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DIRECT DRIVE HORIZONTAL SCAN SYSTEM

by Robert R. Thalner

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DIRECT DRIVE HORIZONTAL SCAN SYSTEM

By

Robert R. Thalner*

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Horizontal output circuits for some time have been viewed with awe and mystery, not only in the manner in which they basically operate but in the apparent changes in linearity and size as various voltages are changed. In general, all present day magnetic scan amplifier systems are alike, however, the direct drive system is perhaps the least complex and easiest to understand. With this system and the asymmetrical yoke, later to be described, some of the advantages are inherent uniformity of linearity, high efficiency and ease of adjustment.

In order to obtain a better understanding of the operation of the direct drive scanning system, this paper will begin with the usual classical approach of a deflection yoke shunted with its distributed capacitance in series with a battery and a switch, as shown in Fig. 1

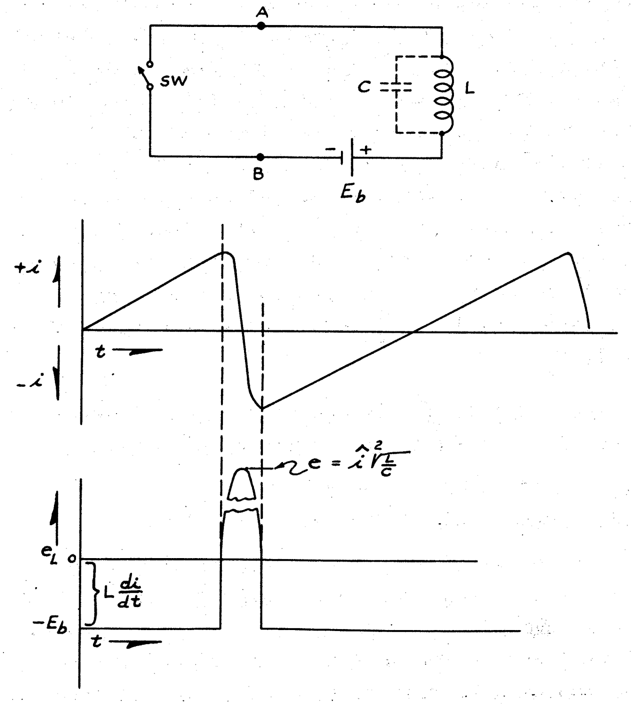

Figure 1

The instant the switch is closed, current will begin to flow from the battery through the deflection yoke. Inasmuch as the battery is shunted directly across the yoke, and the voltage of this battery is constant, the current will rise in such a manner as to make the rate of change of current a constant, dictated by the formula, $E = L\frac{di}{dt}$. If now, the current in the battery and yoke is suddenly interrupted, the energy in the inductive branch of the yoke will begin to transfer to the capacitive branch. The current in the yoke will decrease from its positive value to zero and then to a negative value equal to its positive value, barring losses, in a cosine fashion. The voltage across the coil will, of course, rise from E_b to a high value and then decrease to zero in a sine function. Left in this condition, it would oscillate forever, this particular circuit having no losses. If at the moment the current in the yoke reaches its peak negative value, the switch is again closed, the current will then flow through the battery in such a direction as to charge the battery until all the energy induced in the yoke has been returned to the battery. The current will begin to flow in the opposite direction and energy is again being removed from the battery, and the current will continue to have the same rate of change as before.

Inasmuch as the switch will have to be replaced with a vacuum tube, and vacuum tubes are not bi-directional, as are switches, two oppositely connected tubes will be required. For the first, a diode is shunted across the switch to enable the reverse current to pass through it and thereby charge the battery. The diode has also two other advantages: (1) the diode is automatic as far as the timing is concerned; it begins to conduct when the voltage across the open switch passes through zero, (2) it enables the switch to be closed at any time after that time at which the yoke current reaches peak negative current and that at which it reaches zero current.

