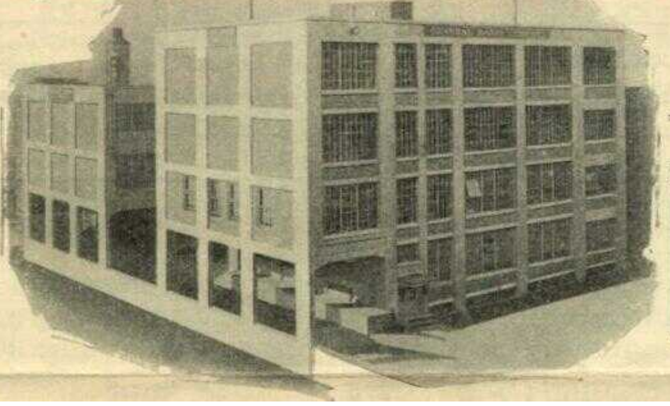
The GENERAL RADIO
EXPERIMENTER



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GENERAL RADIO CO., Cambridge, Mass.

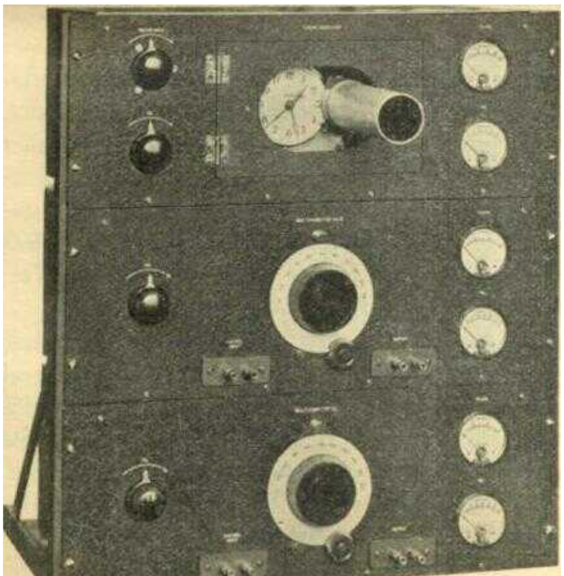
A *New Frequency Standard*

By JAMES K. CLAPP

FREQUENCY, like other physical quantities, is measured by comparing the unknown with a standard whose value has been established either absolutely or arbitrarily by general agreement We measure length with a yardstick, which has been compared by means of many intermediate "measurements" with the length of a certain bar recognized as the international standard. Similarly, we may measure frequency by comparing the unknown signal with one from a piezo-electric oscillator, let us say, which is our standard. If we were to inquire bow the frequency of the standard was determined, we should probably find that it was purchased from a manufacturer who compared it with a more accurate standard which he, in turn, had compared with another, still more accurate.

It is unnecessary to trace further the frequency standardizing sequence in order to understand why the General Radio Company is interested in the problem of standardization and the precise determination of frequency. As a manufacturer of piezo-electric and magnetostriction oscillators and tuned-circuit frequency meters, it is called upon to supply these instruments calibrated with an increasing degree of precision, largely because of the pressure being exerted upon all radio services to stay within their assigned channels. Although the laboratory standard used by General Radio is sufficiently accurate for all present needs, the possibility that even greater precision of calibration might be required made desirable a search for something better.

