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PRACTICAL CIRCUITS FOR COLOR TELEVISION

Part IV. Adder and Output Circuits, D-C Restoration, Sweep Circuits, High Voltage and Dynamic Convergence.

As described in the preceding issue, individual red, blue and green signals are developed in the matrix section. These signals, which correspond to the camera output signals at the transmitter, are fed through separate channels to the No. 1 grids (control electrodes) of the three-gun color CRT. Figure 1 shows the circuit in block diagram form.

Also shown in figure 1 are the circuits that provide deflection voltages, focus and convergence potentials and high voltage. These circuits require special attention and will be described later in this article. Since the a-g-c, sync, a-f-c, vertical multivibrator and horizontal multivibrator circuits are patterned after conventional design for black-and-white receivers, they require no special explanation and are not shown on the drawing.

Adder and output circuits — The adder and ouput stages are simply amplifiers that raise the color signal amplitudes to the required levels at the CRT grids. A signal of approximately 100 volts peak-to-peak is required at the grid of the red gun. The blue and green guns operate with about 70 volts peak-to-peak applied signal. Higher voltage is applied to the red grid because the efficiency of the red phosphor applied to the CRT viewing screen is less than that of the blue and green phosphors.

Although chrominance information is limited to 1.5 mc in the I channel and .5 mc in the Q channel, the adder and output stages must pass frequencies up to approximately 3.2 mc. This is true because the Y signal, which contains frequencies up to about 3.2 mc, is mixed with the I and Q signals in the matrix. The color signals applied to the adder stages therefore contain frequencies as high as those in the Y channel.

It was pointed out in the preceding issue that the ground return for each of the matrix sections is through a cathode resistor. Figure 2 shows the circuits involved. The ground return for the green matrix is through C1, R1, and R4. The return for the blue matrix is through C2, R2 and R5, and the red matrix returns to ground in a like manner. Note, however, that the green and blue matrices have an additional parallel ground return through the green and blue gain controls and R7, while the red channel does not include a gain control.

The effect of the additional resistance in the green and blue circuits is to decrease the total resistance in the return circuits. Since the ground return circuits represent the bottom leg of a voltage divider, and anything that reduces the total resistance in the leg causes a decrease in output voltage, less signal is applied to the green and

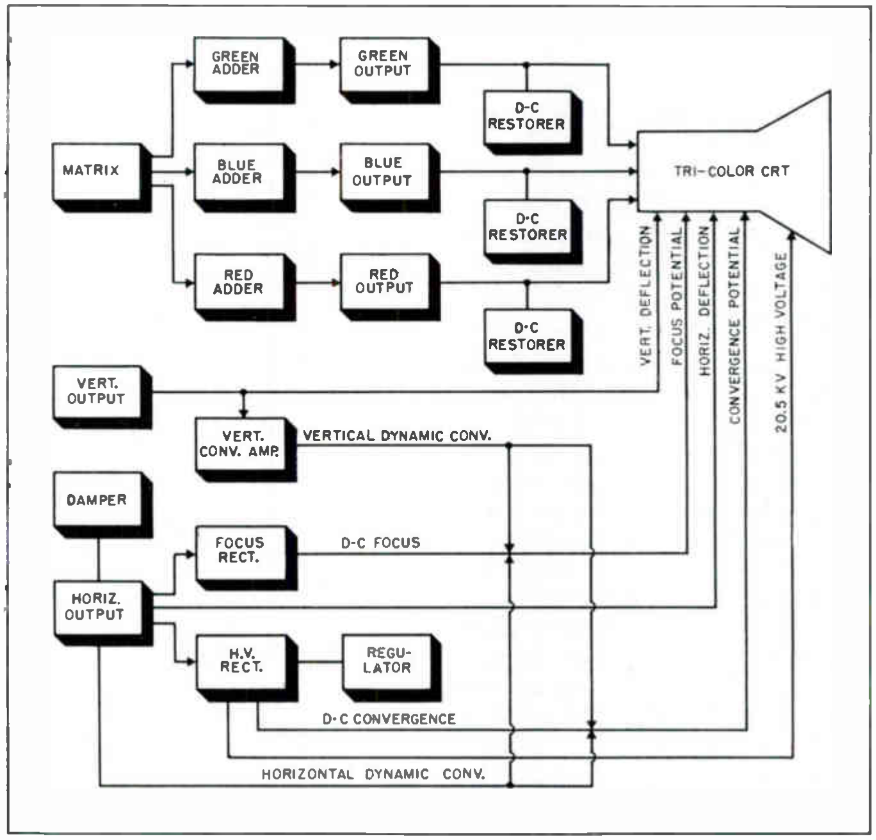

Figure 1. Block diagram of circuits to be described.

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blue adders than to the red adder. The gain controls allow the green and blue signal levels to be adjusted to approximately 70% of the red level in accordance with the relative phosphor efficiencies.

So far as the matrix operation is concerned, the return circuits could be routed directly to ground rather than through cathode resistors. However, by connecting them to the cathode resistors, a convenient degenerative feedback loop is formed. The voltages at the cathodes of the output stages are 180° out of phase with the voltages applied to the adder grids. By feeding cathode voltage from the output stages back to the grids of the adder stages (through R1 in the green channel, R2 in the blue channel and R3 in the red channel), degeneration is obtained. The cathode by-pass capacitors (C4, C5 and C6) tend to shunt high frequencies to ground, reducing the amount of degeneration at high frequencies and increasing the high frequency response.