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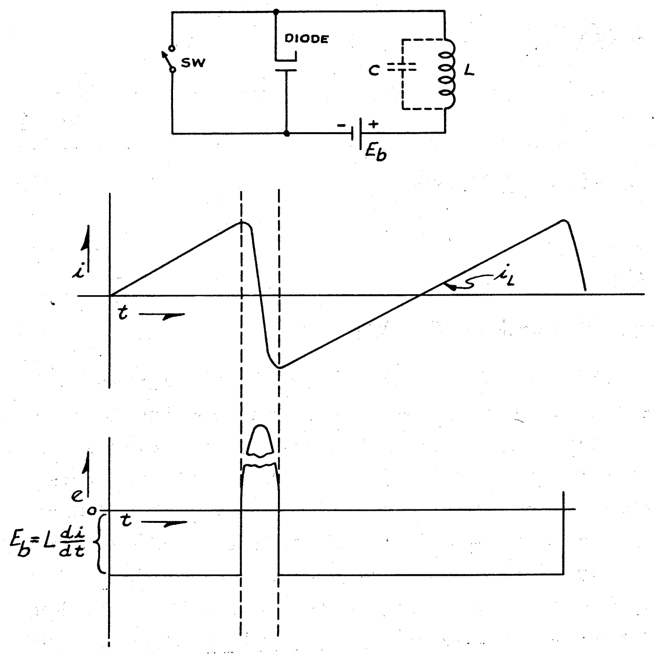

Fig. 2

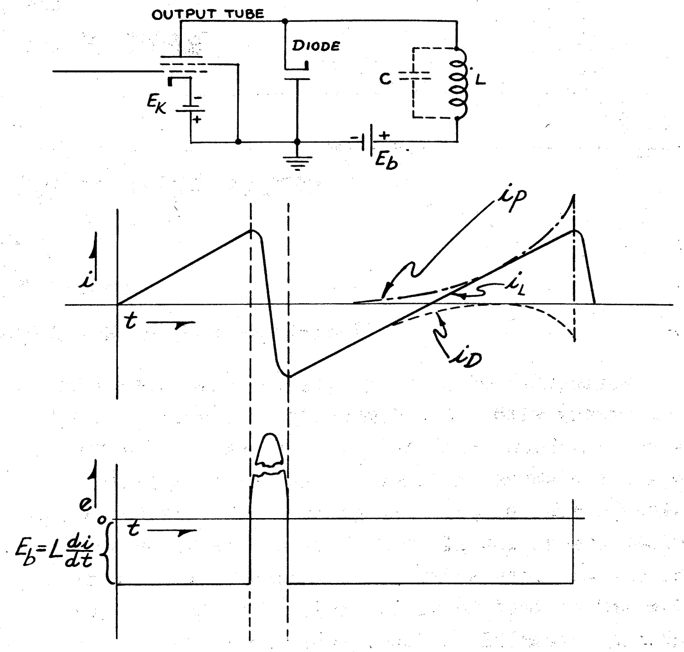

Fig. 3

Until the time the switch is opened, the operation of the circuit in Fig. 2 is identical to the circuit of Fig. 1. At the time the switch is opened, the voltage across the coil begins to increase in such a direction as to hold the cathode more positive than the plate and hence no conduction occurs. After this voltage has gone through one-half cycle, it then tries to go negative, but the diode conducts holding the voltage across the coil constant and therefore $L\frac{di}{dt}$ constant. Under these conditions, the stored energy can be returned to the battery through the diode circuit. The switch can be closed at any time after the diode has begun to conduct as it will only short out the diode.

Obviously, the procurement of a mechanical switch that will close and open in a fraction of a microsecond, and repeat at a frequency of over 15000 cycles per second, is rather difficult to say the least, and must, therefore, be replaced by a vacuum tube. Fig. 3 illustrates the same circuit as Fig. 2 except the addition of a tube and battery and the deletion of the switch. The purpose of the battery is to supply the drop that will occur across the tube, which was not present when the switch was employed. This battery is also used to supply screen power.

