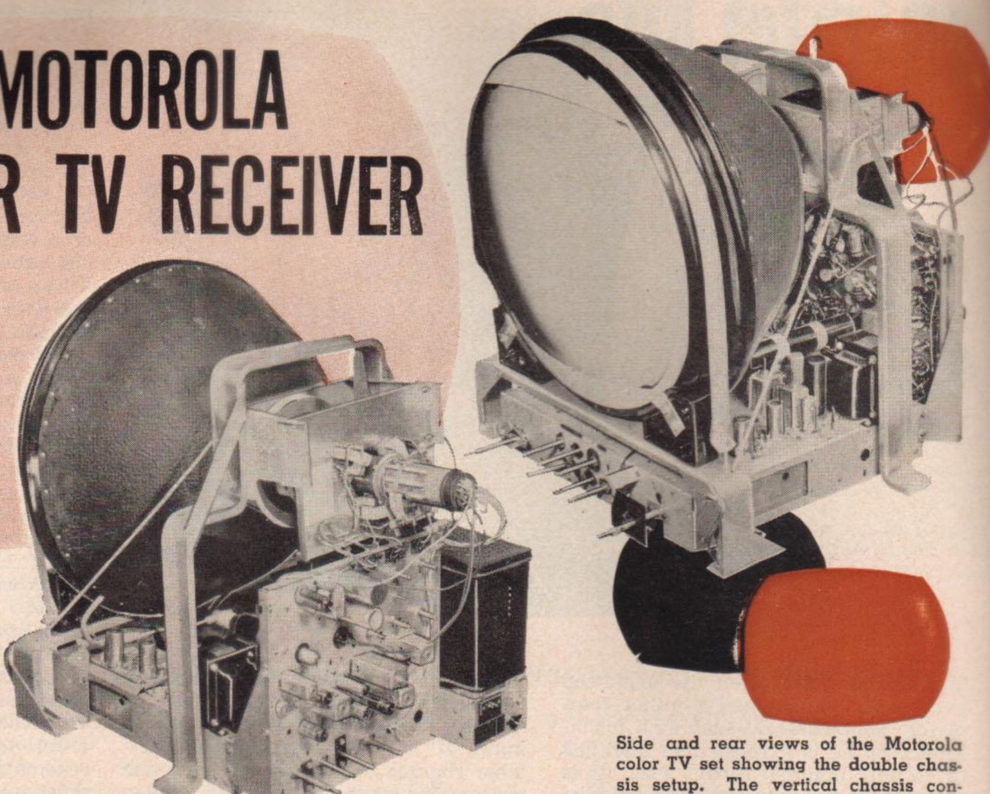
THE MOTOROLA 19" COLOR TV RECEIVER



Side and rear views of the Motorola color TV set showing the double chassis setup. The vertical chassis contains most of the chrominance circuits.

By **M. S. KAY**

Part 1. First complete analysis for service technicians of the first 19-inch color TV receiver widely available.

ONE of the first color television receivers to appear on the market using the 19-inch *CBS* color tube is the *Motorola*. The receiver is built around 29 circuit tubes, a 19VP22 19-inch tricolor picture tube, three germanium diodes, and three selenium rectifiers. Power consumption of the total receiver is a very moderate 375 watts.

The tremendous progress which commercial color television has made in less than one year after its official adoption is best revealed by the fact that relatively so few tubes are required to present a full color picture. When it is recalled that the first color receiver, the *RCA* CT-100, had 36 tubes, 3 germanium diodes, and 2 selenium rectifiers (plus a 15GP22 color tube) only 9 months before, we realize that a 20 per-cent reduction in so short a time is a remarkable feat.

A block diagram of the *Motorola* receiver is shown in Fig. 1. Of the r.f. and video i.f. stages, little need be added to what has already been said in prior articles appearing in this magazine. Actually, *Motorola* is using the same circuits here that they ordinarily use in their black-and-white receivers with some minor modifications to encompass the wider composite color signal. Also, sound take-off is accomplished at the plate of the 3rd video i.f. rather than beyond the second detector. This enables the circuit designers to impose additional attenuation on the sound carrier prior to the video detector in order to minimize the appearance of the 920 kc. signal obtained when the sound and color subcarrier signals beat with each other.

Of particular interest here are the circuits which are found beyond the video detector. The schematic diagram of Fig. 2 reveals two video amplifiers which resemble monochrome video amplifiers except for the lack of special peaking coils in the output of the first video stage. However, it will be noted that the principal load resistor for V_{6A} is only 820 ohms (R_{92}), a value low enough to maintain the amplifier response up to 4 mc. In the output of the 2nd video amplifier there is compensation and hence higher value load resistors are permissible.

Both the color and monochrome components of the composite signal remain together through both video amplifiers. Separation then takes place at the plate of the 2nd video amplifier. The brightness component is led off to a separate brightness output amplifier (V_{29}, a 12BY7) *via* R_{98} and L_{40}, a .6-microsecond delay line. (The reduction in delay time from the usual 1 microsecond to .6 microsecond will be discussed presently). At the same time, the chrominance portion of the signal appears across R_{97A} and R_{96}, and is applied to a 12BY7 bandpass amplifier, V_8. Just how much chrominance signal reaches V_8 is governed by the setting of R_{97A}. This potentiometer, the contrast control, acts in conjunction with R_{97B} in the cathode leg of the brightness output amplifier. Both are mechanically ganged, permitting the simultaneous adjustment of the chrominance and monochrome signal levels. A separate control is available at a subsequent point in the color system to permit independent adjustment of the color intensity of the picture.

Brightness Signal. The brightness or monochrome signal is amplified by V_{29} and then passed through a 3.58-mc. filter before being applied to all three cathodes of the picture tube. The 3.58-mc. trap serves to attenuate any color sidebands that may be present at this point. The trap also tends to limit the bandpass of this circuit to a value somewhere between 3 and 3.2 mc. Hence, in spite of the fact that monochrome signals up to 4.2 mc. are initially sent from the station, only those frequencies up to 3.2 mc. are actually effective in developing the picture.