The d-c voltage developed across the cathode resistor of each output stage is also fed back to the accompanying adder grid through the feedback loop, placing a positive voltage on the adder grids. To compensate for this voltage and provide correct operating bias for the adder stage, the cathodes of the three adder stages are connected to a common cathode resistance, R7 and R8, which develops sufficient cathode bias. The cathode resistors are by-passed at signal frequencies by C7.

If the green and blue gain controls were returned directly to ground, a d-c potential would exist across the controls, leading to a noisy circuit. By properly proportioning the values of R7 and R8 so that the voltage at their junction equals the voltage at the green and blue adder grids, and returning the green and blue gain controls to the junction, the potential difference across the controls is eliminated.

The output circuits contain both shunt and series peaking coils to provide the desired response characteristics. Coupling to the CRT grids is provided by the .1 mfd capacitors, C8, C9 and C10.

D-C restorer and brightness circuits — Figure 3 illustrates the need for d-c restoration. When capacitive coupling is used between stages following the video detector, the d-c component of the signal is eliminated and the amplitude excursions vary about an average level. This condition is shown in A of figure 3. Two undesirable effects occur when a signal of this type is applied to the CRT. First, if the brightness control is properly adjusted for a bright scene, excessive brightness results when a dark

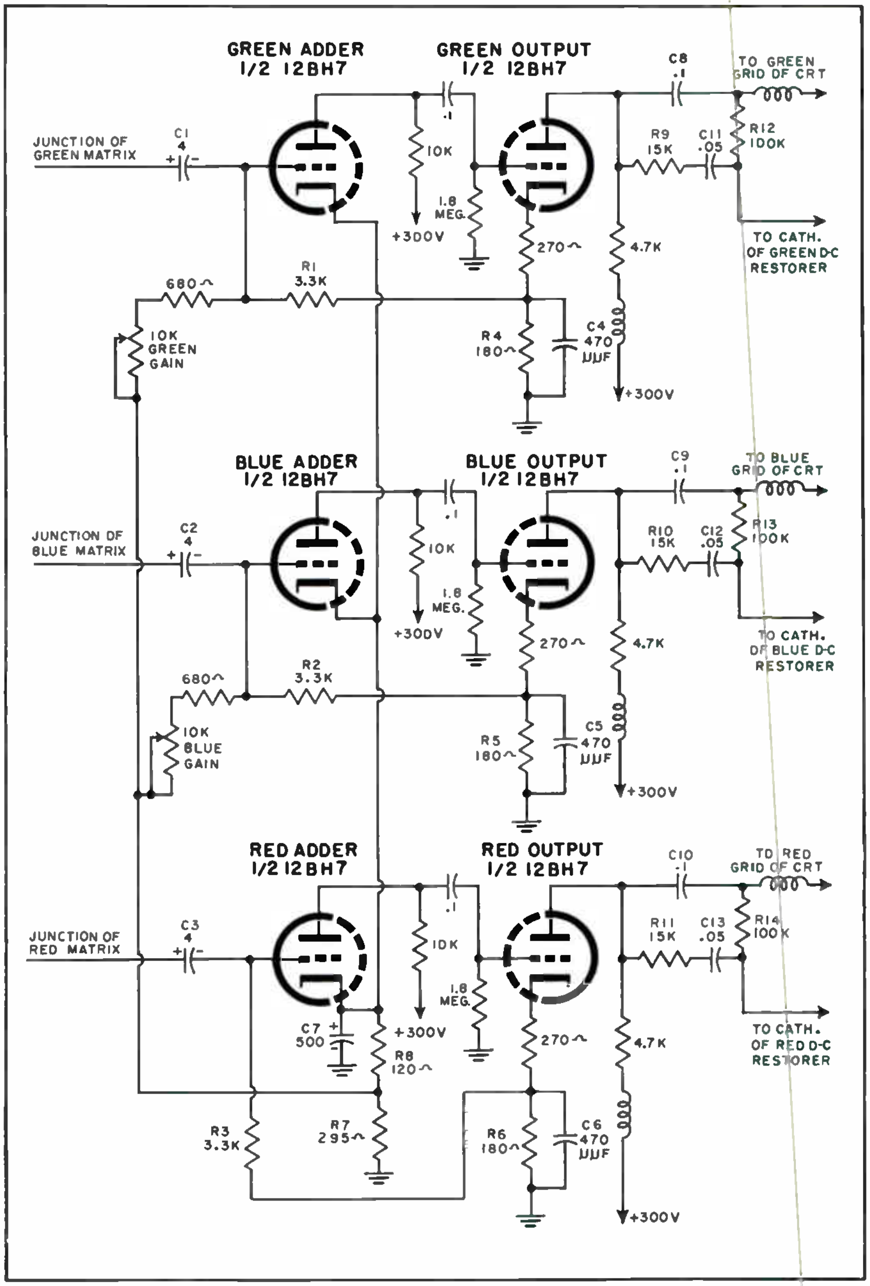


Figure 2. Adder and output stages.

scene is transmitted; if brightness is adjusted for a dark scene, insufficient brightness is obtained on a bright scene. Second, if the brightness control is adjusted for a bright scene, the blanking pulse during a dark scene does not reach the beam blanking level, and retrace lines may appear on the picture.

The desired condition is shown in B of the figure. Correct brightness for all scenes is obtained at one setting of the brightness control, and all blanking pulses reach the beam blanking level. Proper d-c restoration is more important in a color receiver than in a monochrome receiver because brightness discrepancies are more obvious in color than in shades of gray.