A saw tooth of voltage, equal in amplitude to approximately twice that of zero bias to cutoff, at the proper values of plate and screen voltage, is applied to the grid. The tube obtains bias by drawing grid current and, therefore, the peak of the input saw tooth is held very nearly zero bias. During the first half of the cycle the diode is supplying the current to the yoke. Just before the diode current reaches zero, the output tube will begin to conduct. The input wave form, to the grid of the output tube, can be shaped so that the rate of change of current supplied by it is constant. This is the most efficient mode of operation but is not necessary as long as the tube supplies at least enough current to sustain the $L\frac{di}{dt}$ drop. Any additional current supplied by the tube will flow through the diode, for if the current were allowed to go through the yoke, it would cause an additional drop over and above $L\frac{di}{dt}$ which would then make the cathode of the diode more negative with respect to its plate. So it can be seen that the diode regulates the $L\frac{di}{dt}$ drop across the yoke to exactly E_y.

The power losses in the direct drive system can be classified into two distinct classes:

(1.) Power lost in the yoke.
(2.) Power lost in the deflection tube.

The second of these two items is wholly supplied by the battery in series with the output tube V_1. As the voltage on the plate is held at ground potential due to the action of the diode, the total power consumed by this tube is then equal to the voltage of the cathode supply, E_k, times the cathode current. Plate and screen dissipation can be separated quite easily by determining the screen dissipation and subtracting from the total power input to obtain plate dissipation. Screen dissipation is, of course, screen current times screen to cathode voltage.

Power lost in the deflection yoke can be found with equal ease. In all previous examples this power has been zero due to the assumption of a lossless yoke. If now, for example, the yoke has resistance, there would be some power lost due to this resistance. This power lost is a function of the effective "Q" of the yoke at the retrace frequency. If we assume a yoke with a "Q" of 20 at the retrace frequency then the logarithmic decrement will be:

$$\varepsilon - \frac{N\pi}{Q}$$

Where $N = $ Number of cycles
$Q = 20$

Then

$$\varepsilon - \frac{N\pi}{Q} = \varepsilon - \frac{1/2\pi}{20} - \varepsilon - \frac{\pi}{40} = \varepsilon - .0786 = 92.45\%$$

Therefore, the peak negative excursion of the current during retrace time is only 92.4% that of the positive excursion of current just prior to retrace time. This also implies that <u>only</u> 92.4% of the energy stored in the yoke will be fed back to the battery during the first half of the scan. If the peak positive current is 100% i and the peak negative current is 92.4% i, then the total current, peak to peak, is 192% i. The positive peak current of 100% i minus $\frac{192\%\ i}{2} = 4\%$. The DC component is then 2% of the peak to peak current in the yoke due to the "Q" of the yoke. There are, however, other causes which raise this value of direct current through the yoke. One of these is the exponential rise of current, while still another is the "Q" of other circuit parameters. If, for example, the output tube is not cut off sharply at the end of trace, the tube itself will dampen the ringing and thereby lower the efficiency of the circuit. It is not impossible to obtain a system for scanning 50° at 10 kilovolts that will draw as little as 15 milliamperes from the yoke supply. The total losses in the yoke circuit can then be computed by multiplying this direct current by the battery voltage E_y.

The direct drive horizontal scanning system has an inherent uniformity of its characteristic. Under normal operating conditions, the output tube is made to supply more current than is necessary to support the $L \frac{di}{dt}$ drop in the yoke, and the diode, therefore, absorbs this excess current. Under these conditions, grid drive, plate voltage, and screen voltage can be varied considerably without affecting either size or linearity of the horizontal scan. In order to change size with this system, it is only necessary to change the yoke battery voltage. This change of battery voltage does not affect the linearity as this voltage determines only the rate of change of current through the yoke.

In general, non-linearity of trace in the direct drive system can be classified into two classes: (1) the non-linearity due to the exponential rise of current in the yoke and, (2) non-linearity due to tube geometry.

