The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

SOME USES FOR A PRECISION CHRONOGRAPH

THE term chronograph may be applied to any instrument which furnishes a record of events with reference to their time of occurrence. Devices of this sort have long been known and have found wide use in industry and the arts.

Several examples of the chronograph are to be seen in the recording barometer, the recording thermometer, the recording wattmeter, etc. In these devices a rectangular or circular graph is obtained on which one co-ordinate is calibrated in some scale of time, while the other co-ordinate is calibrated in terms of pressure, temperature, power, or whatever quantity is to be measured. Records of this sort are obtained by moving a strip or disc of paper at a uniform predetermined rate while a pen or stylus travels across the paper in a direction perpendicular to the motion of the latter, the deflection of the pen being proportional to the quantity recorded.

Another use of the chronograph is that of recording time intervals, as exemplified by the siphon recorder, wherein the to-and-fro motion of a pen upon a moving strip of paper traces a record indicating intervals of short and long duration (dots and dashes) which may be interpreted as Morse Code in the transmission of intelligence.

Still another application of the chronograph has to do with the measurement of time intervals. It is with this latter use that we shall deal in the following. There are two separate methods which may be employed for measuring time intervals by means of the chronograph.

In one of these, means are provided to produce a uniform motion of the recording paper and to measure the time interval directly in terms of the linear displacement of the record. The drum type of chronograph falls into this class. A piece of paper is mounted upon a uniformly revolving cylinder and records of events are indicated by the displacement of a line drawn by a pen or by minute holes punctured in the paper by means of an electric spark at the beginning and end of the interval. Obviously, the precision of such measurements depends upon the uniformity with which the paper is moved.

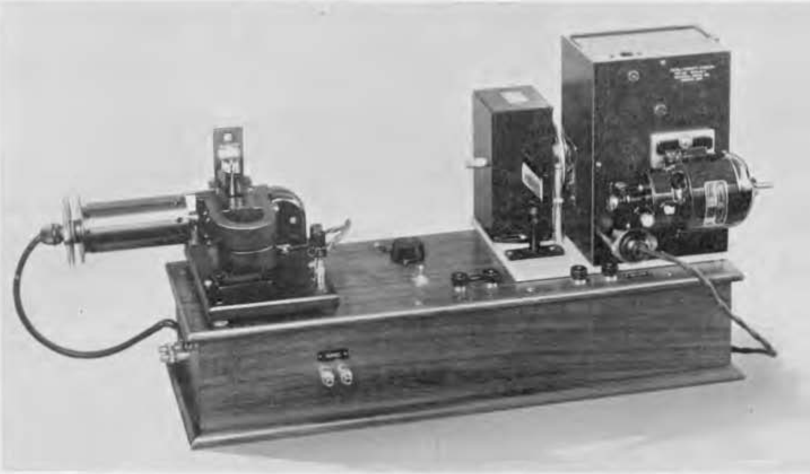

FIGURE 1. The chronograph, consisting of a TYPE 338-L String Oscillograph in which a motor-driven TYPE 408 Oscillograph Camera replaces the usual rotating-mirror box, and a TYPE 407 Synchronous Shutter fitted with a special shutter wheel

The second method, which is inherently capable of greater precision, consists of making two simultaneous and adjacent records upon the paper, the motion of which need be only approximately uniform. One record is produced by the phenomenon to be measured, while the indication of the second record is produced independently at stated and accurately timed intervals and serves therefore as the timing scale. An example of such a double record is seen in Figure 2.

This procedure may be extended to the more elaborate triple record shown in Figure 3. Here the time interval between two separate phenomena is measured against the time scale which is here given by the spaced dots along one side of the paper.