Figure 4 shows that the screen,

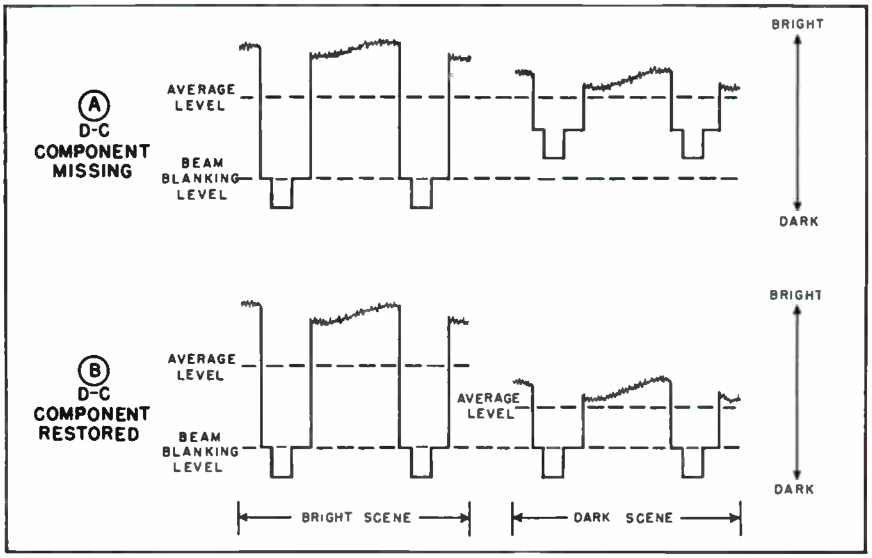


Figure 3. D-C restorer effect.

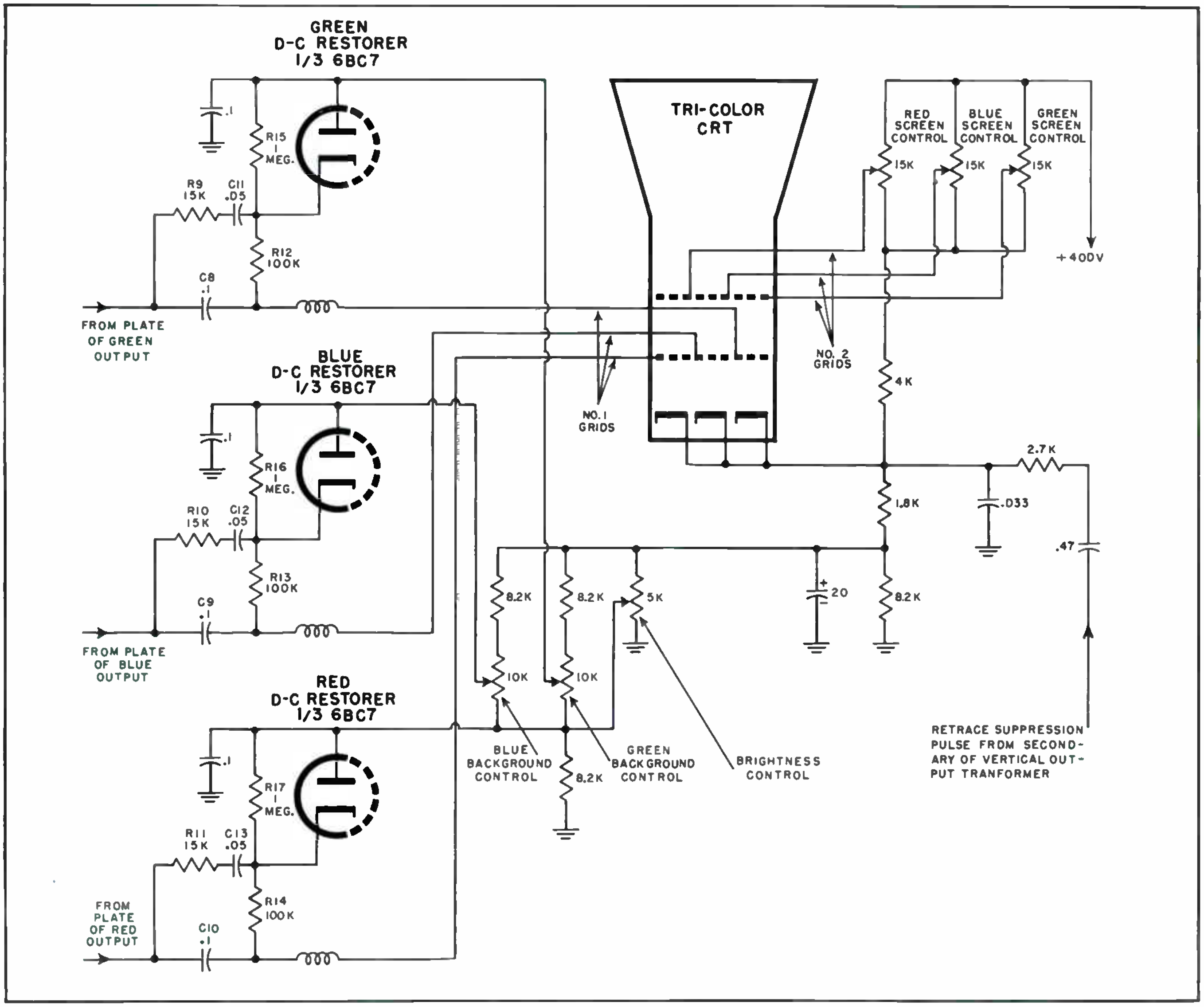


Figure 4. D-C restorer and brightness circuits.

brightness and background controls are part of a voltage divider network. The highest voltages taken from the divider are those applied to the No. 2 (accelerating) grids. The next tap supplies a positive potential for the CRT cathodes. Lower positive voltages for application to the No. 1 (control) grids of the CRT are taken from the brightness and background controls, which form part of a parallel network in the ground end of the divider. Thus, the grid-to-cathode bias for the CRT guns is determined by the setting of the brightness and background controls.