Fig. 4 is a graph in which α, or the angle the beam subtends from an axial line down the center of the tube is plotted versus S spot location as a percentage of the total distance across the tube.

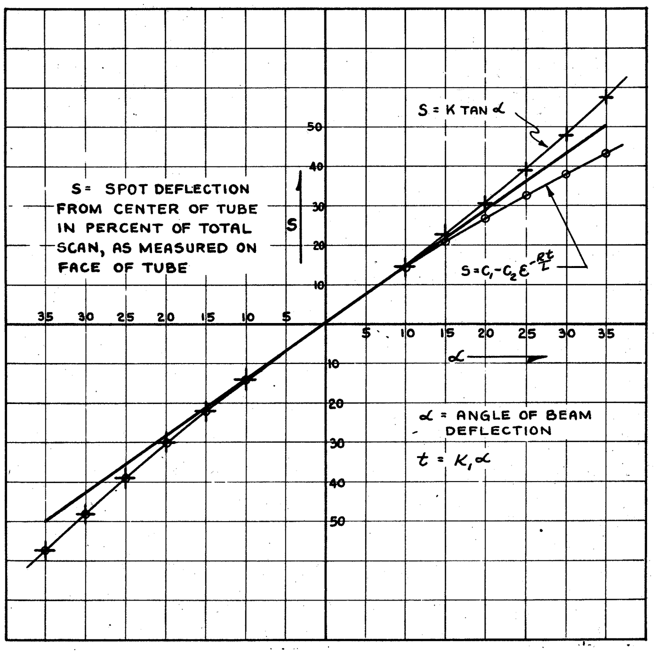

Fig. 4

Assuming constant angular velocity, for the present, the solid line indicates perfect linearity. This condition is not obtained in present day tubes due to the flatness of the face. It can be proven, by simple geometry, that the observed scan will result in a tangent function. This curve has been plotted to the same coordinate, namely S and α in Fig. 4.

Picture tube geometry is such as to cause a stretch in the picture, as viewed on both the right and left hand sides of the picture tube. Somewhat compensating this non-linearity on the right side of the picture tube is the fact that the angular velocity is not constant, but varies in an exponential manner due to resistance in the circuit.

By a trial and error method this resistance was determined and the exponential was plotted. It can be observed from the graph that the two factors causing non-linearities compensate for each other on the right hand side of the picture while they are additive on the left side of the picture.

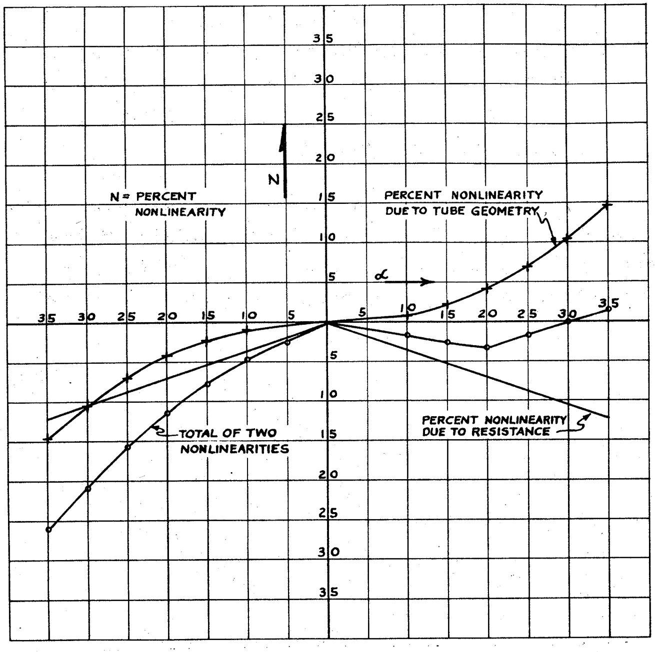

Figure 5

To more clearly illustrate these points, figure 5 is a graph in which percent non-linearity is plotted against α or, more accurately, against a constant multiplied by time. From this graph it can be seen that the non-linearity on the right side does not exceed three percent; however, on the left side of the picture, the linearity has been increased to the point where, for a 70° tube, it reaches 26%. This 26% non-linearity is, of course, not commercial but fortunately, can be cancelled out by a judicious arrangement of the magnetic field in the deflection yoke.

