LB-959

# HIGH-LEVEL TRIODE COLOR DEMODULATOR

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RCA LABORATORIES DIVISION

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**Approved**

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## Introduction

This bulletin describes a high-level demodulator for use in color television receivers. It provides adequate output to drive the kinescope directly. It has good linearity and good d-c stability with changes in drive and supply voltages. In addition, its performance is virtually independent of tube characteristics so no drift (either short-term or long-term) in the chroma output will be experienced until the demodulator tube characteristics have deteriorated seriously. The demodulator tubes are used as switches and will continue to act as switches as long as the tubes have sufficient emission.

The high output and good stability characteristics of this demodulator make it possible to build simpler and more stable color television receivers than heretofore been possible.

In this bulletin two practical applications of the demodulator are described. Both are of the equal bandwidth type. One uses three triodes as demodulators providing R-Y, B-Y and G-Y outputs by demodulating on these axes. The other is simpler, using only two triodes as demodulators producing R-Y and B-Y from the plates and G-Y from a common cathode impedance.

## General Discussion

There are three basic methods of applying chroma information to a color kinescope. The demodulated color information can be added to the luminance information, amplified, and then d-c restored at the kinescope grids. In another method, low-level demodulators can be used, followed by d-c amplifiers which are d-c coupled to the kinescope grids. In the third method, high-level demodulators can be used which are directly d-c coupled to the kinescope grids.

This third method is the simplest but it requires a demodulator having high output with good linearity and a high order of stability. The demodulator must be capable of providing a linear output approximately 50 per cent greater than the maximum luminance drive. It must have good d-c stability with changes in its operating conditions, and a conversion efficiency which is relatively independent of the tube parameters. A demodulator meeting these requirements as does the one described here may be expected to provide more stable and reliable performance than the more complicated first two methods.

## Principle of Operation

Fig. 1 shows the basic circuit of the plate-modulated triode demodulator. The grid circuit is self-biased and driven with sufficient voltage to assure class C operation. The grid resistor is made low enough to insure adequate peak plate currents for peak rectification.

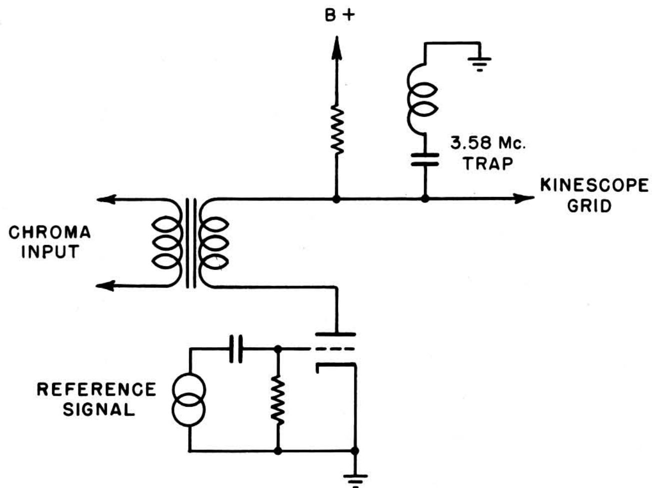


*Fig. 1 - Basic triode demodulator.*

The circuit may be looked upon as a grid-controlled rectifier. Without any chroma voltage at the plate the high peak plate currents bring the average plate voltage down to some low value. Relatively independent of the plate voltage applied, the circuit continues to bring the plate voltage during conduction to approximately this same value by virtue of its clamping action. Thus if it is assumed that the instantaneous plate voltage during the conduction of the triode is a fixed value, the demodulated output voltage will be equal to the p-p chroma signal as the relative phase of grid and plate signals goes from 0 degrees to 180 degrees. However, the plate voltage during conduction must change somewhat to change the average plate current. This is similar to the action of a diode peak rectifier wherein the plate-to-cathode voltage during conduction must change slightly with increasing signal. The amount of voltage change required to produce a given current change depends upon the perveance, and indicates the degree of departure from 100 per cent efficiency.

