

The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

RECENT DEVELOPMENTS IN FREQUENCY STANDARDS

It is now some years since General Radio first set itself to the task of building frequency standards for the radio industry. These years have been years of achievement in the fullest sense of the word. Beginning with the wavemeter in its various stages of development, continuing through the early days of quartz crystals and culminating in the highly accurate primary standard of frequency, General Radio has, through a program of constant development, contributed much to the art of frequency measurement. The aim of this program has been to produce equipment capable of the accuracy demanded by the scientist, simple in operation, and suitable for industrial and commercial use.

The announcement by the General Radio Company of the first commercially acceptable primary standard of frequency in 1929 was an important milestone in the field of frequency standardization since it meant that this class of measurement had been

lifted out of the laboratory nursing stage and made available to industry. It needed neither constant temperature room nor elaborate voltage regulating system, and was designed to operate under vibrations encountered in a factory building. This primary standard, the Class C-21-H Standard-Frequency Assembly, has found a wide use, not only in the electrical communication industry, but such fields as accurate time keeping and time measurement, the transmission of radio time signals, measurements of the velocity of rifle bullets, and of the velocity of light. Approximately thirty units are now in use in the United States and six foreign countries, operating under widely differing conditions of climate, but giving uniformly satisfactory service.

Five years' development produces considerable progress in design and manufacturing. Many improvements can be incorporated in each new lot of instruments, but eventually the point is reached where complete redesign becomes advisable.

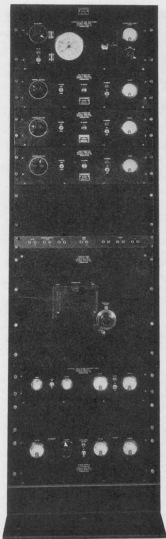


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With the advent of 1934, General Radio announces a new Class C-21-H Standard-Frequency Assembly, Series 690. While identical in its functional aspects with its predecessor, each component unit of the assembly has been redesigned and the result is a considerably higher accuracy specification and a vastly improved stability of operation. New and improved electrical circuits using modern types of vacuum tubes contribute materially to the improved accuracy and stability, while a number of features of mechanical design make the installation and operation a simple matter. The accuracy is conservatively specified as ± 5 parts in 10 million. Actually, one part in 10 million can be obtained over long periods of time.

A few of the outstanding features of this frequency standard are outlined below.

1. Piezo-Electric Oscillator

The crystal oscillator uses an electrical circuit which is a new and successful approach to the problem of making a quartz crystal oscillate at its resonant frequency. The over-all frequency stability with respect to operating parameters exceeds that obtainable with other types of oscillators. Automatic bias control assures constant amplitude and operation at small amplitude contributes materially to the frequency stability. The 50-kc quartz bar uses electrodes deposited directly on the quartz, and its mounting is designed to introduce as little damping as possible.

FIGURE 1. The new Class C-21-H Standard-Frequency Assembly



2. Multivibrators

The new multivibrators constitute a considerable improvement over previous types. The stability of control is exceptionally good, in spite of large changes in operating and control voltages. The circuit elements are adjusted at the factory before shipment and these adjustments are practically permanent, assuring correct operation when received. Three multivibrators are used operating at 50 kc, 10 kc, and 1 kc respectively.

3. Self-Starting Synchronous Clock

The synchronous-motor clock has been provided with a 60-cycle auxiliary motor for starting purposes. To bring the motor up to synchronous speed, it is only necessary to press a button on the panel.

4. Power Supply

The assembly is designed to operate from a 115-volt, 60-cycle a-c line. Two types of power supply equipment are available. One of these provides current for trickle charging lead-type storage batteries as in the previous model. The other furnishes filament and plate power directly from the line without the use of batteries.

There is no essential difference in the frequency stability obtainable from the floating-battery or from the completely a-c operated assemblies, and the choice between the two may well be based entirely upon whether or not 100 per cent continuous service is required.

With the completely a-c operated assembly, of course, a momentary failure of the power line will remove plate and filament supplies and interrupt the timing. The heat supply for

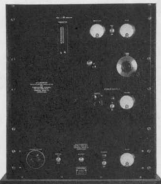


FIGURE 2. A Class C-10 Secondary Standard

the temperature-control unit will also fail, and, if the interruption lasts for more than a few minutes, the assembly will be out of service until the operating temperature of the crystal can be restored to normal. For a great many purposes, such interruptions are of no great moment, either because of an unusually reliable a-c supply or because the annoyance of interruptions in service is more than compensated by the additional cost of the floating-battery assembly and the necessary batteries.