Without d-c restoration, the average signal level in A of figure 3 would correspond to the grid-to-cathode bias level, and the signal would vary about this axis. For correct operation as illustrated in B of the figure, the bias must vary with the amplitude of the signal so that the sync pulse tips are "clamped" to a common level. The bias must be made less negative for a bright scene than for a dark scene. This varying bias is provided by the d-c restorers.

Since the d-c restorer circuits are identical as shown in figure 4, confusion will be avoided by using only the symbol numbers of the green d-c restorer for reference purposes in the discussion that follows.

The signal at the plate of the green output stage is coupled through R9 and C11 to the restorer cathode. R12 provides a d-c path between the restorer cathode and the CRT grid and, at the same time, isolates the restorer from the signal circuit at video frequencies.

The signal polarity is such that the sync pulses are negative-going. When the restorer cathode is driven negative with respect to the plate, the diode conducts and C11 is charged to nearly the amplitude of the sync pulse. After the sync pulse passes and the diode cathode is positive, conduction cannot occur in the diode. C11 then discharges slowly through R15, developing a voltage across R15 that is positive at the cathode end and negative at the plate end.

It should be noted that C11 charges quickly because of the low resistance offered by the diode during conduction. On the other hand, C11 discharges slowly through the 1 megohm resistance of R15. As a result, C11 does not discharge completely between sync pulses, and the voltage developed is a fairly constant value which is determined by the amplitude and duration of the sync pulses.

Since the voltage developed across R15 is in series with the positive potential obtained from the green background control, it adds to the positive potential applied to the No. 1 grid, making the total grid-to-cathode bias less negative. The greater the sync pulse amplitude, the higher the voltage developed across R15. The bias is therefore varied in accordance with the signal amplitude, providing the necessary clamping action.

As mentioned previously, the efficiency of the red phosphor used in the CRT is considerably less than that of the blue and green phosphors. Consequently, beam current and excitation for the red gun must be greater than for the blue and green guns. The best criterion of proper adjustment in this respect is the picture obtained during a black and white transmission. With no chrominance information present at the receiver matrix, the intensity of the light given off by the three phosphors must be equal as evidenced by freedom from color tinting on the picture,

Moreover, the equality of light intensities must be maintained over the full range of brightness control settings. In other words the intensities must "track". To equalize the intensities at *high* brightness control settings, the screen controls are adjusted to provide the correct accelerating potentials for the No. 2 grids. The blue and green background controls, which determine the amount of bias applied to the blue and green No. 1 grids, are adjusted for equal light intensities at *low* brightness control settings.

The brightness circuit is designed so that the bias applied to the red grid changes more with a given rotation of the brightness control than does the bias for the blue and green grids. This, in conjunction with the high and low end adjustments, provides proper tracking .

Tri-color CRT requirements — Control of the electron beams is complicated by the fact that three electron guns are used in the tri-color CRT. The CRT requirements can best be realized by considering the makeup of the tube.

Figure 5 shows the elements of a tri-color CRT in schematic form. It will be observed that each electron gun has three elements that are independent of the other two guns. They are the cathode, control grid and accelerating grid. The functions of these elements are the same as in a monochrome CRT.

The next element of each electron gun is the No. 3 grid which provides for electrostatic beam focus. The three focus grids are connected internally so that all beams are focused simultan-

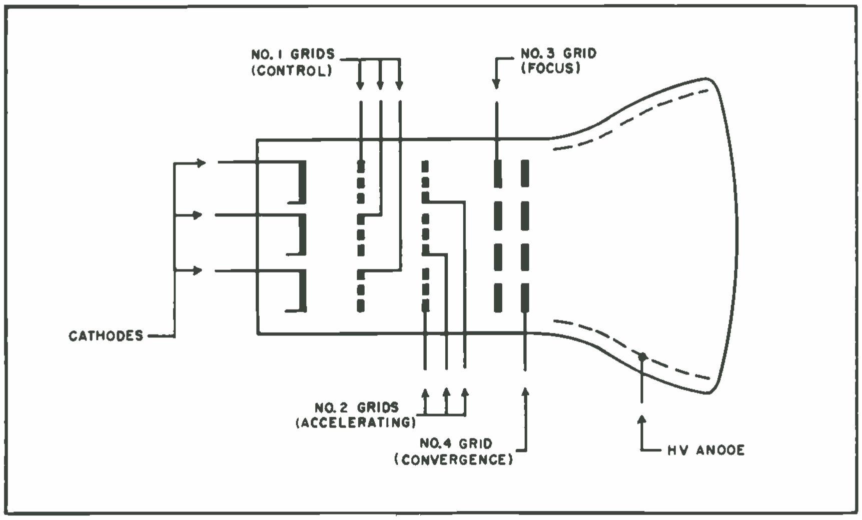


Figure 5. Elements of a tri-color CRT.

eously. As will be described later, the voltages that must be applied to these grids to provide proper focus are somewhat complex.

The last grid of each electron gun is termed the No. 4 grid or convergence electrode. Like the No. 3 grids, the three convergence electrodes are connected together internally so that the same convergence potentials are applied to all three. Here again, complex voltages are required to provide proper beam convergence over the entire viewing area.