Fig. 2 shows the chroma input signal across the transformer secondary, the demodulator plate signal, and the filtered color difference signal for in-phase and quadrature signals. As is shown, for the in-phase signal, depending on whether it is 0 degrees or 180 degrees from the grid signal, the chroma signal is clamped at the peak or minimum of the signal with the resultant demodulated output. For the 90-degree signal, the demodulator always conducts at a point where the sine waves are going through zero resulting in no demodulated output signal. As can be seen from the photographs, there is a 3.58-Mc c-w signal on the demodulator plates in addition to the chroma input signal. This signal is a result of the fundamental component of the demodulator plate current flowing through the transformer secondary. The effect of this signal is merely to shift the d-c plate potential without affecting the demodulator operation since its amplitude is unvarying and its relative phase is constant with respect to the demodulator grid signal.

The demodulated output is taken from the cold side of the transformer secondary across the video load. The 3.58-Mc trap removes the 3.58-Mc signal from the demodulated output and provides a low-impedance return for the demodulator plate currents. Although this trap removes the 3.58-Mc c-w signal from the output, it does not remove the higher harmonic signals which are developed in this class C device. An additional filter should be placed between the demodulated output and the kinescope grids to prevent these higher harmonics from radiating.

The effective driving impedance of the demodulator is in the order of 4000 ohms, which, associated with the circuit capacitance, gives sufficient bandwidth without any additional peaking being required. In general, the chroma band-pass amplifier will be the band-limiting device, with the demodulator bandwidth being greater than 1 Mc.

## Application

Fig. 3 shows a method of applying the demodulators to a color receiver using kinescope adding. The appropriate phase of sampling signal is applied to the grids. The differential gains required for R-Y, B-Y and G-Y are provided in the relative turns ratios of the transformer secondaries. Since the transformer has relatively high coupling coefficients, and the demodulators have high rectification efficiencies, the relative outputs are stably determined by the transformer turns ratios. The outputs are each d-c coupled to each of the kinescope grids. Since the receiver employs equal luminance drive to all guns, an equal voltage change on all kinescope grids will result in a brightness change only, with no

