In the new potentiometer model we used for a null indicator a photo-compensation microvoltammeter F116/2. When it is used as a microammeter in the 0.015 \( \mu A \) range its minimum calibration amounts to \( 2 \cdot 10^{-10} \) amp, which is satisfactory even for the worst possible operating conditions with a high-resistance potential divider. With an external circuit resistance not less than \( 2 \cdot 10^8 \) ohm, the instrument's settling time does not exceed 6 sec. The instrument is made in a portable form with a pointer indicator, and despite the fact that it must be used on a shock absorbing stand, its erection is much simpler than that of a stationary mirror galvanometer of the same sensitivity. A substantial advantage of this instrument as compared with normal mirror galvanometers consists in its sensitivity and settling time being less affected by the measuring circuit resistance variations over wide limits, which is of great advantage for the operation of a potentiometer.

The above work shows the possibility of producing a grade 0.005 potentiometer, which is now being pursued by the VNIIM.

**LITERATURE CITED**

3. Instruction of the Committee of Standards, Measures, and Measuring Instruments, 189-54.

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**OBTAINING A GIVEN PHASE SHIFT BETWEEN VOLTAGES**

**BY THE BEATING METHOD**

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Among the various means of producing voltages mutually displaced in phase, the method based on beating effects plays an important part. The generators based on this principle [1, 2] contain in their fixed frequency channel a time modulator, which normally consists of different types of phase shifters with a range of 0 to 360°. Thus, the accuracy of evaluating the phase difference angle between the output voltages of such a generator depends in the long run on the precision of the phase shifter calibrations and their stability in time. Capacitative, inductive, and other phase shifters do not provide a sufficiently accurate setting of the phase difference between the generator output voltages.

The method which we have developed [3] for setting phase differences between the output voltages is based on strictly determined physical relations and does not require a calibrated phase shifter, thus providing far greater accuracy.

It is known that one of the properties of the Lissajous figures consists in their passing through \( 2\pi \) characteristic positions when the phase of the lower-frequency signal varies by 360°. This property is taken as the basis for precision phase difference measurements.

The circuit for generating voltages with a mutual phase difference is shown in Fig. 1. Oscillations of a frequency of \( n\omega_0 \) are fed from a fixed frequency oscillator 1 to a frequency divider 2 with a scaling factor \( n \) and to oscilloscope 4. The other oscilloscope input is fed from a phase shifter 3. Mixers 5 and 7 are supplied with signals of
frequency $f_0$ from the input and output of phase shifter 3, which varies the phase in the range of $0-360^\circ$ and with the voltage from an auxiliary oscillator 6 of frequency $f$.

The beat frequencies which appear on the mixer loads are fed to filters and output amplifiers (the latter for the sake of simplicity are not shown in Fig. 1).

The phase relations are preserved in frequency conversion, hence, the oscillator output voltages $U_1'$ and $U_2'$ will have a beat frequency of $f_0-f$ and will have the same phase angle between them as oscillations of frequency $f_0$.

The phase difference $\varphi$ between voltages $U_{01}$ and $U_2$ at the input and output of the phase shifter corresponds to the phase difference at the output of the generator, and is conveniently evaluated by fixing the instant of the Lissajous figures "degeneration" into a curve, whose shape resembles a sine wave which we shall call an open Lissajous figure.

The zero phase difference between voltages $U_{01}$ and $U_2$ is set in the following manner:

With the frequency ratio of voltages $U_{01}$ and $U_1$ equal to $1/n$, the initial open Lissajous figure is produced on the screen of a cathode-ray tube by means of an additional phase shifter placed in the frequency divider unit. Voltages $U_{01}$ and $U_2$ are then fed to the oscilloscope and a zero phase difference between them is set with an error of $\pm 2^\circ$ by adjusting the $0-360^\circ$ phase shifter until the ellipse seen on the screen is reduced to a straight line. By observing on the oscilloscope screen the Lissajous figure for a frequency ratio of $1/n$, it will be seen that this figure differs from the initial one owing to the error in setting the zero phase difference. This error may be eliminated by a small adjustment of phase shifter 3, which converts the observed image into an open Lissajous figure.

When the zero position of the phase shifter is set, it is easy to obtain any required value for the phase difference between voltages $U_{01}$ and $U_2$ ($U_1'$ and $U_2'$, respectively) in intervals of $360^\circ/2n$, since the Lissajous figure "degenerates" $2n$ times when the lower-frequency phase is shifted through $360^\circ$. By connecting in series with the main phase shifter an additional calibrated one with a range of $0-360^\circ/2n$, it becomes possible to set any required phase angle within each interval. For measurements which do not require high precision the phase difference may be estimated from the geometrical relationship of the Lissajous figures.

The error in obtaining phase differences between voltages $U_{01}$ and $U_2$ is mainly determined by the inaccuracies in superposing lines observed on the oscilloscope screen. In fact, if we denote by $T_1$ the oscillation period of voltage $U_1$ and by $T_2$ that of voltage $U_2$, we obtain

$$T_1 = \frac{T_2}{n}.$$ 

Considering that segment $AC$ (Fig. 2) corresponds to $T_1$, and that $AB$ corresponds to error $2\Delta\varphi$ due to the inaccuracy in superposing the lines, we shall obtain the following relation:

$$\frac{AC}{T_1} = \frac{AB}{2\Delta\varphi};$$

whence

$$\Delta\varphi = \frac{T_2}{2n} \cdot \frac{AB}{AC} = \frac{360^\circ}{2n} \cdot \frac{AB}{AC}.$$