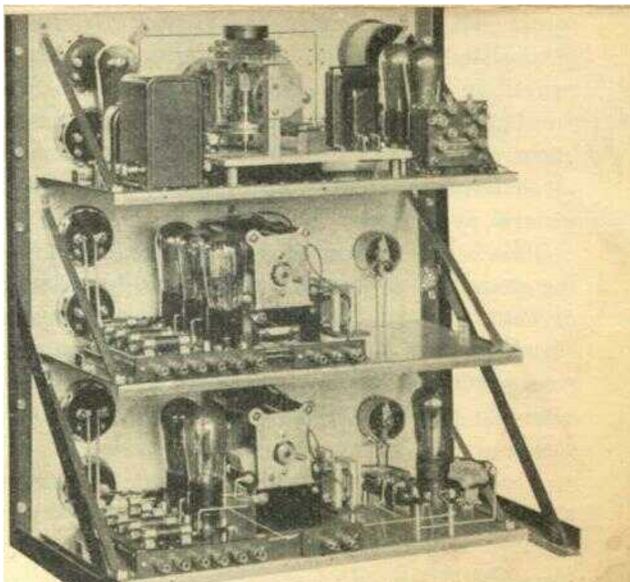
The requirements for General Radio's own frequency



THE. TWO-STAGE MULTIVIBRATOR AND TIMING AMPLIFIER FOR THE NEW FREQUENCY-DETERMINATION EQUIPMENT

FIGURE 1. (LEFT)

(RIGHT) FIGURE 2.



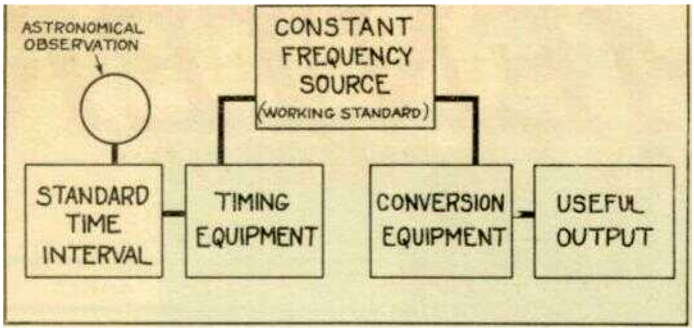


FIGURE 3. AN OUTLINE CHART FOR A PERFECTLY GENERAL FREQUENCY-DETERMINATION SYSTEM

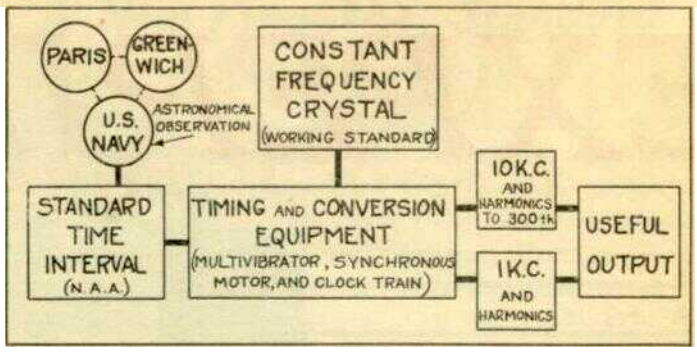


FIGURE 4. AN OUTLINE CHART FOR THE GENERAL RADIO COMPANY'S FREQUENCY DETERMINATION SYSTEM

standard are essentially the same as those for any laboratory that interests itself in the precise measurement of all frequencies. A few of the most important considerations are:

(1) It must be compact. Space is usually at a premium.

(2) It should be possible to check regularly the frequency of the standard without transporting it to some other laboratory for comparison.

(3) Means should be provided for obtaining from the standard a large number of frequencies in all parts of the communication frequency spectrum. For instance, the General Radio calibration laboratory is often called upon to measure in succession a wide variety of frequencies: a frequency meter for short waves, a piezo-electric crystal for a broadcasting station monitor, and the reed of an airplane beacon indicator (60 or 70 cycles), for example.

(4) It should be rugged, reliable, and inexpensive, and be capable of a precision of at least one part in a million.