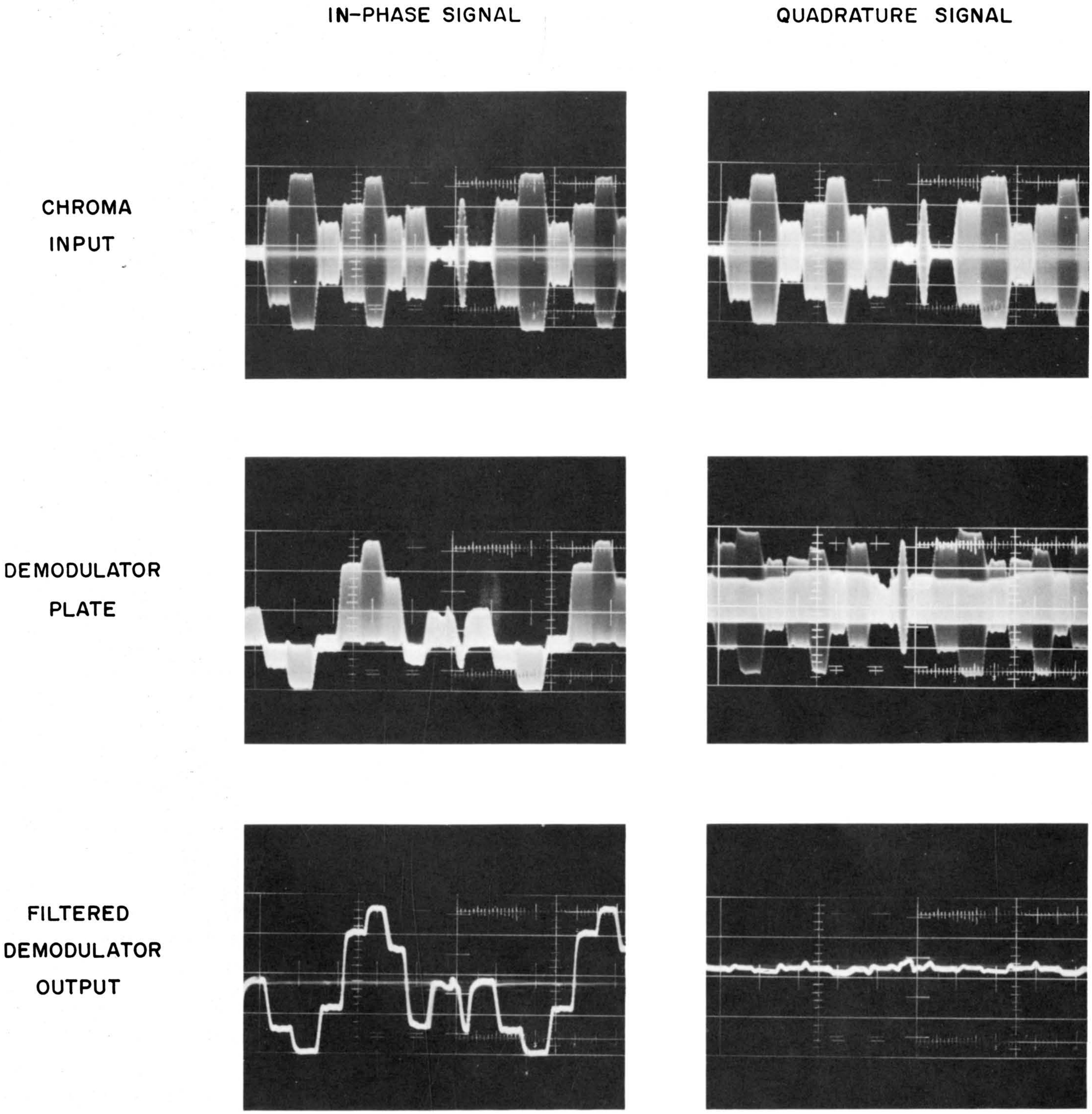


*Fig. 2 - Demodulator waveforms.*

change in the neutral grey scale. Because all the tubes have the same grid drive and the same loads, any variation in the plate voltage due to changes in grid drive caused by drift or aging merely changes the overall brightness which is easily compensated for with the background control.

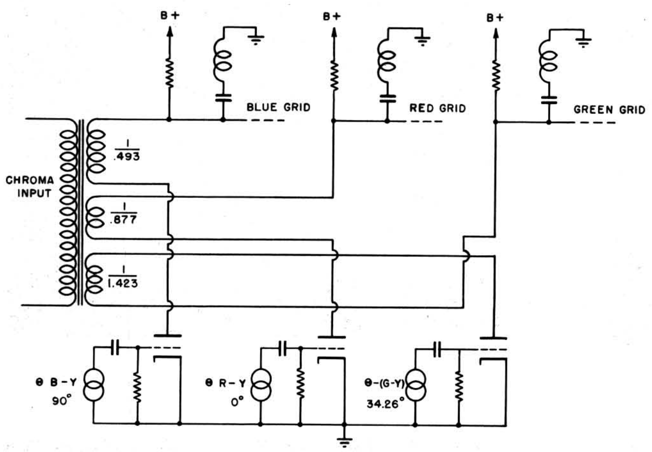


*Fig. 3 - Three-triode demodulator supplying the color difference signals.*

Fig. 4 shows a more economical demodulator circuit which requires only two triodes. This circuit takes advantage of the fact that the G-Y signal requirements are the smallest of the three color difference signals, and that G-Y can be made up of the negative of R-Y and B-Y (G-Y = -0.51 R-Y -0.19 B-Y). The G-Y signal produced in the cathode circuit subtracts from the B-Y and R-Y signals produced in the plate circuit. Therefore, sufficient chroma drive must be applied to the plates to produce the cathode signal as well as the plate signal. Thus, approximately 20 per cent more B-Y and 35 per cent more R-Y chroma drive must be applied in order to obtain G-Y from the cathode.

The three load resistors are adjusted to give the correct ratio of color difference signals. To eliminate the cross talk between R-Y and B-Y which would normally exist due to the common cathode impedance, the R-Y and B-Y sampling angles are moved toward each other from their quadrature position to cancel out the introduced cross talk. An exact analysis follows.