Figure 6 is an illustration of a cross section of such a deflection yoke. It will be noted that the coils are so constructed as to have the half of the winding on the right side, short and thick, while the other half of the same coil, which necessarily must have the same volume, is long and narrow. This slide has, of course, been exaggerated for illustration purposes and is not to scale.

The flux distribution in a yoke of this type is such as to produce non-linearities; however, these non-linearities are of a magnitude and direction as to approximately cancel the already existing distortion.

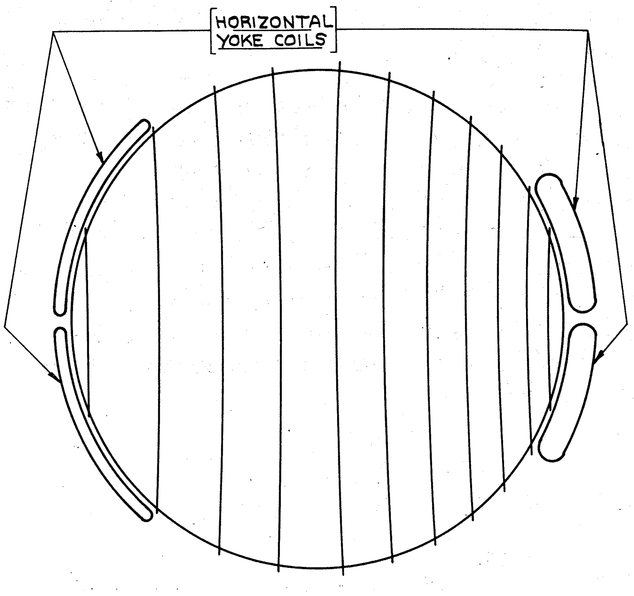

Figure 6

Moving the center of the window over, as is done, could produce a minor amount of trapezoidal and pincushion distortion. With a few geometric changes on the vertical coils these effects can be eliminated. The amount of defocusing of the spot that this yoke introduces is negligible and, in the order of that encountered in normal yokes for minimizing the pincushion effect.

Deflection yokes of the type described have only a minor change in the flux distribution and are not intended for deflection circuits other than the type described, as the non-linearities encountered in other circuits may not have the uniformity that is demanded.

In practice, 4% non-linearity is not an uncommon achievement. This coupled with the stable circuit enables the television set to have good linearity for the life of the set.

I wish to thank Mr. H. R. Shaw and Mr. K. R. Wendt of Colonial Radio Corp. under whose direction this work was completed.

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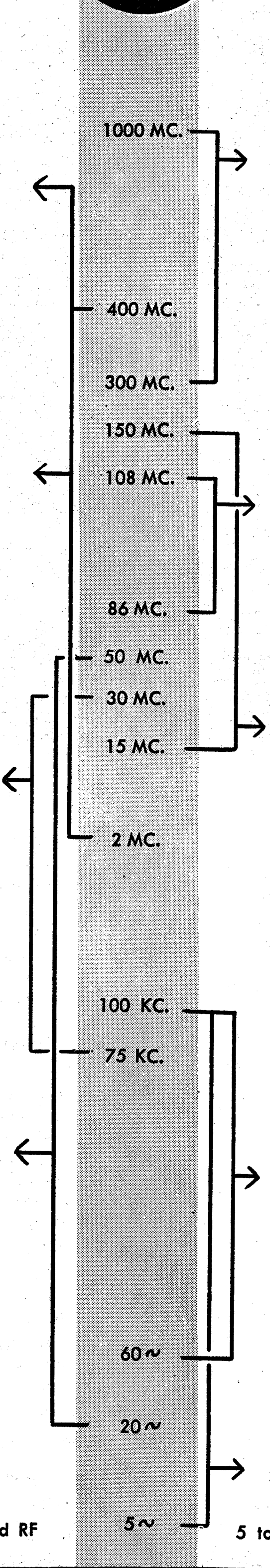