There has recently been developed in the laboratories of the General Radio Company a high-precision chronograph capable of making time-interval measurements to better than the nearest 0.001 second. Such precise measurements could not reliably be obtained with any more-or-less ponderous pen or stylus. The vibrating strings of the TYPE 338-G String Galvanometer, which is of the nature of an Einthoven galvanometer, because of their small mass and short period of vibration, are inherently more quick and reliable in response and more suitable for the purpose. These strings are tuned to have an undamped natural frequency of the order of 2000 cycles per second. Applying the oil-drop damping to the strings renders them essentially aperiodic. This chronograph consists, therefore, of the TYPE 338-G String Galvanometer, together with the TYPE 408 Oscillograph Camera described in the *General Radio Experimenter* for April, 1931. For greater convenience and to obtain higher paper speeds than can be realized by hand cranking, this camera has been

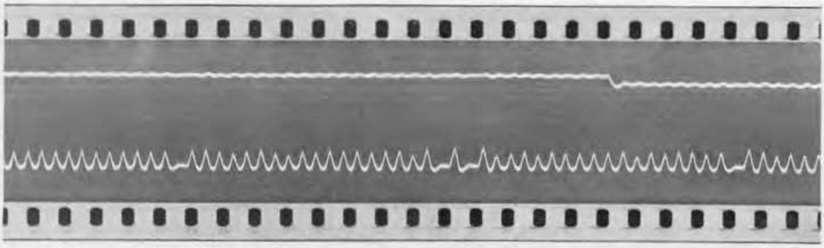

FIGURE 2. A double timing record (full size) obtained by applying signal voltages to both strings in a TYPE 338-P2 Double String Holder. Time increases from left to right

provided with a motor drive. A paper speed of from 80 to 100 inches per second is possible, using a highly sensitive recording paper (Eastman Kodak Company No. 697).

The timing scale record shown in Figure 2 was obtained as follows: A synchronous motor having a shaft speed of 10 revolutions per second was driven either by the 60-cycle mains or by the 1000-cycle frequency obtained from the primary standard of the laboratory. The shaft of the motor carried a disc having a concentric ring of 100 uniformly spaced holes, the spacing between holes approximating their diameter. This "phonic" disc, shown in Figure 4, was equipped with a mercurial stabilizer, thereby minimizing any chance hunting of the motor. By means of a radial slit, a light beam was alternately projected through one hole at a time and eclipsed. These light impulses, 1000 per second, were passed into a photocell which was followed by an overloaded amplifier. The output current wave from this amplifier was applied to one of the two strings of the galvanometer, the vibration of which produced the sharply peaked waves 0.001 second apart. Measurements to about 0.00025 second may be made against such a time scale. The accuracy depends obviously upon the accuracy of the frequency driving the synchronous motor. For convenience, every twentieth impulse (0.020 second) was omitted by leaving out the corresponding hole in the disc. The tenth-second interval (one point on the disc) was specifically marked in the manner shown. By thus indicating the multiple

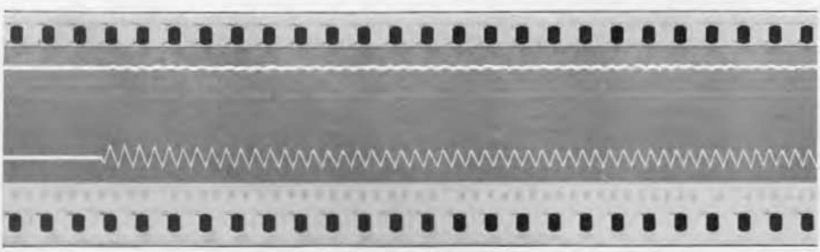

FIGURE 3. A triple record having in addition to the two traces of Figure 2 a third one made by a synchonous motor-driven shutter

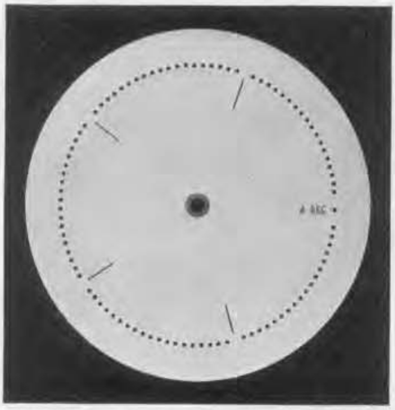

FIGURE 4. A "phonic disc," suitable for mounting on the shaft of a TYPE 407 Synchronous Shutter rotating 10 times a second. Each hole then represents 1 milli-second, the 1/10-second and 20 milli-second intervals being indicated by the spaces shown

time intervals, the records are easily and quickly read and the chance of personal error minimized. The use of a phonic wheel and the photocell is manifestly superior at these speeds to any form of mechanical vibrating contact and, in addition, permits the desirable multiple unit markings.