Figure 6 shows why complex voltages are required to provide proper focus and convergence. The illustration assumes that d-c voltages are applied to the focus and convergence grids and that the applied voltages provide correct focus and convergence *at the center of the viewing area.* The expanded view of the center of the screen (B) shows the three electron beams passing through the shadow mask aperture and striking the phosphor dots correctly.

Assume now that the beams are deflected to the edge of the raster. Since the d-c voltage applied to the convergence grid makes the three beams converge at a given distance from the end of the electron guns, beam convergence follows an arc which has the point of deflection as its center. The shadow mask does not follow this arc. Consequently the beams converge before they reach the shadow mask and strike around the shadow mask aperture. Thus the phosphor dots on the faceplate are either not excited or improperly excited depending on the degree of mis-convergence. This is shown by the expanded view of the edge of the screen (A) in figure 6.

The d-c voltage applied to the focus grid results in proper beam focus at only one given distance from the electron gun also. Therefore, without the application of a-c correction voltages, defocusing is encountered as the beam is deflected away from the center of the screen and the electron path to the phosphor deposits becomes longer.

To compensate for these effects and thereby obtain correct focus and beam convergence over the entire viewing area, the voltages applied to the focus and convergence grids are made to increase as the beam is deflected away from the center of the screen. This is accomplished by developing two a-c voltages that are parabolic in shape, one at a repetition rate of 59.94 cps (the vertical sweep frequency) and the other at 15,734 cps (the horizontal sweep frequency), and applying them to the d-c focus and convergence voltages. The resultant waveform is shown in figure 7. The circuits that supply these voltages will be described later.

Horizontal output circuit — As indicated by figure 8, the load circuit of the horizontal output stage is basically a flyback system. Two 6CD6 tubes in parallel are used to supply the heavy load requirements. Boosted plate voltage for the horizontal output tubes is developed by the damper circuit which uses a pair of 6AU4 tubes in parallel. The boosted voltage is not fed to other circuits as is the case in many monochrome receivers.

A straight-forward sweep circuit is employed, with the horizontal windings of the deflection yoke tapped across a portion of the transformer primary through capacitors. Chokes L1 and L2 isolate the yoke windings from the horizontal centering circuit at the sweep frequency, but allow the centering circuit to apply either a negative, positive or zero d-c voltage across the yoke windings as required for centering.

Included as parts of the load circuit are the pulse takeoff points, the high voltage rectifier and regulator and the focus rectifier. As indicated on figure 8, the focus rectifier circuit is conventional. A variable voltage divider is used to provide for adjust-

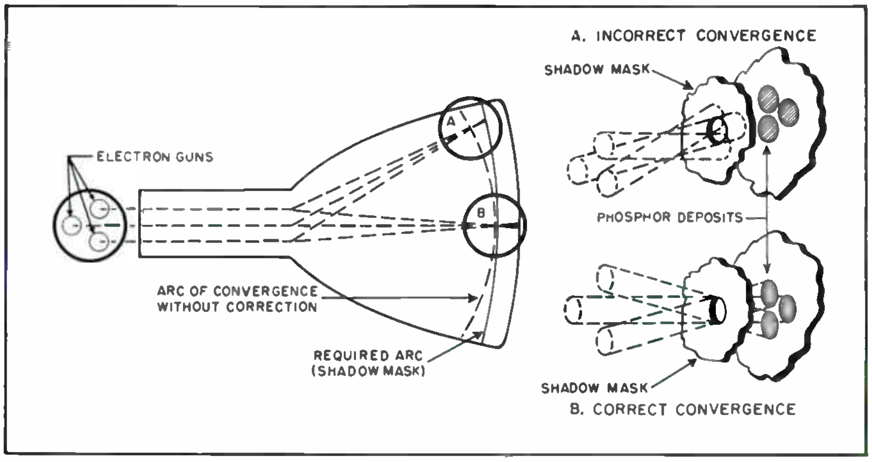
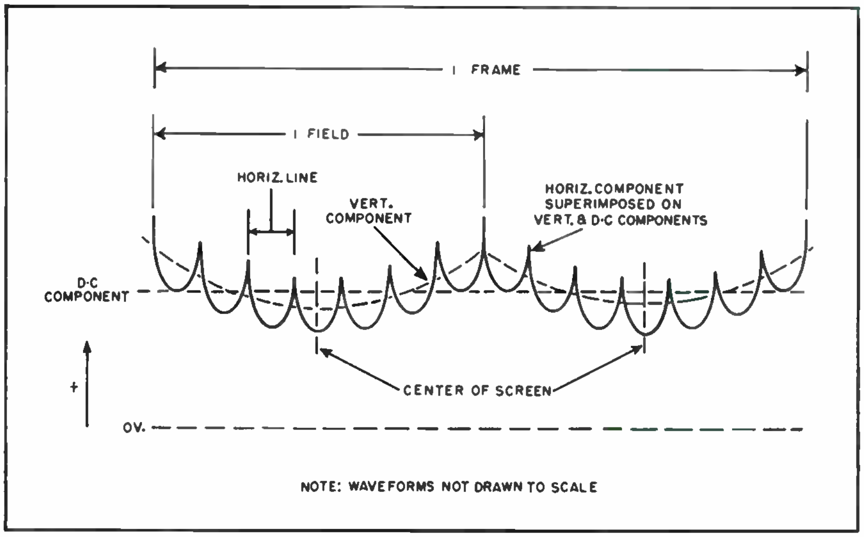


Figure 6. Illustration of the need for dynamic convergence voltages.