The monochrome signal at the picture tube cathode has negative polarity, a condition that is required for the proper combination of the brightness and chrominance components of the color signal. Actually, the matrixing of the two portions of the color signal occurs within the picture tube itself rather than in a separate resistive network.

Bandpass Amplifier. The color signal, once it leaves the 2nd video amplifier, travels to V_8. A potentiometer in the cathode leg of this tube varies the gain of this stage and since only the color portion of the signal is thus affected, the control is labeled on the diagram as the chroma control. For the consumer, this knob is labeled "color intensity," this being considered more descriptive of its action. Maximum gain occurs when the knob is fully clockwise so that the 10,000-ohm resistor is completely out of the circuit.

The color burst signal also passes through the bandpass amplifier. To insure that sufficient burst voltage is available at all settings of the chroma control, a special positive pulse is fed into the grid circuit of V_8, the bandpass amplifier. This pulse is obtained from the horizontal output transformer and is so timed that it arrives at the same instant as the color burst. The pulse decreases the bias on the tube, causing it to furnish more plate current during this interval. In this way, a color burst signal is obtained which, at every setting of the chroma control, is strong enough to adequately drive the color a.f.c. network.

A 1N60 germanium diode is connected between the chroma control and the grid circuit to maintain the amplitude of the burst signal at its most efficient level. Here is how it does this. The cathode end of the 1N60 is connected to the top end of the chroma control and hence is subject to whatever positive potential exists at this point. Let us say this is +5 volts. The other end of the 1N60 connects to R_{102}, a 10,000-ohm resistor in the grid circuit of V_8. This same resistor develops the positive boosting pulse. If the pulse raises the voltage across R_{102} above +5 volts, the 1N60 conducts and serves to maintain the voltage across R_{102} at the same level as the voltage across the chroma control. When the chroma control is completely in the circuit, V_8 grid bias is greater and more positive boost voltage is received for the arriving color burst. On the other hand, when the chroma control is completely out of the circuit, V_8 is operating at full gain. At this point no intensifying pulse is needed and none actually reaches it because the 1N60 tends to maintain the voltage across R_{102} at zero volts.

Burst Amplifier. The output of the bandpass amplifier is applied to two points: a bandpass cathode follower and a burst amplifier. Considering the latter first, the signal is brought to the amplifier by way of L_{204}. L_{204} and C_{206} form a 3.58-mc. tuned step-up network in which the applied burst voltage is actually fed to the grid of V_{23A} in greater amplitude than it is applied. Adjustment of C_{206} will vary the phase of the burst which the burst amplifier receives. When the circuit is precisely tuned to 3.58 mc., the signal developed by the circuit will have the same phase as that of the incoming burst signal. If C_{206} is detuned, the signal developed by the resonant circuit will either lag or lead the incoming burst signal. Since the color a.f.c. stage receives the burst from this amplifier, it will shift the phase of the generated 3.58-mc. subcarrier to follow suit. This, in turn, will alter the colors produced on the screen. Because of this action, the shaft of C_{206} is extended to the front panel and labeled "color shading control." Its proper setting is determined by the set user according to the color of some familiar object.

The burst amplifier stage shown in Fig. 2 appears to have no "B+" screen voltage. Instead, the grid is connected to a special winding on the horizontal output transformer and from this point it receives periodic positive pulses. These pulses are timed to arrive with the color bursts and possess sufficient amplitude to drive the tube into conduction. R_{201}, R_{202}, and C_{201} serve as a phase shifting and shaping network to insure that only the color burst passes through the stage. The action of the network is illustrated in Fig. 3.

Color Sync Section

The entire color sync section, consisting of V_{24A}, V_{24B}, V_{28A}, V_{28B} and V_{22B} is sufficiently similar to the color sync sections discussed in previous issues of RADIO & TELEVISION NEWS not to warrant any additional explanation here. Of interest, however, is the phase shifting network, T_{204}, which provides two 3.58-mc. signals to the color demodulators which are 90° out-of-phase with each other.

The network is shown by itself in Fig. 4A. The plate of the buffer connects to the top of L_{210} and it is from this point that the *R-Y* demodulator obtains its 3.58-mc. signal. On a vector diagram of this network, then, we can use the *R-Y* vector as our starting point. See Fig. 4B. Let us call the voltage across L_{210}, E_1. This same voltage also appears across the series combination of C_{212} and C_{213} and divides across them in inverse ratio to their capacitance. Of interest is the voltage across C_{213} and this is shown as E_2 in Fig. 4B. E_2 is also the voltage which is applied across the series combination of C_{211} and L_{209}. Since this combination is resonant to 3.58-mc., whatever current flows through C_{211} and L_{209} will be in phase with E_2. This current is labeled I_2 in Fig. 4B. The voltage drop produced across L_{209} by I_2 leads the current by 90°. This is E_3 and is the 3.58-mc. voltage which the *B-Y* demodulator receives.

Of interest to the service technician is the manner in which this circuit would be adjusted. A v.t.v.m. is connected to the cathode of V_{25A}, the *R-Y* demodulator by means of a chassis test point through a 100,000-ohm isolating resistor. The ground terminal of the meter goes to the receiver chassis. With the receiver in operation, a d.c. voltage will appear at the cathode of V_{25A} because the diode is detecting the applied 3.58-mc. oscillations. This voltage will be somewhere in the neighborhood of 25 volts. The slug in L_{210} is now adjusted until the v.t.v.m. reading is maximum.

