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SWEEP CALIBRATION WITH LOW FREQUENCY STANDARDS

by

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One of the most common applications of the cathode-ray oscillograph is the examination of the wave shape of a signal plotted on the time-base of the oscillograph sweep. Generally, the sweep is linear with time, and, in this usage, the time calibration is determined if the sweep frequency is known. It is customary to obtain the sweep calibration by comparison with a series of known frequencies furnished by an oscillator. But if the entire range of the sweep frequencies is to be covered, the frequency range of the oscillator must be as extended as that of the sweep, at least at the high frequency end of the range. In the absence of such an oscillator, and, if only the 60-cycle standard of the power supply is available, sweep determinations are limited to relatively low frequencies. The method presented here is a means for overcoming such a limitation. If only a 60-cycle sinusoid is at hand, sweep frequencies up to 6000-cycles may be determined with a fair degree of precision, and, in general, sweep frequencies up to some 100 times greater than the available standard may be measured.

THEORY

If a standard sinusoid of comparatively low frequency, F, is applied to the vertical plates of the oscillograph, and the sweep is made to oscillate successively at different frequency values, f, greater than F, then, at certain values of f, moderately stationary patterns are obtained such as those illustrated in figure 1. We shall refer to

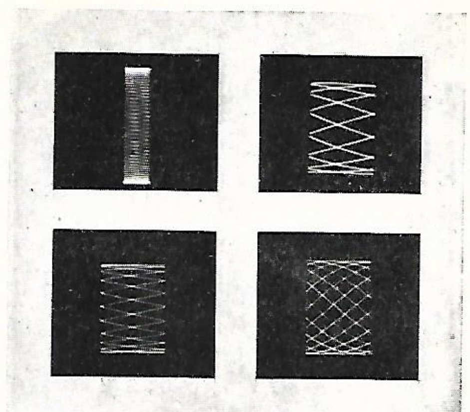

Figure 1.

Typical mesh-patterns as they appear on the cathode-ray screen. 60-cycle standard. Various sweep frequencies: highest, in upper left photograph; lowest, in lower right photograph.

these as "mesh-patterns". Each mesh-pattern consists of a number of criss-crossed segments of the low frequency sinusoid and the average angle of these segments with the horizontal axis decreases as the sweep frequency increases. At any particular value of f, the angle of interception of the segments with the sweep axis bears a simple relation to f. This is demonstrated as follows.

Let A be the width, and B, the height, of the rectangle formed by the mesh-pattern. Consider any segment of the pattern at its point of interception of the X- (i.e., the sweep-) axis., making at this point an angle, α, with the X-axis. Now,

$$\tan \alpha = \frac{dy_0}{dx} = \frac{dy_0/dt}{dx/dt} \qquad (1)$$

where, t, is the time, and the subscript, o, means that the indicated derivatives are to be evaluated at the value $y = 0$. The time derivatives of equation (1) are easily obtained. Remembering that it is assumed that the sweep is linear, we have,

$$dx/dt = Af \quad . \qquad (2)$$

Now dy_0/dt may be obtained from the relation of y to t. Since this is a sine function with amplitude, B/2, and frequency, F, we have,

$$y = B/2 \sin 2\pi Ft \quad .$$

Taking the time derative of this, and noting that at the value $y = 0$,

$$t = \frac{\frac{1}{2}(n+1)}{F},$$

where n is an integer, it follows, disregarding signs, that

$$dy_0/dt = B\pi F \cos 2\pi \left(\frac{n+1}{2}\right) = B\pi F \qquad (3)$$

Combining equations (1), (2), and (3) we find,

$$f = B\pi F/A \tan\alpha \quad . \qquad (4)$$

Thus f is expressed as a function of F, which is known, and A, B, and α, which are all measurable.

MEASUREMENT

Examination of equation (4) shows that, for a given F, f will be greater the smaller is α, and the large is the ratio B/A. But the largeness of B/A and the smallness of α are, in practice, limited by the only moderate accuracy with which these quantities can be measured. It has been found that it is unsatisfactory to have B/A greater than 6 (on a five inch screen), and α less than 10°. (It is assumed that, in general, not α, but 2α, will be measured in order to increase the precision of determining α.) Substitution of these values in equation (4) leads to the relation $f = 107$ F. Thus sweep frequencies of the order of 100X that of the standard may be determined. Obviously, at the highest frequencies, there is the least precision, Greater precision will obtain at the smaller values of f since, for such values, both A and B may approximate the maximum values permitted by the screen diameter, and α may be much larger than 10°.

Actual determinations of the sweep frequencies of a DuMont Type 175A oscillograph have been made using the 60-cycle sinusoid of the supply voltage as the standard. The standard voltage was connected to the verticle input, and the recurrent sweep, with zero synchronizing voltage, was then operated at increasing rates until a stationary mesh-pattern was formed. (The patterns attain only moderate stability since, for a given setting of the sweep controls, the sweep frequency is not constant. The patterns are sufficiently stationary, however, so that the necessary measurements can be made.) The horizontal and vertical input potentiometers were then varied until a mesh-pattern was formed that offered a combination of values of A, B, and α that permitted the best all-round precision of measurement. While good results were obtained by direct measurement on the cathode-ray screen, a more satisfactory procedure was to make the measurements from photographs of the patterns. This procedure was repeated at increasing sweep frequencies until the whole measurable range (up to about 6000-cycles) was covered. Equation (4) was then used to calculate f for each sweep adjustment. In order to obtain a measure of the precision of the method, values of the sweep frequencies were also determined directly by means of an accurately calibrated oscillator. The mesh-pattern values differed from the precisely determined frequencies by an average deviation of $\pm 3\%$.

The upper limit of the range of sweep frequencies obtainable by this method may be extended by using a standard calibrating frequency, F, of higher value than the 60-cycle voltage used above. Since many test instruments provide 400 and 1000 cycle outputs, it is obvious that corresponding sweeps up to 40,000 and 100,000 cycles, respectively, may be measured. Thus, if, in addition to the 60 cycle standard, only the 400 cycle standard is used, the full range of the sweep frequencies of the ordinary oscillograph may be determined.

The calibration procedure outlined above is hardly recommended to take the place of more reliable methods. The relatively large inaccuracies in measuring B/A and α, especially at the higher frequencies, have already been mentioned as imposing limitations on the method. In addition, it must be noted that usual laboratory oscillography does not absolutely satisfy the rigorous requirements that are implicit in the theory. For, a consideration of the theoretical basis of equation 4 shows that: (1) the sweep must be a true linear function of the time, (2) the calibrating voltage must be a pure sine function of the time, and (3) the cathode-ray screen, at least in its center portion, must be of low and uniform curvature. But, in the absence of the instruments needed for highly precise calibration, a substitute is offered in the mesh-pattern method. It can be used with a minimum of apparatus and with a degree of reliability that may be acceptable in much oscillographic work.

Our Apologies

We are deeply indebted to Mr. Frank May of the Oak Manufacturing Company, Chicago, Illinois for his article "The Oscillograph as a Production Tool" which appeared in the July-August-September-October 1943 issue of the DU MONT OSCILLOGRAPHER.

Our apologies to Mr. May for not including his name with the article.

Announcement

An attratcive loose-leaf binder is now available to hold all copies of the DU MONT OSCILLOGRAPHER.

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