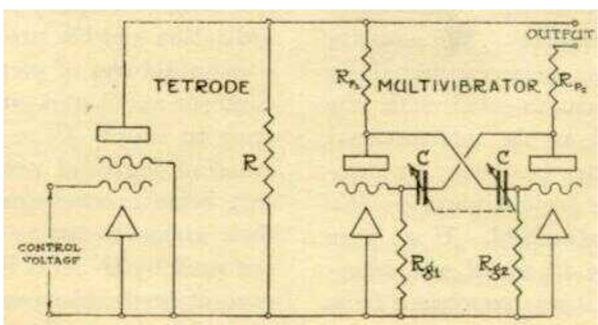


FIGURE 5. SCHEMATIC CIRCUIT OF THE MULTIVIBRATOR AND ITS AMPLIFIER

Before describing the new frequency determination equipment, let us refer to the writer's discussion of a generalized frequency determination system which appeared in the EXPERIMENTER for March. There it was pointed out that any such system must consist of three basic elements. The principal methods available for use in each of these were listed and an outline chart of a general system was drawn up.

This is here reproduced as Figure 3. It shows a working standard or source of constant frequency, a method of counting the number of oscillations executed by the standard over a long time interval, and a method of deriving from the working standard, directly or by means of a simple auxiliary, a sufficient number of useful frequencies.

The article also pointed out that the frequency measurement problem is essentially one of measuring a time interval and that the standard time interval (and, therefore, the standard of frequency) is the Mean Solar Day of which the second is a 1/86,400th part. In any discussion of frequency measurements, this concept cannot be overemphasized, for if, by some means, the number of oscillations of a constant-frequencv generator in a given time be counted, then the frequency or number of oscillations per second can be determined.

II

In the present system a piezo-electric crystal-controlled oscillator with a fundamental frequency of very nearly 50 kilocycles is employed as the working standard. This oscillator drives a step-down frequency converter of the multivibrator type, so that a voltage having a frequency one-fiftieth that of the working standard is available for running a synchronous-motor-driven clock. Crystal oscillator, frequency divider, and clock operate continuously, and, by the use of an attachment for comparing the clock time with radio time signals, the average frequency of the standard can be determined with a high degree of precision.

Besides driving the clock, the frequency divider furnishes continuously a 10 kilocycle fundamental with harmonics up to the 300th as well as a one kilocycle fundamental which also has a large number of harmonics. The 1000-cycle signal is available through a line amplifier at any point in the laboratory. The equipment;, therefore delivers a large number of frequencies from one to 3,000 kilocycles, but, what is most important, each frequency is known with the same precision that the frequency of the working standard is known.

To show how this system fits into the general system outlined in the EXPERIMENTER for March, the chart of Figure 4 has been drawn up. It will be noticed that both the timing and the conversion of the working-standard frequency are provided for by the same multivibrators.

Figure 4 also calls attention to the fact that the radio time signals used for timing the working standard are

(Concluded on page 4)

An Alternating-Current-Operated Radio-Frequency Oscillator

EVERY laboratory has need, at least occasionally, for a radio-frequency oscillator. Some time ago the General Radio Company designed and built its TYPE 384 Oscillator which when equipped with plug-in coils would cover a wide range of radio frequencies. This instrument is battery-operated and uses a tube of the 199-type. Another oscillator of even greater utility is now announced. It is similar in many ways to the older one, but it has a considerably greater power output besides operating from the 110-volt alternating-current supply.

The new equipment is entirely self-contained except for the plug-in coils. It makes use of a 227-type tube as an oscillator and a 201-A type tube as a rectifier in the plate-voltage supply. A transformer and a smoothing filter for supplying the filaments of the two tubes and for the plate voltage supply of the oscillator tube are included.

The frequency range, using the standard TYPE 384 plug-in coils is from 10 kilocycles to 20,000 kilocycles. Tuning is done with a straight-line wavelength variable condenser having a maximum capacitance of 500 micromicrofarads, together with an auxiliary 50 micromicrofarad condenser for fine adjustment. Knowing the type of condensers used and the frequency band covered by each coil, some idea about the criticalness of tuning for each coil can be estimated.