The next step is to adjust L_{209} and a moment's reflection will reveal that since C_{211} and L_{209} form a series resonant circuit, they will impose maxi-

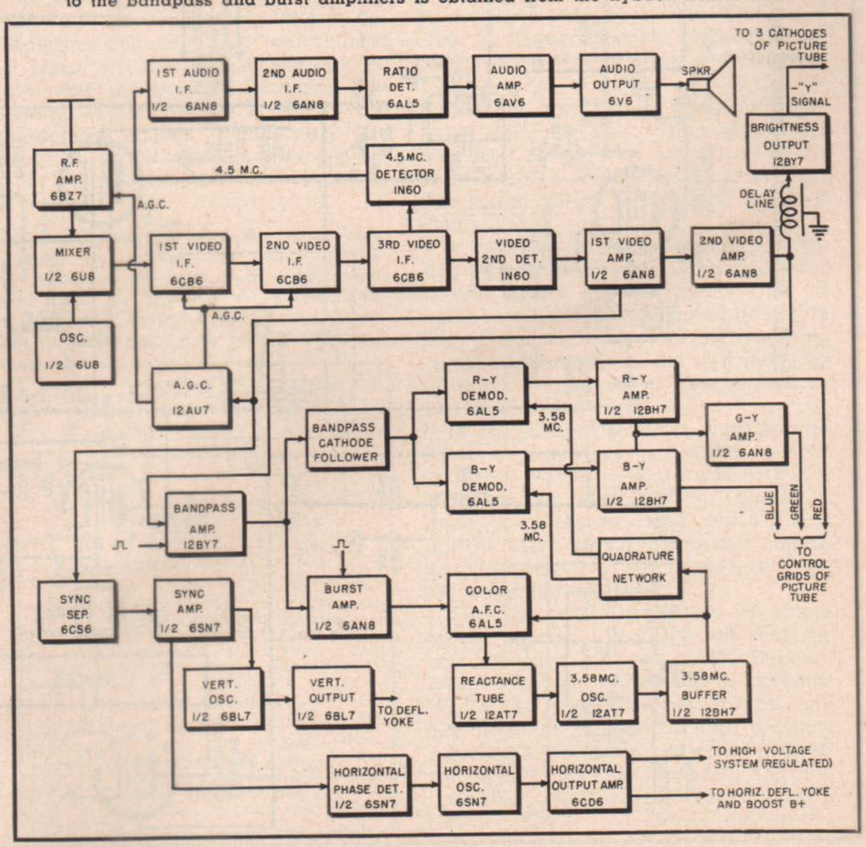


Fig. 1. Block diagram of the Motorola 19-inch color TV receiver. The pulse fed to the bandpass and burst amplifiers is obtained from the flyback transformer.

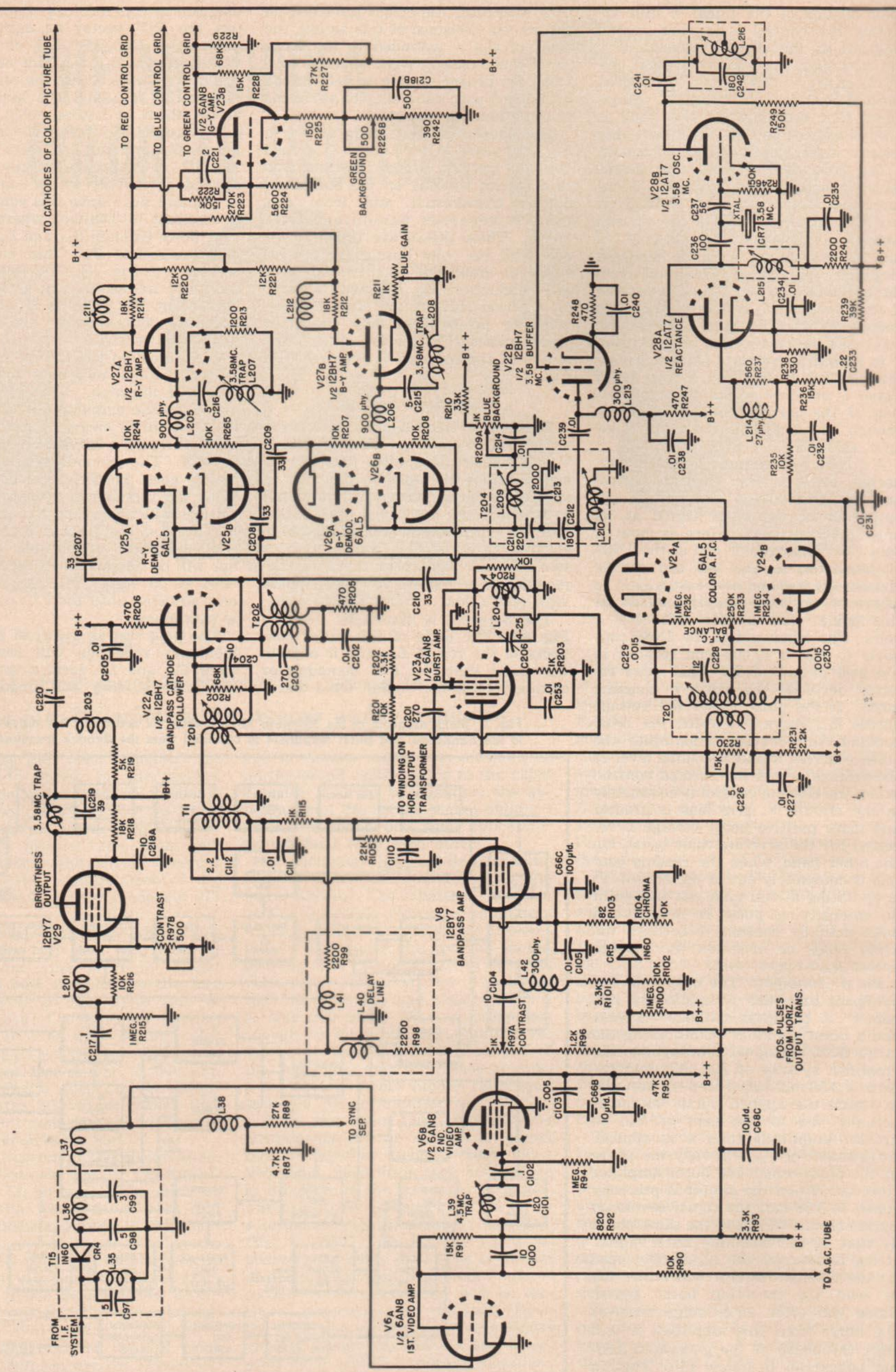


Fig. 2. Schematic diagram of the chrominance circuits of the Motorola receiver.

mum load across the rest of the quadrature network when they are tuned to 3.58-mc. Hence, the slug in L_{209} is rotated until the meter at the cathode of V_{25A} dips. To insure that the alignment is precise, the over-all procedure is repeated several times until no further adjustments are required.

