# APPLICATIONS OF CATHODE RAY TUBES IV.

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*The recording of diagrams*

While the cathode ray tube is usually considered to be an oscillograph, it is actually in the first place an instrument which can record simultaneously and in mutually perpendicular directions two voltages (or currents). It is typically an instrument which records diagrams directly, and the diagrams only become oscillograms when one of the voltages to be recorded is connected with the time by a simple relation, and therefore provides a time base.

If is therefore quite natural that a great many applications of the cathode ray tube consist in the recording of diagrams or characteristics, and in most cases the ordinary cathode ray oscillograph is particularly adapted for these applications.

The recording of a diagram on the cathode ray tube offers several advantages over the point-by-point construction of the diagram by static measurements. The taking of meter indications point by point is undoubtedly the most accurate method in most cases. This static method can, however, not always be used.

In the first place it is impossible when overloading and consequent damage to the object to be measured might occur during static measurement. The cathode ray oscillograph makes possible much shorter but continually repeated measurements. Such rapid measurements would not be possible with a slow pointer instrument.

Very rapid measurements may also be necessary when it is a question of momentary values in a typical periodic phonomenon. The relation between current and voltage in a self-induction, for example, is dependent upon a definite speed, and can therefore never be measured statically.

A further very obvious advantage is the fact that the complete diagram is obtained so quickly. The diagram can usually be traced at a relatively arbitrary speed by the light spot, and if it is repeated regularly an impression of a stationary figure is obtained as in the case of oscillograms. This last advantage is particularly important for measurements in series production, where accuracy may to a certain extent be sacrificed to speed.

In the examples to be discussed the advantages mentioned will play a part individually and collectively. In the foregoing article of this series one case of the recording of a diagram was mentioned incidentally, namely the recording of the modulation characteristic of a transmitter. This is a typical example of a control measurement during the process of manufacture which is striking because of its simplicity and its rapidity.

## Measurement of valve characteristics

In the development and manufacture of radio valves measurements of longer or shorter series of valves of the same type are often very important. It may in one case be a question of purely quantitative measurements, as in the determination of deviations in the products, or in other cases it may be more a question of qualitative determinations, or the detection of certain deviations which might occur in a few cases. In the last case the cathode ray tube is certainly the most suitable instrument.

An important characteristic of a valve is the one which gives the relation between anode current and anode voltage with the grid voltage as a parameter. In some cases a single value of this parameter is enough, in other cases a series of characteristics is required. The circuit with which such characteristics are recorded for receiver valves in the Philips Laboratory is shown in principle in *fig. 1.*

The anode circuit of the valve to be examined $X$ is fed with a voltage which varies periodically between zero and its maximum value. This voltage

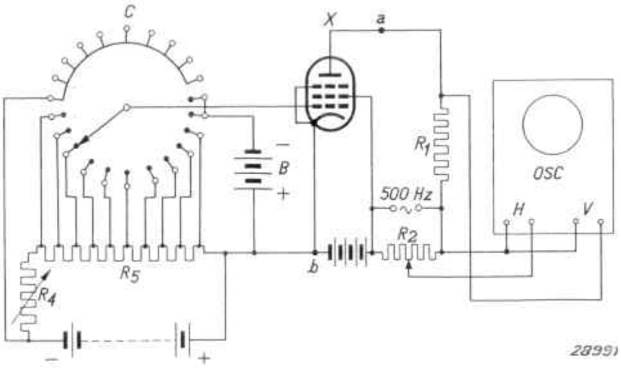

Fig. 1. Circuit for the recording of diagrams. The oscillogram shows the anode current of the valve $X$ as a function of the anode voltage. By means of the rotating commutator $C$ a number of different control grid voltages are allowed to act during each revolution ($^1/_{25}$ sec), so that a series of curves appears on the screen. One of the grid biases (-6 volts) is not taken from the resistance $R_4$, but it is supplied by the battery $B$. This is connected with two of the contacts. Because of this the line for -6 volts appears stronger than the other curves in fig. 2.