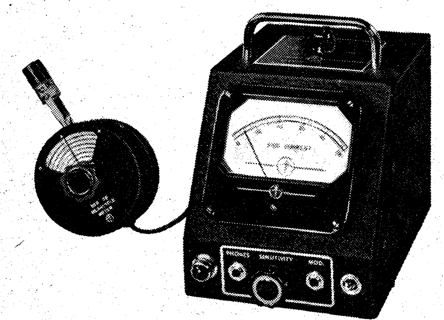

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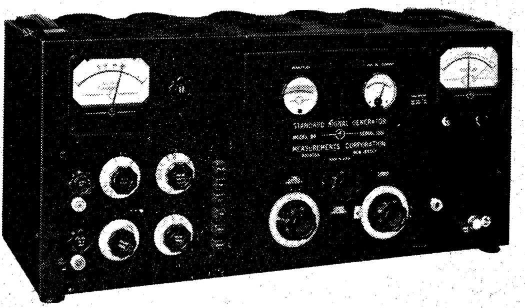

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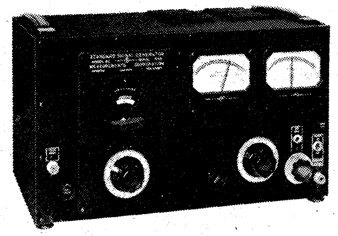

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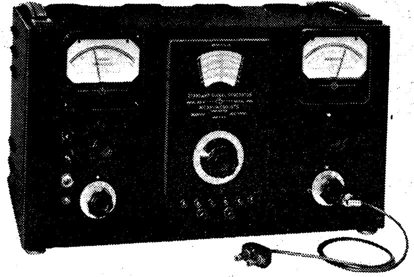

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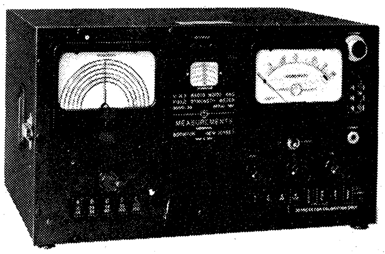

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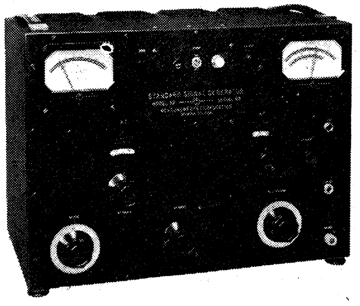

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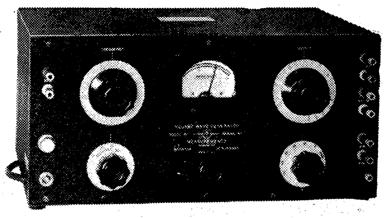

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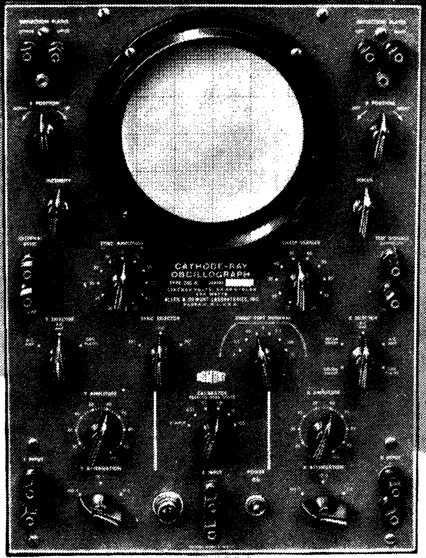

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