The floating-battery assembly is the ideal installation where as close an approach as possible to continuous service is required. Both filament and plate supplies are carried by batteries and these can be chosen in sizes sufficiently large to carry the assembly for any emergency that the user cares to anticipate. Power for the temperature-control system comes directly from the a-c line, but, when it fails, relays automatically transfer the heater circuits to an "auxiliary heat reserve" which

can be any independent power source that the user sees fit to install.

5. General Considerations

Complete connecting cables, vacuum tubes, spare fuses, and pilot lamps, and blank panels for filling the rack are provided. All external wiring is enclosed and connections between the panels and the cable are made by insulated plugs. The general appearance is shown in the accompanying photograph. The Class C-21-II Standard-Frequency Assembly for floating-battery operation is priced at \$1,950.00; for complete a-c operation, \$1,875.00.

SECONDARY STANDARDS

The improved electrical and mechanical design features employed in the primary standard have also been incorporated in an a-c model of the Class C-10 Standard-Frequency Assembly. This secondary standard of frequency consists of a TYPE 675-L Piezo-Electric Oscillator, a TYPE 692-A Multivibrator (10 kc), either a TYPE 676-A (50-kc) or Type 476-A (100-kc)

Quartz Bar, and a TYPE 480-B Relay Rack.

The TYPE 675-L Piezo-Electric Oscillator uses the same oscillator circuit as does the primary standard just described. It includes two output amplifiers, one for supply output at the fundamental frequency, and the other for generating harmonics of the fundamental. A self-contained power supply has sufficient capacity to operate a maximum of three multivibrators. While the assembly is normally supplied with a single multivibrator, others can be added if desired.

The accuracy is ± 20 parts in one million and the stability over long periods is in the vicinity of ± 5 parts in one million. Power is obtained from a 115-volt, 60-cycle a-c line, and all vacuum tubes are included in the price.

Class C-10 Standard-Frequency Assembly, Series 600, with 50-kc quartz bar \$595.00

Class C-10 Standard-Frequency Assembly, Series 600, with 100-kc quartz bar \$565.00

—CHARLES E. WORTHEN

NEW VARIACS

A NEW SMALL SIZE, ALSO, 230-VOLT MODELS

A NEW type of voltage-adjusting device called the *Variac* was described in the June-July issue of the *Experimenter*. The *Variac* consists of a transformer so arranged that the voltage can be continuously adjusted in steps of about 0.4 volt. At no time is the circuit interrupted, and there is no rise in voltage between steps; that is, the *Variac* operates like a

wire-wound rheostat or voltage divider.

The *Variac* possesses several important advantages over the resistance controls commonly used for voltage adjustment purposes. The change in voltage with setting of the knob is essentially linear and is practically independent of the load current. Hence the *Variac* can be used to produce any voltage between the rated voltage and



zero for any load current within its range, unlike the rheostat in which control is lost as the load current approaches zero.

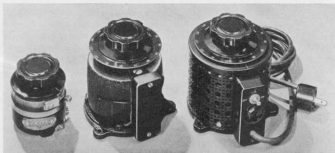
Furthermore, since series resistance is not introduced into the line as the control is varied, the voltage regulation afforded by a *Variac* is much better than with a rheostat. The high efficiency of a transformer is substituted for the necessarily inefficient resistance control.

Further development work has been done on *Variacs* for different line voltages and load current ratings. There is now available the TYPE 200-B *Variac*, a smaller unit designed for 115-volt service and a maximum current of 1.0 amperes. It is intended for building into other instruments requiring a smooth voltage control. Typical applications would be to vacuum-tube rectifiers whose output voltages must be adjustable under varying load conditions or to small motors requiring a speed control.

The small *Variac* is designed to give any desired voltage between 0 and full line voltage. Prices: TYPE 200-B *Variac* (for 115-volt line), \$8.50.

The small *Variac* is suitable for mounting either on a baseboard or behind a panel like all General Radio rheostats. By removing the knob shown in the photograph, loosening the brush arm, and pushing through the shaft, the knob can be attached to the other end, thus making over the unit for behind-the-panel mounting.