Important, also, to the service technician is the manner in which the entire color oscillator a.f.c. system would be aligned. In black-and-white receivers the only a.f.c. system used is that found in the horizontal deflection section; in color sets we not only have the latter, but the a.f.c. network in the color sync section as well.

First, connect a v.t.v.m. to the cathode of V_{24A} (Fig. 2) using a 100,000-ohm isolation resistor. The meter should read approximately 12 volts of 3.58 mc. oscillator injection. (Short the control grid of V_{23A} to ground to eliminate spurious incoming signals.)

Next, remove the short circuit from the V_{23A} grid and tune in a color signal. Set the color shading control to midrange. Fully retract the slugs of the burst amplifier grid coil, L_{204}, and T_{20}, the coupling transformer to the a.f.c. circuit. Adjust both slugs for maximum v.t.v.m. readings. This insures that both diodes of the a.f.c. network are obtaining the maximum color burst amplitude.

Now, remove the burst signal by grounding L_{204}. Move the v.t.v.m. to the center arm of R_{233} and adjust this potentiometer to give a zero reading on the v.t.v.m.

Remove the short from L_{204} and adjust L_{215} in the plate circuit of the reactance tube to bring the 3.58 mc. oscillator in phase with the incoming burst. This condition is reached when the v.t.v.m. reads 0 volts, indicating that no correction voltage is being developed by the a.f.c. circuit.

Note how the diodes are used to demodulate the 3.58 mc. signal for the meter.

Color Demodulators

This receiver uses balanced diode demodulators which respond to phase differences in the incoming color signal in much the same manner as the diodes in the color sync section. As a matter of fact, both circuits are similar, as the following analysis will reveal. (The discussion will cover only the *R-Y* demodulator, since the *B-Y* demodulator is exactly similar to it).

The incoming color sidebands appear across transformer T_{202} and both *R-Y* diodes receive equal and oppositely-phased portions of this voltage. See Fig. 2. The connection of the two transformer windings is placed at a.c. ground potential by the presence of a .01-μfd. capacitor (C_{202}).

At the other end of this circuit, a 3.58-mc. subcarrier voltage is applied from the buffer stage, linked to the 3.58-mc. crystal oscillator. If we were to draw a vector diagram depicting the phase relationship in this circuit, it would appear as shown in Fig. 5A. BC, the voltage across the first winding of T_{202}, represents the color signal applied to V_{25A}, and BD, the voltage across the second winding of T_{202}, is the color signal for V_{25B}. At the same time, the 3.58-mc. subcarrier is present across L_{210} and it assumes the vector position BA.

Tube V_{25A}, then, is subjected to voltages BC and BA, producing a combined voltage which, in Fig. 5A, is labeled "Resultant No. 1." V_{25B} and its circuit produces "Resultant No. 2." In the case shown in Fig. 5A, both resultant voltages are equal and since they develop equal and opposite voltages across their respective load resistors, R_{241} and R_{265}, the net output voltage from the circuit will be zero.

(If the current path through R_{241} and R_{265} appears somewhat obscure, remember that each 33-μμfd. capacitor (C_{207} and C_{208}) charges up whenever V_{25A} and V_{25B} conduct and then the capacitors discharge through the load resistors during each half cycle when the diodes do not conduct.)

Zero output is obtained when the incoming color sideband voltages are 90° out-of-phase (i.e., in quadrature) with the injected 3.58-mc. subcarrier voltage. In the *R-Y* demodulator this, of course, will happen when the *B-Y* color sidebands are applied to it. However, for *R-Y* signals, the phase relationship is other than 90° (or 270°) and output voltages are obtained. See the resultants in Figs. 5B and 5C. These represent the demodulated *R-Y* color voltages and their sum is transferred to the following *R-Y* amplifier through a 3.58-mc. trap.

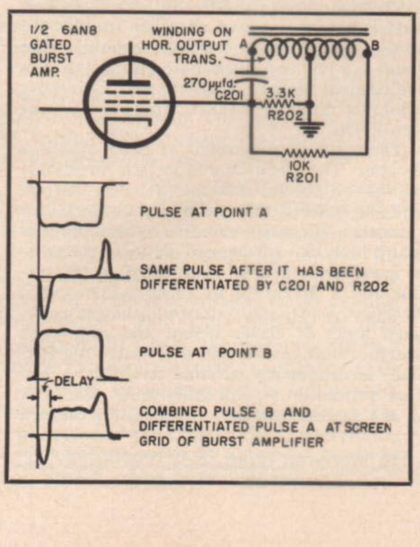
The polarity of the signal voltages which are obtained from these demodulators depends upon two things: the phase of the applied subcarrier signal and the manner in which the incoming signal voltage is fed to the demodulator diodes. Concerning the subcarrier signal, this can be applied to its respective demodulator either possessing the proper phase or 180° from this position. When the latter condition holds, we obtain $-(R-Y)$ from the demodulator instead of *R-Y*. The same action is true of the *B-Y* demodulator.

A reversal in signal output polarity will also be obtained if the connections to the diodes are reversed. Thus, if you examine the two demodulators in Fig. 2 you will note that the incoming signal connections to the *B-Y* demodulator are the reverse of the connections to the *R-Y* diodes.

In the present receiver, both sets of detectors produce negative output voltages, that is, $-(R-Y)$ and $-(B-Y)$. Reversal to the positive phase is achieved by separate *R-Y* and *B-Y* amplifiers after which these two signals are transferred to the control grids of the color picture tube.

For the proper rendition of colors on the screen, it is important that the two diodes comprising each demodulator be balanced as closely as possible. While the circuit is not critical and small circuit unbalances due to parts tolerances will not noticeably affect the color reproduction, still any appreciable unbalance will have a very marked effect. *(To be continued)*

Fig. 3. In order to key the burst gate amplifier on correctly to coincide with the arrival of the color burst, the keying pulse from the flyback transformer must be delayed. Shown below is the phase shift network used and how it performs.