Let $i_1$ = current in R-Y demodulator

Let $i_2$ = current in B-Y demodulator

$$(i_1+i_2)\,R_k = G-Y = -0.51\,(R-Y) - 0.19\,(B-Y)$$

$$i_1R_1 = R-Y$$

$$i_2R_2 = B-Y$$

Let $R-Y = 0$

$$i_2R_2 = B-Y$$

$$i_2R_k = 0.19\,(B-Y)$$

$$\frac{R_2}{R_k} = \frac{1}{0.19} = 5.23$$

Let $B-Y = 0$

$$i_1R_1 = R-Y$$

$$i_1R_k = 0.51\,(R-Y)$$

$$\frac{R_1}{R_k} = \frac{1}{0.51} = 1.96$$

$$\therefore R_2:R_1:R_k = 5.23:1.96:1$$

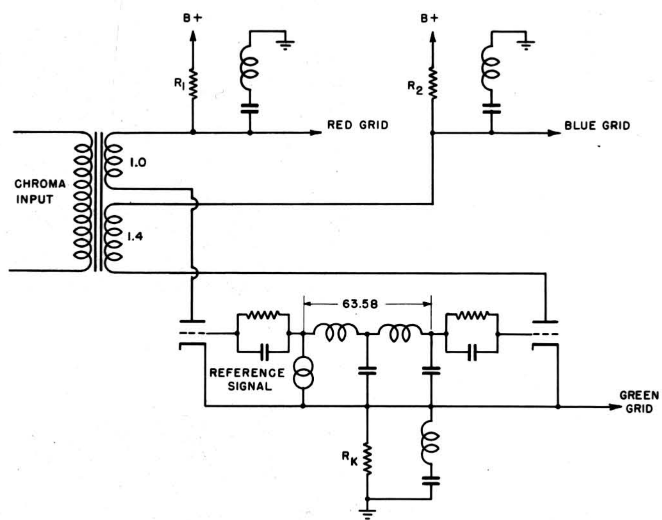


*Fig. 4 - Two-triode demodulator.*

Assuming that the demodulators are perfect switches and have 100 per cent rectification efficiency:

Let $e_1$ = voltage applied to R-Y plate

Let $e_2$ = voltage applied to B-Y plate

$$e_1 = (G-Y) - (R-Y)$$

$$e_2 = (G-Y) - (B-Y)$$

$$G-Y = -0.51\ (R-Y)\ -0.19\ (B-Y)$$

$$e_1 = -1.51\ (R-Y)\ -0.19\ (B-Y)$$

$$e_2 = -0.51\ (R-Y)\ -1.19\ (B-Y)$$

$$e_1 = 1.51 \times 1.14\ \left(\frac{R-Y}{1.14}\right)\ -0.39\ \left(\frac{B-Y}{2.03}\right)$$

$$\tan\theta = \frac{0.39}{1.72} = 0.266\quad \theta_1 = 12.95 \text{ degrees}$$

$$e_2 = -0.51 \times 1.14\ \left(\frac{R-Y}{1.14}\right)\ -1.19 \times 2.03\ \left(\frac{B-Y}{2.03}\right)$$

$$= -0.582\ \left(\frac{R-Y}{1.14}\right)\ -2.42\ \left(\frac{B-Y}{2.03}\right)$$

$$\tan\theta_2 = \frac{0.582}{2.42} = 0.24\quad \theta_2 = 13.47 \text{ degrees}$$

$$\theta_3 = 90^\circ - \theta_1 - \theta_2 = 90^\circ - 26.42 = 63.58 \text{ degrees}$$

$$e_1 \cos\theta = 1.72$$

$$e_1 = \frac{1.72}{\cos 12.95^\circ} = 1.765$$

$$e_2 = \frac{0.582}{\sin 13.47^\circ} = 2.50$$

$$\frac{e_2}{e_1} = \frac{2.50}{1.765} = 1.415$$

Therefore, with the load resistor sizes in the prescribed ratio, with the plate drives in about the relative ratio of 1.4 to 1, and with the grid drives 63.58 degrees apart, the proper signals will be obtained.