The unmounted and the mounted models of the large 5-ampere *Variac*, shown at the center and right in the photograph below and described in the June-July issue of the *Experimenter*, are also available for operation from a 115-volt, 60-cycle line. It has an output-voltage range from 0 to 130 volts so that it can be used to compensate for low line voltages.



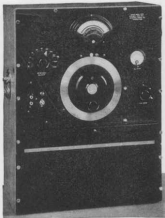
The three *Variacs*. Left to right, the TYPE 200-B described in the accompanying article and the TYPES 200-CU and 200-CM described in the *Experimenter* for last June-July



AS THE WAVE ANALYZER VIEWS THE TUNING-FORK OSCILLATOR

THE tremendous range in voltage that can be measured with the frequency-selective voltmeter known as the wave analyzer is nowhere better illustrated than in the analysis of a TYPE 213-B Audio Oscillator, shown on the opposite page. Harmonics as high as the eighth were picked off and measured even though the amplitudes got down to as little as 0.006 per cent of the fundamental voltage. The magnitude of the fundamental can be estimated for any value of load impedance by considering the curve of output in milliwatts.

In taking these data, the straightforward simplicity of the wave analyzer was of considerable help. After the preliminary adjustments (calibration check and detector balance) were



The TYPE 636-A Wave Analyzer



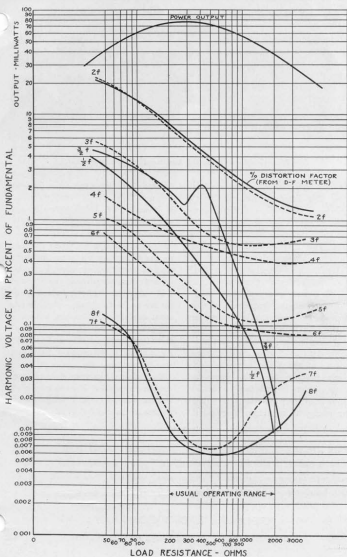
The 400-cycle TYPE 213-B Audio Oscillator whose waveform characteristics are shown on the opposite page

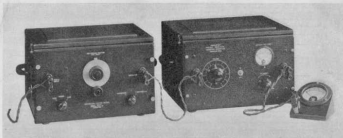
made, it was merely necessary to make one series of measurements for each value of load resistance into which the oscillator was to be worked.

The amplitude of the fundamental was first measured. The multiplier adjustment on the voltmeter was then changed until a deflection of 1000 divisions was obtained. The amplitude of each successive harmonic voltage was then taken, using the same multiplier setting, so that the amplitude of each harmonic expressed as a percentage of the fundamental could be read directly from the meter.

Of particular interest is the curve representing data taken with the distortion-factor meter on the same oscillator. The data agree to within ± 5 per cent of the values obtained by calculation from the wave-analyzer data. The distortion-factor meter, it will be remembered, is an instrument containing filters that reads directly in







The Distortion-Factor Meter and Auxiliary Equipment for distortion measurements at 400 cycles

per cent the distortion factor of the wave, the distortion factor being the ratio (expressed in per cent) between the r-m-s value of the complex wave without the fundamental to the effective value of the fundamental alone. It is an accurate and convenient instrument for distortion measurements at a single fixed fundamental frequency. Since the filter cuts out everything above the fundamental frequency, the instrument, of course, takes no account of the contribution of energy at $f/2$.

It should also be noted when using these data as a measure of the usefulness of the audio oscillator for a given purpose that the impedance range shown is extremely wide. For all normal purposes (such as supplying energy to a bridge) the load im-

pedance will lie somewhere between 200 and 2000 ohms. The data given, incidentally, are for the MEDIUM output impedance tap of the oscillator.

The oscillator has two other taps on its output transformer. The data given in the curves on the preceding page may be considered as applying to the other two taps by dividing by 10 to obtain values for the LOW tap and multiplying by 10 to obtain values for the HIGH tap. In other words, a load of about 30 ohms on the LOW tap would have the same harmonic content as 300 ohms on the MEDIUM tap or 3000 ohms on the HIGH tap.

Complete explanatory data concerning the TYPE 636-A Wave Analyzer will be found in the *General Radio Experimenter* for June-July, 1933.



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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