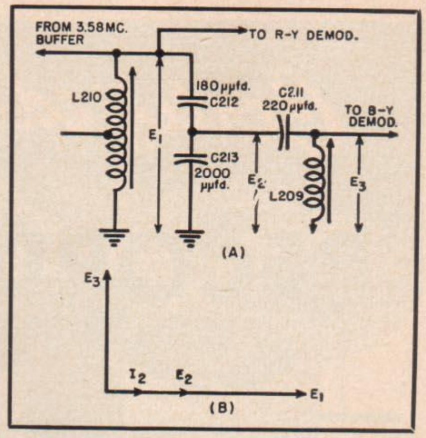


Fig. 4. (A) Simplified version of the quadrature network (T_{204} in Fig. 2) and (B), the phase relationships of the voltages in this network for demodulators.

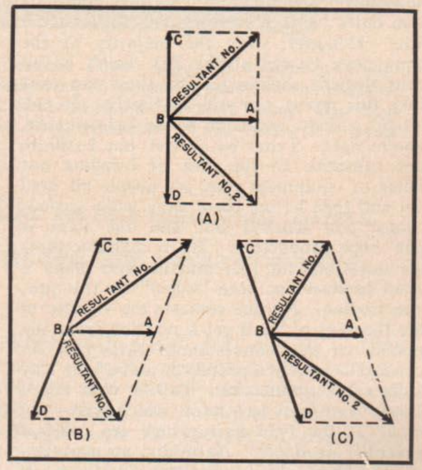


Fig. 5. Vector diagrams illustrating the operation of the diode color demodulators.

THE MOTOROLA 19" COLOR TV RECEIVER

By
M. S. KAY

Part 2. Sweep and convergence circuits of this first commercial large screen color TV set; also CRT circuits.

IN LAST MONTH'S article we covered the signal circuits of the *Motorola* color television receiver, from the antenna to the cathode and three control grids of the picture tube. In this article we will concentrate principally on the deflection and convergence circuits and on the color picture tube itself.

Deflection Systems

The deflection systems of a tri-gun color television receiver possess a marked similarity to the deflection systems of monochrome receivers. The same type of deflection waveforms are required at the deflection yoke and these are produced in more or less the same manner. Circuit variations that do exist stem primarily from the altered requirements of the high-voltage supply or because of the added precautions needed to maintain the three beams in close convergence over the entire area of the screen. Just what these differences are will become evident as we analyze, step-by-step, the deflection system of the *Motorola* color television receiver.

In the vertical section there is an integrating network, a blocking oscillator, and an output amplifier. The incoming sync pulses, both horizontal and vertical, are applied to the integrator network but, because of the time constant involved, only the vertical sync pulses develop a sizable voltage at the grid of the blocking oscillator. The latter, in turn, uses these periodic pulses to synchronize its frequency to that of the received broadcast. A vertical hold control helps bring the oscillator frequency to a point where effective lock-in can be achieved.

The amplitude of the deflection wave developed by the oscillator is governed by the vertical size (*i.e.,* height) control. The saw-tooth shape of this wave is established by a time-constant network in the output circuit of the vertical oscillator. This signal is then applied to the grid of the vertical output amplifier and, beyond this, to the vertical deflection coils of the yoke.

The only significant departure from monochrome practice is the fact that the bottom end of the vertical output transformer connects to a vertical convergence circuit. More on this presently.

In the horizontal sweep system there is an a.f.c. network, a stabilized horizontal multivibrator, and a power output amplifier. These are then followed by the horizontal output transformer, the high-voltage system, and the boost "B+" circuit, wherein additional "B+" voltage is developed by utilizing the excess deflection energy. (The latter portion of the circuit is shown in Fig. 1.)

The final stage in the horizontal deflection system is a 6CD6 power output amplifier. The power requirements of the final stage in a color receiver are greater than for a comparable monochrome receiver because, first, three beams must be deflected instead of one and, second, a 25 kv. accelerating voltage is required by the tri-gun picture tube.

The horizontal output transformer contains two principal windings and a number of auxiliary windings. The two principal windings provide connections for the plate of the 6CD6, the high-voltage rectifiers, the deflection yoke, and the 6AU4 damper tube. The auxiliary windings provide positive and negative triggering pulses for the various a.g.c. and chrominance circuits, and filament power for the high-voltage rectifiers. In the circuit of Fig. 1, three high-voltage rectifiers are employed to develop the 25 kv. accelerating potential required by the tri-gun picture tube.

The accelerating potential required by the focus electrode is much less than the 25,000 volts of the *Aquadag* coating. Hence, it is possible to obtain the focus voltage from a prior point in the high-voltage rectifier system. A variable resistor is inserted between the first 3A2 and the diode coupler that follows it, and from this resistor the needed focus voltage is obtained.

Within the same high-voltage supply is a special gaseous regulator. The unit, labeled CR6, is a long, narrow cylinder which is filled with hydrogen gas. The purpose of this device is to maintain a constant load on the high voltage power supply so that changes in picture contrast will not cause the high voltage to change, with corresponding variations in brightness, focus, and deflection (*i.e.,* picture size). What the regulator tube does, in essence, is vary its internal resistance in a manner opposite to the current drawn by the picture tube. For exam-

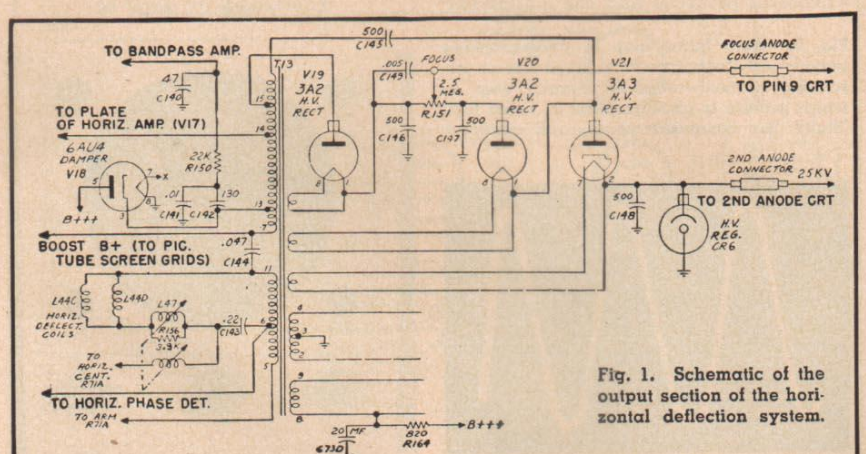


Fig. 1. Schematic of the output section of the horizontal deflection system.

ple, when a bright element is being traced out on the screen, picture tube current is high and the drain on the high-voltage power supply is increased. During this interval the drain of the regulator tube is reduced by a proportionate amount.