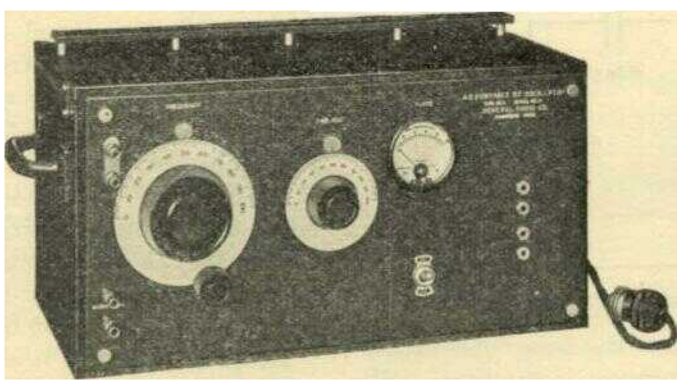


FIGURE 6. THE TYPE 584 A.C. PORTABLE R. F. OSCILLATOR. COILS ARE PLUGGED INTO THE FOUR JACKS AT THE RIGHT

The following table listing the coil ranges is taken from Catalog E with the wavelength ranges there listed converted into frequency:

Coil	Range		Price
Type 384-A	20,000—10,000	kc.	$3.00
Type 384-B	10,000—3750	kc.	3.00
Type 384-C	4,290—1500	kc.	3.00
Type 384-D	1,579—.522	kc.	3.00
Type 384-E	531—176	kc.	4.00
Type 384-F	176--68	kc.	4.00
Type 384-G	68—25	kc.	5.00
Type 384-H	25—10	kc.	8.50
Type 384-D8	1,500—500	kc.	4.50

The Type 384-D8 coil is a figure-8 coil designed to have a minimum external field.

A strip mounted on the cabinet top is provided for storing coils that are not being used.

The TYPE 584 Oscillator has a provision for injecting into its plate circuit a modulating voltage from any desired audio-frequency oscillator. A beat-frequency oscillator is suitable for this use.

A milliammeter is provided for indicating the average plate current of the oscillator tube. It is useful for showing when the tube is oscillating, and, in addition, it may be used as a reaction indicator in adjusting for resonance. Terminals for connecting a telephone head set into the circuit at a point of low radio-frequency potential have been provided.

The whole assembly measures 18 inches X 9-1/4 inches X 9-l/4 inches and weighs 22-1/2 pounds without tubes or coils. Being light in weight and relatively inexpensive, it is a handy addition to the equipment of any laboratory. It can be stored on a shelf when not in use and put into operation in only a moment when needed. It is the ideal laboratory heterodyne and general-purpose radio-frequency oscillator.

Price $140.00
Code Word.. OZONE

A *Speaker Filter for the 245-Type Tube*

THE heavy plate current required by the tubes commonly employed in power amplifiers can seriously damage the winding of a speaker through which it flows. Some device is, therefore, necessary for isolating the speaker from the plate circuit of the output tube. Either a transformer or a so-called speaker filter can be used for this purpose.

When the reproducer has a high impedance the filter makes the most economical unit. In general it consists of a choke coil and condenser combination connected as shown in Figure 8 reproduced on page 4. For best operation the choke coil should have a high impedance and the blocking condenser a low impedance at all voice frequencies. The lower the frequency, the farther both of these values depart from the ideal, so that for good low frequency response a large choke coil and a large con denser arc required.