An interesting aspect of this application comes about upon inspection of the demodulation angles. The angle of the R-Y demodulator is in quadrature with the pure blue (not B-Y) signal, and the angle of the B-Y demodulator is in quadrature with the pure red signal. Thus upon transmission of a blue bar there is no current change in the R-Y demodulator and vice versa. This situation is readily understood by analyzing the drive requirements during a blue bar. The plate of the B-Y demodulator must go positive, adding to the luminance signal and further turning on the blue gun. The red and green grids, however, must go equally negative to cancel the same amount of luminance signal. Thus, the plate and cathode of the R-Y tube must move in the negative direction by an equal amount. This necessitates no current change in the R-Y demodulator. The same situation would exist with a pure red bar where the plate and cathode of the B-Y demodulator would have to move equally.

As in the three-triode case, the demodulated outputs are d-c coupled to the kinescope grids. In this arrangement, any change in the plate-to-cathode voltage will appear as a differential brightness voltage between guns. No such differential variations will exist and the system will be stable if the plate-to-cathode voltage remains constant with incidental changes in grid drive and if the tubes have sufficient current capability to act as efficient switches. This situation is aided by the class C nature of the demodulators. Thus, as the grid drive increases, the peak currents rise and the conduction angle goes down tending to maintain relative constant average current. Almost all triodes used in this circuit showed relatively constant plate voltage within the range of grid drives used. Some even displayed relatively constant plate voltage all the way down to zero. Fig. 5 is a curve of plate voltage vs grid drive for various triode types.

To assure that the demodulated components at all frequencies are distributed according to the load resistor ratios, the time constants must be made equal. A simple method of accomplishing this is to use minimum capacitance on the B-Y load, and to increase the capacitance of the 3.58-Mc traps in the R-Y and G-Y loads to make the time constants equal.

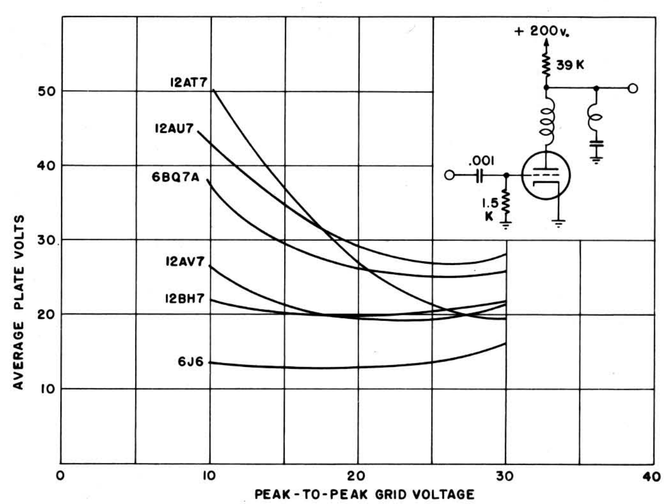


*Fig. 5 - Variation of average plate voltage with grid drive.*

## Operational Details

The triodes operate best when they conduct at that part of the characteristics where the plate voltage vs plate current curve is steepest. Although it is not at all critical, for each value of supply voltage there is an optimum value of load resistor to obtain the most desirable operating point.

Since the plate voltage during conduction is only about 25 volts, the conduction is primarily determined by the grid current conduction angle; that is, almost independent of μ, when the grid voltage goes slightly below zero bias the tube cuts off. The conduction angle is then determined by the grid driving impedance, and the grid-leak resistance. As the grid resistor is decreased and conduction angle increases, the linear output range is reduced. In other words, when conducting over a wide angle the demodulator becomes somewhat dependent on the linearity of the plate-voltage vs plate-current characteristic. When the grid resistor is increased the conduction angle gets small but the peak current is reduced to the point where it may be incapable of rapidly discharging the output capacitance, resulting in poor frequency response. Using a type 12BH7, a 300-ohm driving source, and a grid resistor of 3.3K, the linearity will be excellent and the frequency response such as to be limited only by the chroma band pass preceding the demodulators.

Since these triode demodulators are efficient peak detectors, their output voltage being dependent on the chroma input and not on any tube characteristics as such, no differential controls are needed to adjust for the various gains of R-Y, B-Y and G-Y. A transformer is used whose secondary windings are tightly coupled to the primary, and whose turns ratios are in the proper ratio of the desired demodulated output voltages. Since the transformer ratios cannot drift, and the demodulated output is relatively independent of tube characteristics, color fidelity is assured without any differential controls.

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