is obtained by the connection in series of a direct voltage and an alternating voltage of 500 cycles and of the same amplitude. In the cathode ray tube a horizontal deviation must be obtained which is proportional to the variation in anode voltage. For this purpose a potentiometer $R_2$ is connected over the alternating voltage, which reduces the value used to a figure suitable for the tube. The voltage tapped off is led to the terminals of the plates for horizontal deflection of an ordinary oscillograph (terminals $H$ in fig. 1). The Philips cathode ray oscillograph G.M. 3152 is also provided with such a connection. The anode current flows through the measuring resistance $R_1$ and the fairly low voltage which occurs over this resistance is fed to the built-in oscillograph amplifier $V$. In this way a vertical deviation is obtained which is proportional to the current.

In this simple manner a single diagram can already be recorded with a given screen grid and control grid voltage.

The way in which a series of characteristics is recorded simultaneously is also indicated in fig. 1. By means of a rapidly rotating commutator the control grid is momentarily connected to the successive taps of a potentiometer $R_5$. The difference in potential between successive contacts can be set at 1, 2, 3 volts, etc. by means of a series resistance. One would be inclined to suppose that the commutator should be exactly synchronized with the frequency of the anode alternating voltage. This is, however, unnecessary. Without the slighest difficulty it is possible to pass from one characteristic to the following one, even before the first one has been completed. The part lacking is then traced during the next rotation of the commutator Since the frequency at which the commutator rotates, and therefore at which the whole series of characteristics is repeated, is of the order of 25 c/s an impression is given of a single picture with no interruptions.

The commutator is composed of 22 contact-lamina. 10 of these are connected to the successive taps of $R_5$. Series of 10 characteristics are therefore recorded. For the first characteristic $V_g = 0$; all the other curves are recorded with negative grid bias. Two lamina are connected to a calibration voltage of, for instance, —6 volts. Because of this two characteristics are always traced one over the other for $V_g = -6$ volts, independent of the setting of $R_4$. This line is noticeable because of its greater brilliance. It is now possible to adjust $R_4$ in such a way that the second, third, fourth, etc. characteristic of the series coincides with that for $V_g = -6$ volts. Then it is known that $V_g$ changes by the amounts 6, 3 or 2 volts, respectively.

Finally the other 10 laminae of the commutator are connected to a fairly high negative voltage, so that the anode current is completely suppressed during half of every revolution. This is necessary for the following reason. The anode voltage reaches a very low value for some time during the measurement (it falls as far as zero.) In pentodes an abnormally high screen grid current occurs at these low anode voltages. In order to protect the screen grid from excessive heating the cathode current is suppressed for some time during each measurement. This is an example of the first advantage mentioned above to be derived from the use of the cathode ray tube.

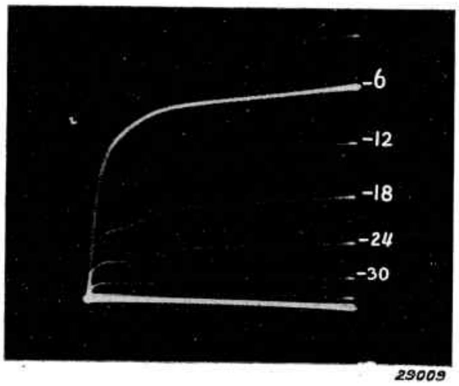

Fig. 2. Diagram of the anode current as a function of the anode voltage recorded with the help of the circuit shown in fig. 1. The abscissae run from 0 to 500 volts, the ordinates from 0 to 200 mA.