Conversely, when a darker portion of the picture is being traced out, the current requirements of the picture tube are reduced. This reduction would tend to cause the high voltage to rise were it not for the fact that now the regulator tube increases its current drain, thereby maintaining a constant overall load on the power supply.

The damper tube in the output circuit absorbs whatever excess energy is developed during the horizontal retrace interval and converts this into an equivalent amount of voltage which is then combined with the receiver "B+" to provide a boosted "B+" voltage. In the circuit of Fig. 1 this boosted "B+" is employed only by the plate of the 6CD6 horizontal output amplifier and by the screen grids of the picture tube.

Electrical centering is usually employed with the tri-gun color picture tube. For this purpose there are vertical and horizontal centering potentiometers, each with enough d.c. potential difference across it to achieve the picture centering variation.

Convergence Circuits

The one remaining section of a color television receiver still to be examined is the convergence circuit. Convergence, it will be recalled, is the action which causes the three electron beams to pass through the same hole in the aperture or shadow mask at the same time. When the beams do this, they emerge from the mask at the correct angle to strike the dots of the proper color.

At the center of the screen, beam convergence is accomplished by physically tilting the electron guns inward as well as by external, individually adjustable, beam-bending magnets. The adjustment of beam convergence at the center of the screen is known as static convergence.

There is, in addition, dynamic convergence and this is concerned with maintaining the beams in proper convergence at points away from the center. The need for this arises from the fact that the shadow-mask surface is not completely spherical and therefore does not follow the curve necessary to keep the beams converged at all points. To correct this condition, we must introduce an additional voltage which will change the convergence point of the beams as they sweep over the face of the screen, both from side to side and up and down. At the center of the screen no additional convergence voltage is needed. The shape or form of the voltage best suited to achieve this variation is a parabolic wave.

The dynamic convergence system consists of three separate coils mounted on the neck of the picture tube. Each coil is positioned over a pair of pole pieces which is part of the structure of each electron gun. The internal pole pieces shape and confine the fields so as to affect only the particular electron beam to which the individual pole pieces correspond. Each beam will be moved at right angles to the magnetic field produced by the coils. Furthermore, since the guns are spaced at intervals of 120 degrees from each other, the red and green beams will be shifted at an angle while the blue beam will move straight up and down.

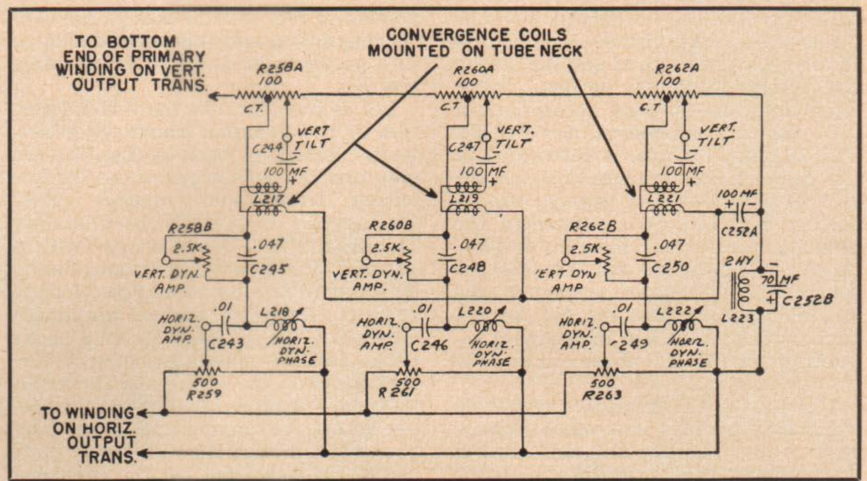


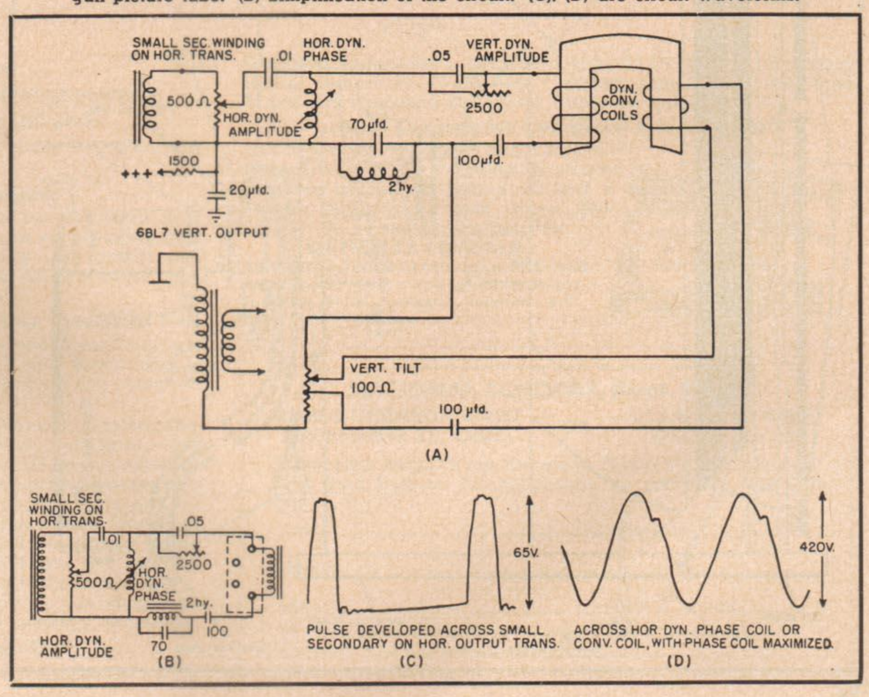
Fig. 2. Schematic diagram of the dynamic convergence circuit used by Motorola.