The timing record, shown in Figure 3, was obtained by a similar 100-hole disc driven by a synchronous motor. This timing unit, shown in Figure 5, is so placed that the disc intercepts directly the edge of the light beam falling on one end of the camera slit and accurately prints a series of dots 0.001 second apart along one side of the paper. The same system of multiple interval markings is employed. The latter procedure eliminates the photocell and amplifier, gives a record readable at least to 0.0005 second, and, with the double-string element in the galvanometer, permits a triple record.

The complete assembly of the chronograph shown in Figure 1 consists of the TYPE 338-G String Galvanometer and base cabinet together with the camera and synchronous shutter which are mounted in place of the rotating mirror viewing box. The instrument is, of course, a photographic recording oscillograph. Obviously the oscillograph assembly shown in the April, 1931, *Experimenter* may be used as a chronograph by adding the motor drive to the camera for high speed work.

One of the important uses for which this precision chronometer is well adapted is the accurate comparison of two clocks. Separate impulses from the clocks may, at stated times, be put individually upon the two strings and a triple record obtained showing the time interval between these impulses, so that highly accurate rates of the clocks can be measured hour-by-hour or day-by-day. It is wise, when working with such precision, not to introduce relays, etc., with their variable time lags, between the clocks and the galvanometer strings. Some technique employing photocells and eclipsing light slits carried by the primary moving member of the clock, that is, the pendulum, is to be recommended.

It is proposed shortly to make an interesting use of this chronograph in a routine daily measurement in our laboratory. The General Radio piezo-electric primary frequency standard contains a synchronous clock driven by the standard 1000-cycle frequency. This clock is checked daily against Mean Solar Time by means of the U. S. Naval Observatory radio time signals. The motor shaft driving this clock, and turning ten revolutions per second, carries an electromagnetic generator which gives an electrical impulse of exceedingly short duration once per revolution. These impulses, spaced 0.100 second apart, are recorded on one string of a triple record while the other string receives the audio note of the radio time signals, the "nose" of which is thus compared with the synchronous clock. Although the impulse from the clock generator is less than one millisecond in duration, the recorded impulse on the string lasts about ten milliseconds. This is due to the action of the energy-storing elements of the amplifier. The nose of this clock impulse can, however, be determined with great accuracy. A heterodyne type of radio receiver is employed with suitable audio tone filters which serve to minimize extraneous disturbances and to render the nose of the time signal more clearly defined. By averaging the records of several successive seconds, a comparison to about 0.0002 second is anticipated.

In order to minimize the amount of photographic paper required for such a series of observations, a "sampling" technique has been perfected. By means of an auxiliary synchronous cam contact driven by the standard frequency and closed for about 0.2 second every second, it is possible to start and stop the camera motor for a short period during each second, thus using about 18 inches instead of 100 inches of paper for each second recorded. By proper adjustment of this cam "within the second," the paper will be traveling at maximum speed at the instant of arrival of each nose of the radio time signals.

Many and varied applications of such a precision chronograph will occur to our readers. The time of throw of a relay armature between back and front contacts, and also the time lag between the application of voltage to a relay and the make and break of its contacts are readily measured. Numerous problems involving the precise measurement of velocity would offer possibilities for this instrument. The "pick-up" and speed of an athlete or motor vehicle traveling over a race course and intercepting a succession of light beams passing into photocells may be measured with a precision far exceeding that obtained by any stop-watch technique.

Another application which should be of considerable importance concerns the measurement of the speed, the acceleration, and the deceleration of any form of revolving shaft. This merely requires some form of phonic disc or its equivalent mounted upon the shaft to intercept a light beam passing into a

FIGURE 5. A TYPE 407 Synchronous Shutter, fitted with a shutter wheel like that shown in Figure 4

photocell which in turn energizes one of the galvanometer strings with a pulsating current whose increasing or decreasing frequency may accurately be measured against the time scale. If, on the other hand, it is mechanically feasible, the phonic disc on the shaft may intercept directly the light passing through the camera slit and thereby print a photographic record on the recording paper. In this manner automotive engineers might apply such equipment to study the irregularities of shaft rotation due to lack of balance and to investigate the "slip and grab" action of brake systems.