NOTE: WAVEFORMS NOT DRAWN TO SCALE

Figure 7. Addition of vertical and horizontal dynamic convergence voltages to a d-c potential.

ment of the d-c focus potential. The high voltage rectifier circuit is also conventional, providing about 20.5 kv to the CRT anode. A high resistance voltage divider is connected between the output of the high voltage rectifier and ground. From this divider, the d-c convergence voltage is taken.

The 6BD4A high voltage regulator tube maintains an essentially constant 20.5 kv potential at the CRT anode despite changes in loading. Its plate is connected to the 20.5 kv line, and 400 volts d-c is applied to its cathode. A portion of the high voltage is applied to its grid through the HV control. It is apparent that any conduction in the regulator tube represents a load on the high voltage supply. The HV control is adjusted so that the regulator conduction represents sufficient load to bring the high voltage to 20.5 kv. If the load presented by the CRT decreases (as during a dark scene), the high voltage tends to increase greatly. But since this increases the positive potential on the regulator grid, increasing conduction and causing the regulator to present a heavier load, the high voltage increases only slightly. The opposite occurs when the CRT load increases as during a bright scene.

Vertical output—In addition to supplying sweep voltages to the deflection yoke, the vertical output stage is required to furnish excitation to the vertical convergence amplifiers. Except for this additional requirement, the vertical sweep circuit operates in the conventional manner. Figure 9 shows the circuit. Observe that a series centering circuit is employed to provide the required d-c centering voltage across the yoke windings.

Vertical dynamic convergence — The parabolically shaped voltage required for correct beam convergence, when the beams are deflected vertically, is available across C1, located at the "low" end of the vertical output transformer primary winding (see figure 9). This voltage is applied through C2 and R1 to the vertical convergence amplitude control. Also applied to the amplitude control are two sawtooth voltages that are obtained from the vertical output stage. One (waveform A on figure 9) is taken from the grid circuit, and the other (waveform B) is developed in the plate circuit. These voltages are applied to opposite ends of the shape control, so that the control setting determines the relative amplitudes of the sawtooth voltages applied to the amplitude control. For example, with the shape control set at position 1, the signal applied to the amplitude control contains more A component than B component. At posi-

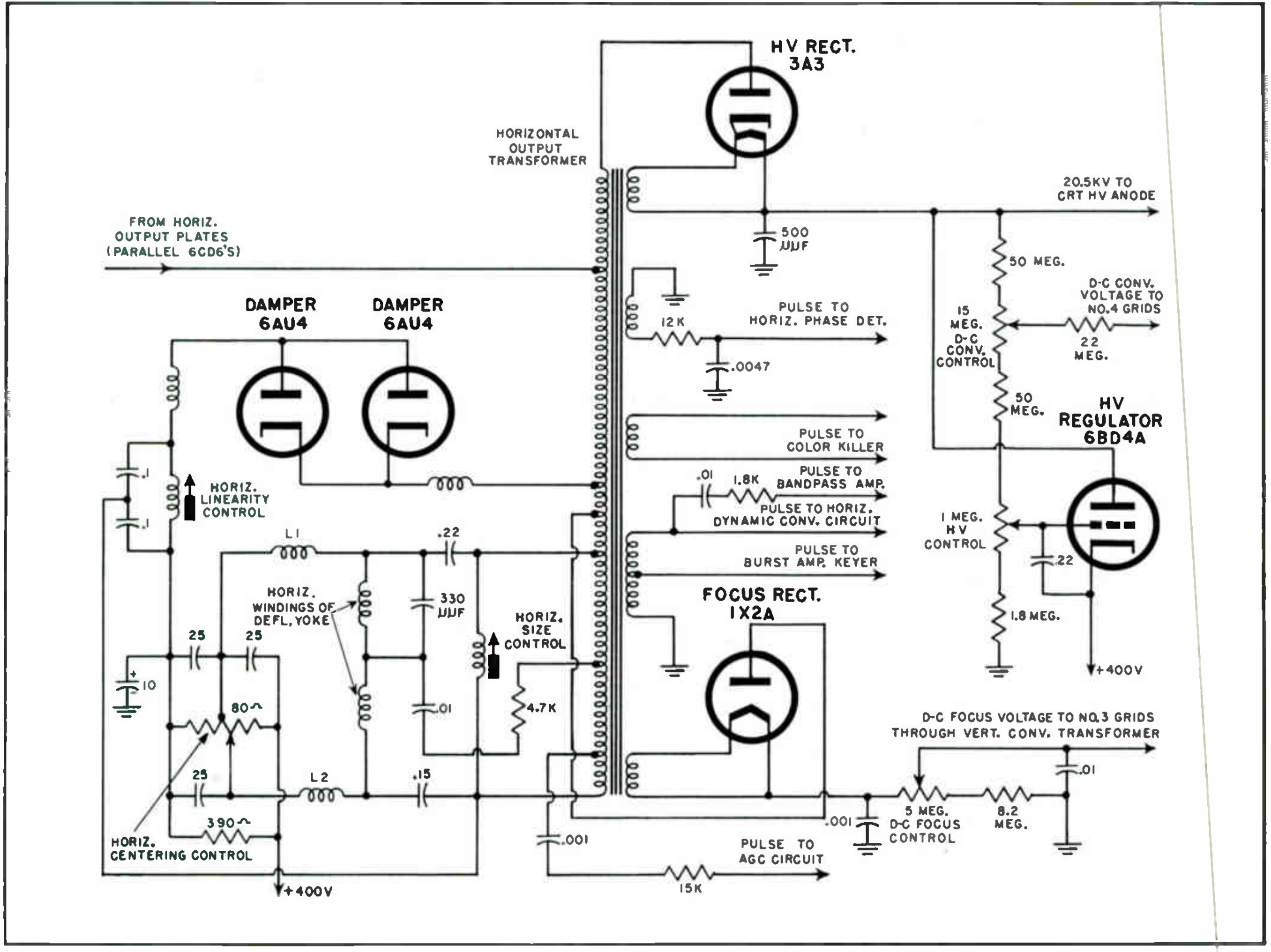


Figure 8. Horizontal output load circuit.