Each of the foregoing coils is supplied with vertical and horizontal parabolic currents and it is the amplitude and phase of these currents which govern the convergence of the three beams at every point on the screen. In the paragraphs to follow the dynamic convergence circuit of the *Motorola* will be examined. See Fig. 2.

Driving voltages for this circuit are obtained from two points—the plate circuit of the vertical output amplifier and from a separate winding on the horizontal output transformer. Let us start with the horizontal section of this circuit first.

A simplified diagram of the convergence network is shown in Fig. 3A and if we consider the operation solely in terms of the horizontal line frequency, then the diagram can be further simplified to the form shown in Fig. 3B. A pulse having an over-all amplitude of 65 volts is made available at the horizontal output transformer winding. The portion of the pulse which the rest of the network receives is governed by the arm setting of the horizontal dynamic amplitude control. Whatever value of pulse the control picks off is then used to shock-excite a series resonant circuit formed by the .01 μfd.

Fig. 3. (A) The horizontal and vertical dynamic convergence circuit for a single convergence magnet. There are three of these mounted on the neck of the three-gun picture tube. (B) Simplification of the circuit. (C), (D) are circuit waveforms.



capacitor and the horizontal dynamic phase coil. The circuit is tuned to 15,750 cycles per second and the strong circulating currents develop fairly large sine-wave voltages across each of the resonant components. See Fig 3D. This voltage, in turn, is forwarded to the dynamic convergence coils on the picture tube neck and through the resulting magnetic field, influences the electron beams which the guns develop. So far as the 15,750 cps voltages are concerned, the .05 μfd. capacitor, the 70 μfd. capacitor, and the 100 μfd. capacitor all present low impedances between the horizontal phase coil and the convergence coil.

The horizontal dynamic amplitude control determines how much voltage reaches the convergence coil and, in consequence, how powerful a magnetic field is developed. The phase of the 15,750 cps sine wave depends upon the adjustment of the phase coil. Changing the frequency of the circuit by adjusting the phase coil slug will vary the phase of the voltage applied to the convergence coil. This, in turn, will change the deflection angle of the electron beam and thereby alter its point of convergence with the other two beams as they move from left to right across the screen. Thus, it is possible to change the beam convergence at the sides of the screen permitting us to counteract the normal misconvergence of the beams. Each beam has a similar convergence circuit and responds in a similar way.

One further point concerning this circuit. The series resonant network develops a sine wave instead of a parabolic wave. However, only the bottom portion of the wave is used in the converging action and this is close enough to a parabola in shape to do an effective job.

Let us consider now the vertical portion of the dynamic convergence network. Referring back to Fig. 3A, we note that the bottom end of the vertical output transformer reaches "B+" through the vertical tilt potentiometer (100 ohms), a 2 henry choke (with a parallel 70 μfd. capacitor), and finally a 1500 ohm resistor. The flow of plate current (from the vertical amplifier) develops a voltage across the 2 henry choke and the subsequent flow of current between the choke and its parallel capacitor produces a parabolic voltage across the combination. What happens here is that the saw-tooth plate current is converted *via* the capacitor (principally) into a parabolic wave and this voltage is applied across the convergence coil. The path from the choke and the 70 μfd. capacitor to the convergence coil consists of a 100 μfd. capacitor, the horizontal dynamic phase coil, and the parallel combination of a .05 μfd. capacitor and a 2500-ohm potentiometer. At the vertical sweep frequency of 60 cycles, the horizontal dynamic phase coil and the 100 μfd. capacitor offer negligible opposition. The vertical current, however, finds that the opposition of the .05 μfd. capacitor is high and, so, the current is driven through the 2500-ohm potentiometer. The latter, then, rightfully becomes the vertical dynamic amplitude control.

Still required is some method of varying the phase of the vertical dynamic convergence voltage and this is achieved through the presence of another winding on each convergence coil. This is the so-called tilt coil, the word tilt referring to the effect which its voltage has on the vertical parabolic wave.

The method of developing the required tilt (or phase) voltage is quite simple. The saw-tooth plate current of the vertical output amplifier flows through a 100-ohm potentiometer. The control contains a center tap and the movable arm may be moved above or below this tap. When the arm position is above the tap, the saw-tooth voltage fed to the tilt coil possesses one polarity; when the arm is below the tap, the polarity is reversed. Finally, no saw-tooth voltage is fed to the tilt coil when the arm and center tap coincide. In other words, a saw-tooth of variable amplitude and with positive or negative polarity may be added to the electron beam. The net effect of this is to add the saw-tooth to the vertical dynamic parabola voltages to shape them as required for best convergence in the vertical plane.

External Picture Tube Components

We come now to the components which are mounted on the neck of the 19-inch tri-color picture tube. See Fig. 4. The first item that we recognize is the deflection yoke. This is, to a considerable extent, similar to the deflection yokes used with black-and-white tubes. However, its design is more complex because three beams must be deflected instead of one and it is of the utmost importance that a symmetrical and uniform magnetic field be maintained throughout the deflection area. Also, the deflection power required is about twice that of present black-and-white TV sets (for the same size screen) and special insulation must be employed in the yoke structure to prevent arcing.

A second component found on the neck of the color picture tube is the purity coil or magnet. This device adjusts the axis of each electron beam so that it approaches each hole in the shadow mask at the right angle to strike the appropriate color phosphor dot. In other words, the purity magnet provides for the proper alignment of the three beams with respect to the phosphor-dot plate and the shadow mask. When this component is properly set, a uniform color field will be obtained for each gun. For example, with only the red gun in operation a uniform red raster should be observed. Any departure from pure red at any point on the screen indicates that the beam is striking phosphor dots other than red. Similarly, when only the green gun is in operation, a uniform green raster should be obtained, and when only the blue gun is active, a blue field should be visible.