*Fig. 2* shows a series of characteristics recorded on a test model of a pentode end valve. The second curve from the top corresponding to $V_g = -6$ volts is noticeable because of its intensity. The grid voltage was apparently varied by steps of 6 volts. Furthermore in the bends of the third, fourth and fifth characteristics an irregularity may be seen which indicates secondary emission of the anode. This irregularity is the weak counterpart of the much greater dip which occurs with tetrodes (see Philips techn. Rev. **3**, 215, July 1938).

When the resistance $R_1$ in fig. 1 is added to the screen grid circuit of the valve to be examined, the characteristics are obtained of the screen grid current as a function of the anode voltage (*fig. 3*). In this figure also the guiding line for —6 volts may again be recognized. Furthermore irregularities in the curve may also be seen which are due to the secondary emission of the anode; for every fall in the anode current due to secondary emission there is a corresponding rise in the screen grid current.

Finally it may here be seen that relatively high currents flow when the anode voltage is low. These currents would overload the screen grid in static measurement.

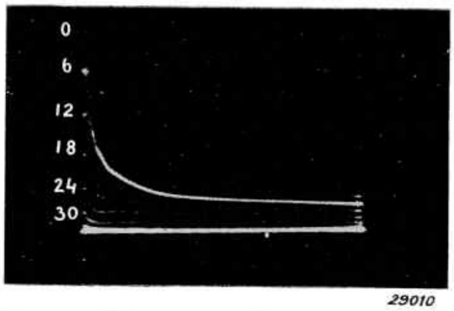

Fig. 3. Diagram of the screen grid current as a function of anode voltage, recorded with the same valve as in fig. 2, and on the same scale.

### The measurement of a hysteresis loop

Another example of a measurement in which a dynamic method gives a certain simplification compared with static measurement is the determination of the induction $B$ in a magnetic material, *i.e.* the measurement of a hysteresis loop. A ballistic galvanometer is usually used for this, and the induction impulse occurring in a secondary winding is measured when the magnetizing field is interrupted by switching off the current in the primary winding (see J. J. Went, Philips techn. Rev. **2**, 84, 1937). A secondary voltage occurs with momentary values proportional to $\mathrm{d}B/\mathrm{d}t$. When the magnetization is not changed suddenly, but periodically, the induced voltages can be integrated very simply electrically, instead of mechanically as in the ballistic galvanometer, so that voltages proportional to $B$ occur.

The principle of the circuit with which this is done is shown in *fig. 4.* A closed ring is made of the test material in the usual way and two windings are laid around it. The primary winding $S_1$ is supplied with alternating voltage over a resistance $R_1$. A voltage therefore occurs over this resistance which is proportional to the number of ampere turns, and this voltage can be led directly to the terminals $H$ for horizontal deflection.

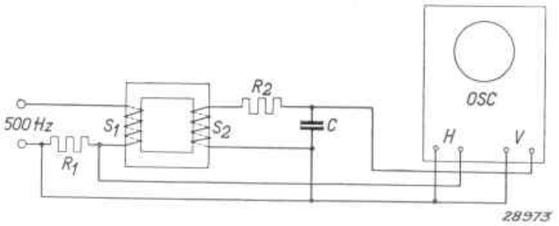

Fig. 4. Circuit for recording hysteresis loops. The voltage at the coil $S_2$ is proportional to $\mathrm{d}B/\mathrm{d}t$. If the impedance of $C$ is small with respect to $R_2$ the voltage at $C$ is proportional to the momentary value of $B$.

As mentioned above the following voltage occurs over the secondary winding $S_2$:

$$v_2 = \text{const.}\ \frac{\mathrm{d}B}{\mathrm{d}t}\cdot$$

The combination of resistance $R_2$ and capacity $C$ is connected with this winding. When care is taken that the voltage at $C$ is very small compared with $v_2$, it may be assumed that a current flows through $R_2$ and $C$ which has a momentary value of:

$$i_2 = \frac{v_2}{R_2} = \frac{\text{const}}{R_2}\frac{\mathrm{d}B}{\mathrm{d}t}\,.$$

The voltage at $C$ thereby becomes:

$$v_C = \frac{1}{C}\int i_2\ \mathrm{d}t = \frac{\text{const}}{R_2\ C}\ B.$$

The voltage at $C$ is therefore actually a measure of $B$. This voltage must be small with respect to that at $S_2$, while the latter will not for practical reasons be much higher than for instance 100 volts. From this it follows that the oscillograph amplifier must be connected between $C$ and the plates for vertical deflection.