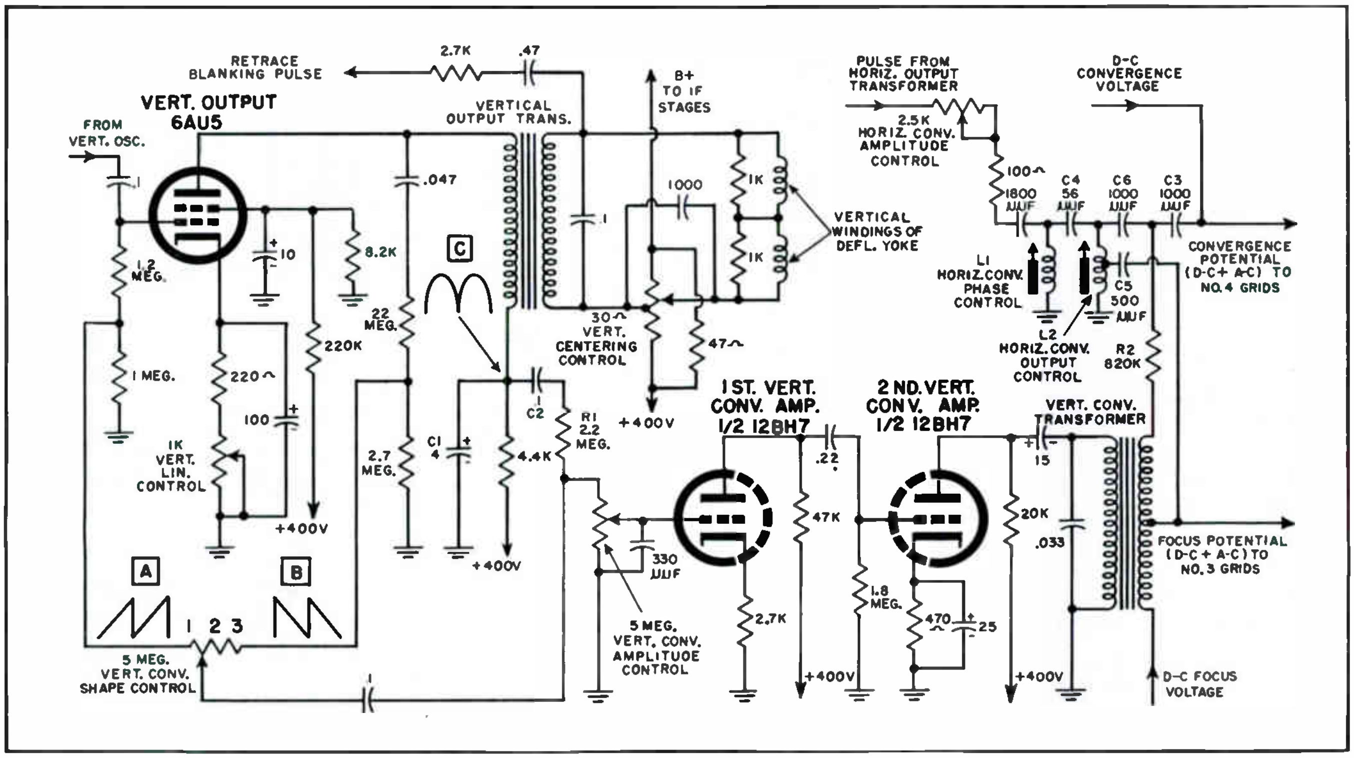


Figure 9. Vertical output stage and dynamic convergence circuits.

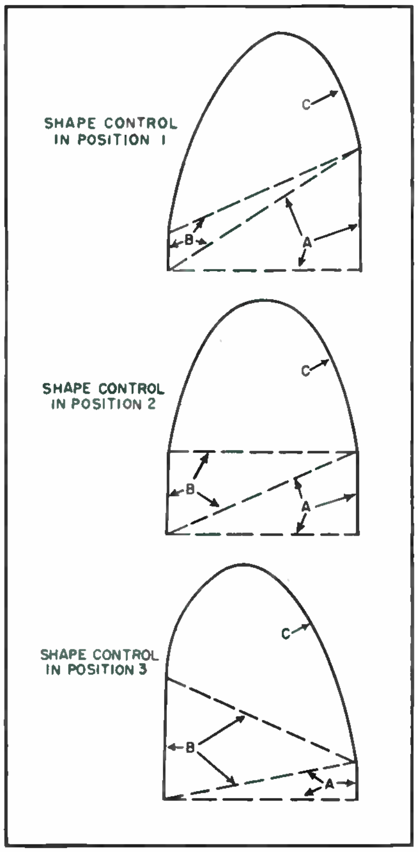


Figure 10. Vertical dynamic convergence waveforms. Control positions and waveform components are shown in figure 9.

tion 3, the B waveform predominates, and at position 2, the sawtooth amplitudes are approximately equal.

The two sawtooth voltages and the parabolic voltage combine across the vertical convergence amplitude control. Figure 10 illustrates the additive effect for three different sawtooth relationships. Observe that the shape of the resultant varies as the shape control is rotated. This provides compensation for irregularities in tubes and components.