Sometimes a section of the blocking condenser is placed in each of the speaker leads. This serves to keep the high voltage plate supply out of the speaker, but it also reduces the total condenser capacitance. If a condenser

FIGURE 7. THE TYPE 587-C SPEAKER FILTER

were to be placed in either speaker lead in the example shown in the diagram each section would need to be of

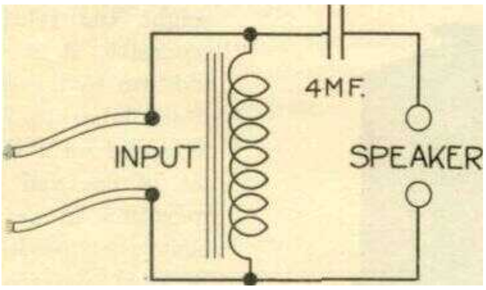


FIGURE 8. WIRING; DIAGRAM FOR THE TYPE 587-C SPEAKER FILTER

eight microfarads in order to have the same total capacitance that the four-microfarad unit now gives. The single condenser section is, therefore, much more economical. The choke-coil inductance is 40 henrys with rated current flowing.

The TYPE 587-C Speaker Filter has been designed for use with reproducers having an impedance averaging about 3000 or 4000 ohms. A class which includes almost all of speakers that are not of the so-called dynamic type. It was built primarily for use with a tube of the 245-type, and it will withstand without damage the maximum rated plate current of one of these tubes.

Connections can be made as shown in the diagram or the low potential terminal of the speaker may be connected to the negative side of the plate voltage supply. Sometimes regeneration occurs in an amplifier due to coupling in the common plate supply, but it can usually be minimized by the use of the alternative connection in which audio-frequency output currents are kept out of the B-supply.

SPECIFICATIONS

Maximum current	86 milliamperes
Choke coil inductance with maximum current	40 henrys
Direct-current resistance	700 ohms
Blocking condenser	4 microfarads
Impedance of choke coil at 25 cycles	6000 ohms
Impedance of blocking condenser at 25 cycles	1600 ohms

Code Word: FAVOR Price: $8.00

A New Frequency Standard

(Concluded from page 2)

dependent upon astronomical observations made at the U. S. Naval Observatory. The observatory checks the time signal transmissions from NAA for their accuracy, and compares them with those from GBR at Rugby, England, and from FYL at Bordeaux, France. Each month a report is issued in which the daily error in transmission is recorded as well as the results of comparisons with the two above-mentioned foreign stations. Although the time signal as transmitted from NAA (on its 113-kilocycle channel) has an average lag from true time of about 0.0.5 second, the interval between two successive noon-to-noon transmissions is correct to about 0.005 second. That is to say that, on the average, the 24-hour interval defined by the time signals is accurate to within one part in 13 million.

The clock used in the counting mechanism of the timing equipment consists of a Type 411 Synchronous Motor modified by the addition of a shaft carrying a shutter which makes one revolution per second. A neon lamp operated by a time-signal receiver is mounted behind the shutter, and with every received time dot the lamp flashes. By means of a suitable eye-piece, it is possible to compare the clock with the time signal to within 0.005 second. This precision is a close approach to the accuracy of time signal transmission, so that but little further refinement in the comparing device is needed at present. If necessary, however, other comparison methods already tried in our laboratory may be applied to increase the precision of comparison by at least five times.

Frequency division is accomplished by means of multivibrators, a circuit for which is shown in Figure 5. The multivibrator is a relaxation oscillator whose frequency is determined by the value of the condensers, C, and the resistances, Rp. The application of a voltage to the grid of the tetrode isolation amplifier results in an injection of a voltage of the same frequency into the multivibrator circuit, and, for a range of values of C, the fundamental frequency of the multivibrator assumes discreet values that arc submultiples of the control frequency and independent over that range of C. In this condition, the frequency of the multivibrator is determined by the frequency of the control voltage.

In the General Radio equipment, the 50-kilocycle working standard controls a multivibrator having a fundamental frequency of 10 kilocycles, and this multivibrator controls another with a fundamental of one kilocycle. Each multivibrator is also a source of harmonics of its fundamental frequency, which explains how this system can furnish so many useful, accurately determined frequencies for calibration and other comparison work.

A lack of space precludes a more detailed description of the new frequency-determination equipment, but the interested reader is referred for more details to a paper by L. M. Hull and the author appearing in the February issue of the *Proceedings of the I. R. E.*