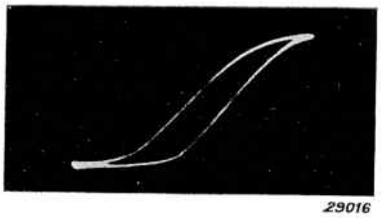

Fig. 5. Hysteresis loop recorded by means of a circuit like that of fig. 4

Fairly heavy demands as to phase fidelity are made of the oscillograph amplifier in this and in the previous case. In general a constant amplification over a very wide frequency range is the primary requirement in the case of an oscillograph. Over the greater part of this range the phase fidelity is also practically perfect. At the boundaries, however, inevitable small phase shifts occur. Since very slight shifts are very disturbing in the reproduction of diagrams (double lines), in the two cases described the measurements were carried out at a frequency of 500 c/s instead of at the usual 50 c/s since upon amplification of these low frequencies phase shifts would already occur.

A hysteresis loop recorded according to fig. 4 is reproduced in *fig. 5.*

### Measurement of frequency with the cathode ray tube

A type of measurement which is connected with the two preceding ones to only a certain extent is the comparison of unknown frequencies with a standard frequency, *i.e.* for example a method for the measuring generators which are used in acoustic measurements.

The comparison of the frequency of a generator to be calibrated with a standard frequency is often done by ear, when the frequency to be determined differs from the standard by a whole number of octaves. This method may be very accurate, because of the fact that slight deviations can be detected due to the occurrence of beats. When, however, one of the two oscillations contains overtones, it becomes difficult to determine the number of octaves difference. Similarly the comparison by ear is not possible with great accuracy when the frequency to be calibrated does not differ from the standard frequency by a whole number of octaves.

By supplying two alternating voltages of different frequency to the two sets of plates of a cathode ray tube a very accurate comparison is possible. This is also true in the case of quite arbitrary relations between the frequencies, as long as they may be expressed in the form of a ratio of two whole numbers which are not too large.

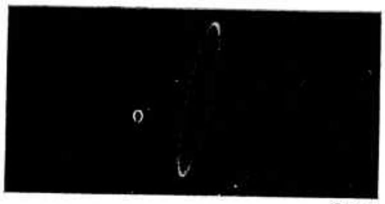

Fig. 6. If sinusoidal alternating voltages of the same frequency but of different phase are supplied to the horizontal and vertical deflection plates of a cathode ray tube, the resulting figure is an ellipse.

When voltages whose frequencies are related as whole numbers, are supplied to the plates, a stationary figure results. If the frequencies are the same, a straight line or an ellipse is obtained according to the phase relation of the voltages (*fig. 6*). With other ratios of frequencies the so-called Lissajous figures are obtained. *Fig. 7* gives an example of one of these.

Fig. 7. Lissajous figure which occurs when the frequencies of the vertical and horizontal deflecting voltages are in the ratio 5/2.

The ratio of the frequencies may be deduced from the last figure in the following way. In the time during which the figure is completely traced five upper peaks have been reached in the vertical direction, therefore there have been five periods. In the horizontal direction the left (or right) side of the figure has been reached twice, therefore two periods have elapsed. The frequency of the vertical oscillation was therefore the higher, and was apparently $^5/_2$ of that of the horizontal oscillation. As soon as the ratio of the frequencies deviates slightly from $^5/_2$, the successive figures no longer exactly coincide, and the figure appears to move. Because of this it is possible to measure frequencies very accurately.