The desired amplitude of this dynamic convergence voltage is obtained through the amplitude control and applied to the two-stage vertical convergence amplifier. After amplification, the signal is applied to the d-c focus voltage which is fed through the secondary of the vertical convergence transformer. The signal is also applied to the d-c convergence voltage through R2 and C3.

Horizontal dynamic convergence — As shown in figure 9, a pulse from the horizontal output transformer is applied to the resonant circuit formed by L1 (horizon convergence phase control), L2 (horizontal convergence output control) and C4. The "flywheel" effect of the resonant circuit results in the formation of an a-c voltage that is shaped approximately like a sine wave (see figure 11). For practical purposes, this voltage is sufficiently like the desired parabolic waveform and fulfills the dynamic convergence requirements.

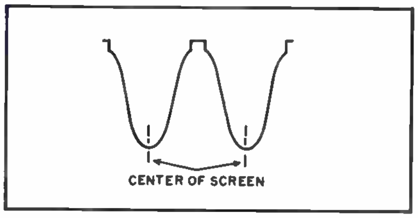
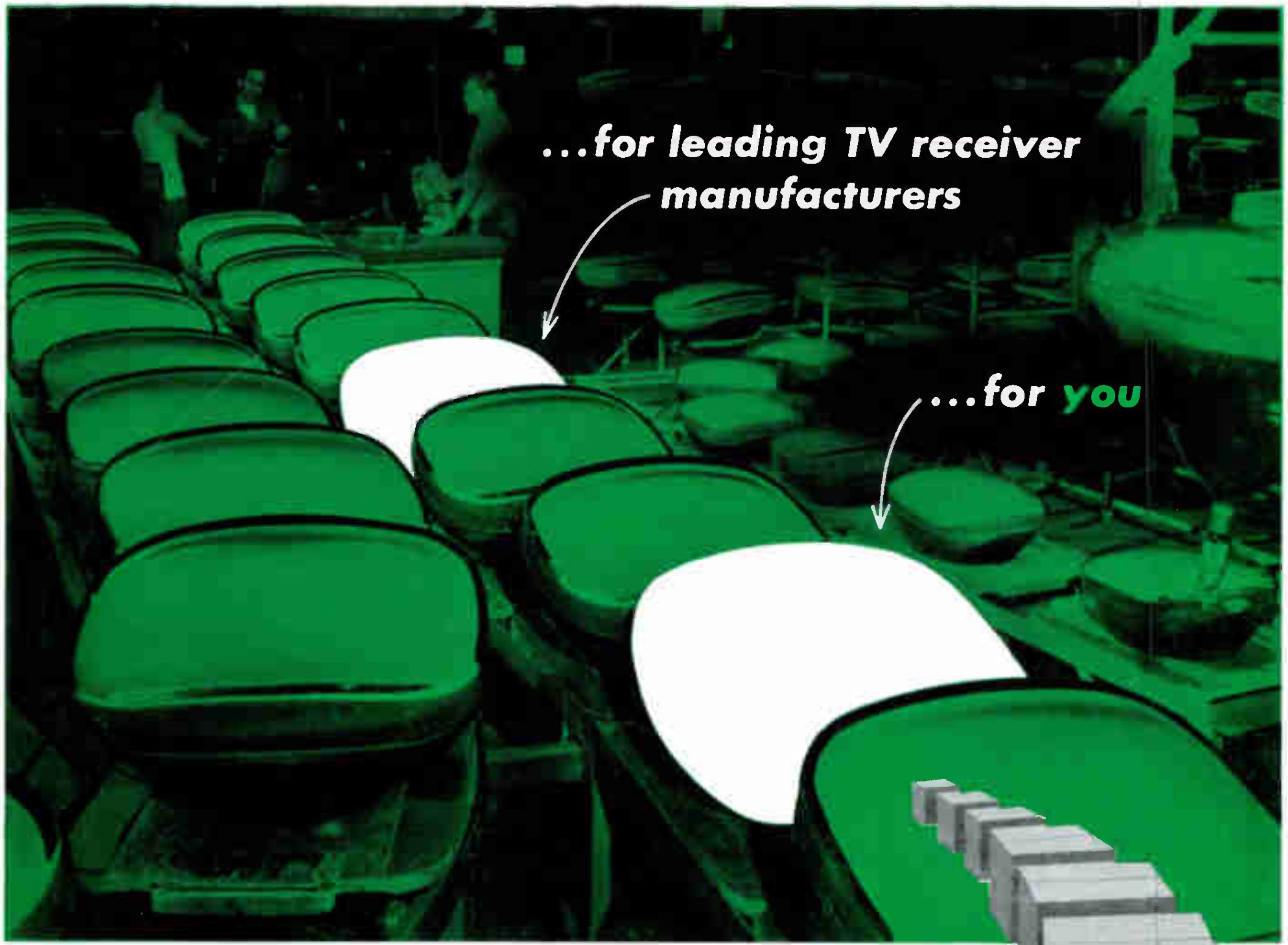


Figure 11. Horizontal dynamic convergence waveform.

The waveform amplitude is adjusted by the horizontal convergence amplitude control, and its phase is controlled by the phase control. A portion of the voltage across L2 is applied through C5 to the focus electrodes, and the entire voltage across L2 is applied through C6 and C3 to the convergence electrodes. These voltages serve to keep the electron beams in correct focus and convergence as the beams are deflected horizontally.

This concludes the discussion of "Practical Circuits for Color Television." Color servicing techniques will be discussed in future articles.



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