The color tubes with which we are most concerned utilize magnetic convergence and toward that end employ three sets of convergence coils, each positioned directly over the pole pieces

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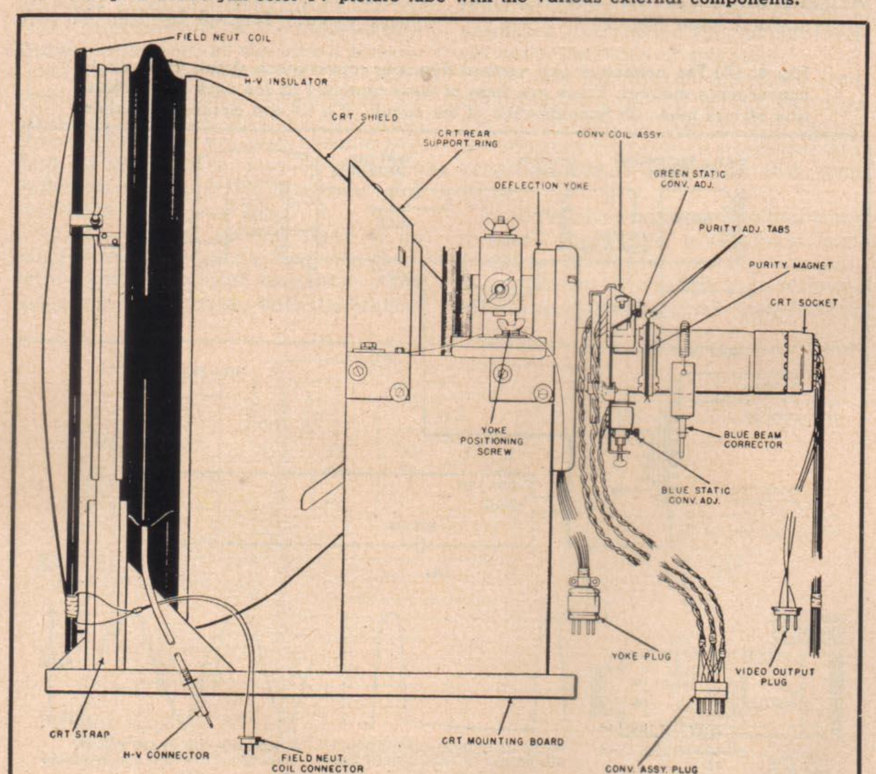
Fig. 4. Three-gun color TV picture tube with the various external components.



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which are internally associated with each grid No. 4. The magnetic fields set up by the coils are coupled through the glass neck of the tube to the internal pole pieces which serve to shape and confine the fields so as to affect only the particular electron beams to which the individual pole pieces correspond. For example, the change in convergence angle of the red beam is a function only of the current through the external coil which couples to the internal set of pole pieces adjacent to the red beams. Likewise, the currents through the green and blue external magnets affect respectively only the green and blue beams.

Each external coil possesses two separate windings to provide for horizontal and vertical dynamic convergence correction. For the static convergence adjustment, each coil has associated with it a small permanent magnet whose position can be varied.

A diagram of the individual static convergence magnets is shown in Fig. 5A. The heavy dots represent the individual electron beams as they pass through the gun on their way to the screen. The arrows at these beams indicate their direction of movement. Note that the red and green beams are confined to paths which make an angle of 60 degrees on either side of a vertical axis. The blue beam, on the other hand, can only move vertically, up or down.

Now it could readily happen that while the color dots of the green and red beams fall within the same trio, that of the blue beam does not. This means that while we can always cause the red and green beams (or color dots) to converge, it may not be possible to have the blue beam meet the other two. Still required is another adjustment, that of being able to move the blue beam from side to side (or laterally). To effect this, a special blue beam positioning magnet is also found on the neck of the tube. See Fig. 4. Now perfect convergence of the three beams at the center of the screen is always possible.

Note that no ion traps are used in this tube, principally because the color screen is aluminized. The layer of aluminum presents a barrier to any oncoming ions and prevents them from reaching and damaging the screen. Electrons, having only 1/1800th of the mass of an ion, encounter little difficulty in passing through this aluminum layer.

We would like to thank the *Motorola* Service Department for its cooperation in the preparation of this series. Particular thanks are due Mr. T. M. Alexander and Mr. Frank Uhrus.

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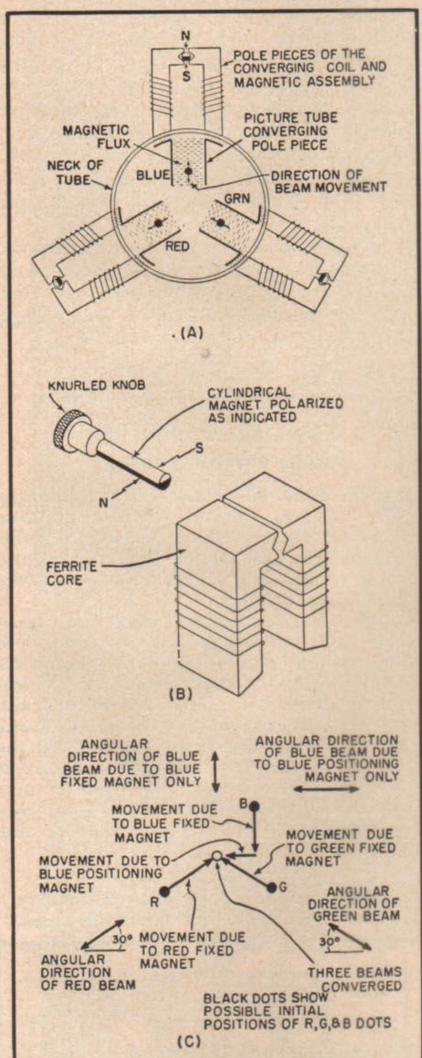
Fig. 5. (A) External and internal convergence components of the CRT. (B) Detailed drawing of the convergence coil and magnet assembly. (C) Effect of the three fixed magnets and the blue positioning magnet on the three CRT beams.



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Courtesy of Charlie Trahan