In the fields of medicine and psychology there are many uses for the chronograph as, for instance, in the timing of nerve action currents and in measuring reflex responses to shock or to visual and aural stimuli. The acoustical engineer is interested in the measurement of short time intervals in the study of reverberation characteristics of enclosed spaces. Here is an instrument which should give accurate data of this sort.

The study of radio wave propagation and the timing of sky wave echoes requires some form of high speed chronograph. With these random suggestions we leave it to our readers to expand the list of possible applications.

The price of the chronograph equipment, complete with motor-driven camera and synchronous shutter for operation from a 110-volt, 60-cps. supply, is $468.50. All items but the motor drive for the camera and the special "phonic disc" are carried in stock.

—Horatio W. Lamson

WAGNER GROUNDS ▲ ▲ ▲ There are two possible means of avoiding errors in bridge measurements due to unbalances of the power source to ground. One is to isolate the power source from the bridge by means of a well shielded and balanced transformer; the other is to employ a Wagner Ground which, in effect, shifts the ground point of the power source to agree with the ground point of the bridge. Unbalances of the power source are annoying because they introduce shunt impedances on opposite sides of the bridge which are not in the same ratio as the ratio arms. In some circuits this is particularly troublesome and unless precautions are taken large errors are introduced.

Where the ratio arms are fixed and equal, as in the Type 216 Capacity Bridge, it is possible to design a power-

The Type 193 Decade Bridge with a Type 193-P1 Wagner Ground attached supply transformer which isolates the bridge from the source and introduces shunt capacitance equally on the two sides of the bridge. In a bridge with adjustable ratio arms, such as the TYPE 193 Decade Bridge, however, it is obviously impossible for a single transformer to achieve balance under all conditions. For this work the General Radio Company recommends the Wagner Ground and has developed a unit for attaching to the latter instrument.

The TYPE 193-P1 Wagner Ground consists of a 400-ohm potentiometer which is intended to be connected in parallel with the power source. This unit, with the ratio arms of the bridge, forms an auxiliary bridge, balance of which indicates that the apparent ground of the power source and the ground in the bridge are at the same potential. Provision is made for inserting an additional 500 ohms on either one or both sides of the potentiometer.

A switch is also incorporated in the unit for connecting the phones or other balance indicator either to the bridge or to the Wagner Ground. At the same time this switch furnishes an easy means for shifting the resistance balance arm from one side of the bridge to the other.

The price of the unit is $20.00.

WAVEMETERS ▲ ▲ ▲ Recent experimental work by General Radio engineers seems to indicate that the precision frequency meter of the future will be similar to those shown in the accompanying photograph. These were built for the United States Coast Guard and had their counterpart in another design and construction order from the United States Navy.

Calibrating a group of special self-checking heterodyne wavemeters designed and built by General Radio for the United States Coast Guard

In general, a self-calibrating heterodyne wavemeter consists of a heterodyne oscillator fitted with interchangeable coils and a straight-line-frequency condenser for covering a wide band of frequencies. A piezo-electric oscillator is also included, harmonics from which serve to furnish points at which the calibration of the heterodyne may be checked. It is also possible by this arrangement to abandon the use of a calibration for the heterodyne except as a rough one is needed to help identify harmonics. By giving sufficient attention to the linearity of the tuning condenser, it is possible to so construct the instrument that interpolation between adjacent crystal harmonics is carried out by a simple graphical process.

As an example of the possible range of such an instrument, the ones shown in the photograph covered 150 to 500 kc. and 2200 to 4280 kc. using two piezo-electric oscillators, one at 100 kc. and one at 110 kc.

CAPACITY BRIDGE, TYPE 216 ▲ ▲ ▲ A new instruction book for the Type 216 Capacity Bridge has just been completed and copies are available without charge to those who own the bridge. The book not only gives suggestions for the use of the bridge but includes a detailed discussion of its principle of operation. Two charts to aid in computing power factor and dielectric constant are included.

Please mention the serial number of your bridge when writing for your copy of the book.

THERMOCOUPLES ▲ ▲ ▲ In addition to the line of contact-type vacuum-mounted thermocouples described in Part 2 of Catalog F, the General Radio Company is about to announce separate heater thermocouples mounted in the same style of bakelite case. An article discussing the general principles of thermocouple design and describing the General Radio thermocouples will appear in the next issue of the *Experimenter*.

THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the

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