The GENERAL RADIO EXPERIMENTER

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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

BETTER MIXER CONTROLS

THE introduction of the General Radio TYPE 653 Volume Control early in 1933 was the beginning of the almost universal present practice of using step-by-step mixer controls in low-level circuits. The step-by-step design eliminates the three objections common to wire-wound controls: excessive noise, uncertain or fragile contact, and difficulties of cleaning and maintenance. Properly designed step-by-step controls combine very low electrical noise level with rigid mechanical construction and simplicity of cleaning.

Several thousands of the TYPE 653 Volume Controls are now in everyday use in hundreds of broadcast studios and sound motion picture installations in the United States and abroad. The past three years of experience with these controls has led to the development of a new design which incorporates several important improvements. The new unit is illustrated on page 2.

Two of the most essential features of any mixer control are a very low noise level (particularly since they are often used in low-level microphone circuits), in order that adjustments during a program are inaudible, and absolute dependability. Both the three-bladed switch arm and the contacts of the new TYPE 653 are made of beryllium-copper alloy. Since the switches and contacts are the same material, although differently tempered, electrical contact-potential noise is completely eliminated. Beryllium copper, which is a relatively recent development for this purpose, possesses remarkable strength, springiness, and wearing properties. Less tough contact materials when improperly lubricated may have a tendency to cut. The new alloy largely eliminates this difficulty. As a result, this switch assembly has indefinitely long life.

All contact surfaces which receive as much wear as a mixer control should, however, be cleaned and lubricated as a matter of routine maintenance. The dust cover of the new control is in two sections, and only the rear section can be taken off after installation. Removal of this section exposes the contacts but leaves all of the windings completely covered by the other section, so that there can be no possibility of damage to the windings during cleaning. In fact, all fine-wire windings and leads are completely covered at all times, except when the unit is removed from its panel mounting.

In redesigning the unit the depth has been shortened, and it now requires only 2$\frac{3}{16}$ inches clearance behind the panel. The diameter is 2$\frac{3}{4}$ inches, making it possible to mount six in a row on a standard 3$\frac{1}{2}$-inch relay-rack panel. New soldering terminals which are smaller in size and mechanically stronger have been added.

Another useful feature is the addition of a button on the skirted control knob, so that the setting can be determined in dimly lighted monitoring booths or without looking away from the program. The design of the skirted control knob was the result of a considerable investigation to find the size and shape most comfortable for long periods of manipulation. After three years of use the "feel" of the knob is still generally approved. The index button is added for improved utility.

The attenuation system is a ladder network having 33 attenuation steps of 1.5 decibels per step over most of the range but increasing increments toward infinite attenuation. The impedance is essentially constant over the entire attenuation range and is constant with frequency up to 30 kilocycles. The unit is arranged for panel mounting using the etched-metal dial plate for a drilling template. The dial plate is calibrated to show the approximate attenuation in decibels at all settings.

Four impedance sizes are available: The usual 50-, 200-, and 500-ohm values, and, in addition, a new 250-ohm size for use in the many present-day voice circuits of that impedance.

— Arthur E. Thiessen

Type	*Impedance*	*Code Word*	*Price*
653-MA*	50 Ω	CLUMP	$12.50
653-MB	200 Ω	COACH	12.50
653-MD*	250 Ω	CARAT	12.50
653-MC	500 Ω	COAST	12.50

* Delivery after May 1.

Photograph of the new Type 653 Volume Control

DIRECT MEASUREMENTS WITH GENERAL RADIO INSTRUMENTS

As a result of the continued demand of the commercial engineer and the academic research worker for accurate and convenient means of measurement of electrical quantities in their laboratories, the General Radio Company has, from time to time, in the course of the twenty years of its existence directed the abilities of the engineers to the solution of the measurement problems that have come to its attention. The General Radio *Experimenter* for June, 1935, gives, in the anniversary license of reminiscence, a brief historical account of the resulting developments.

Irrespective of sequence, where has the Company arrived?

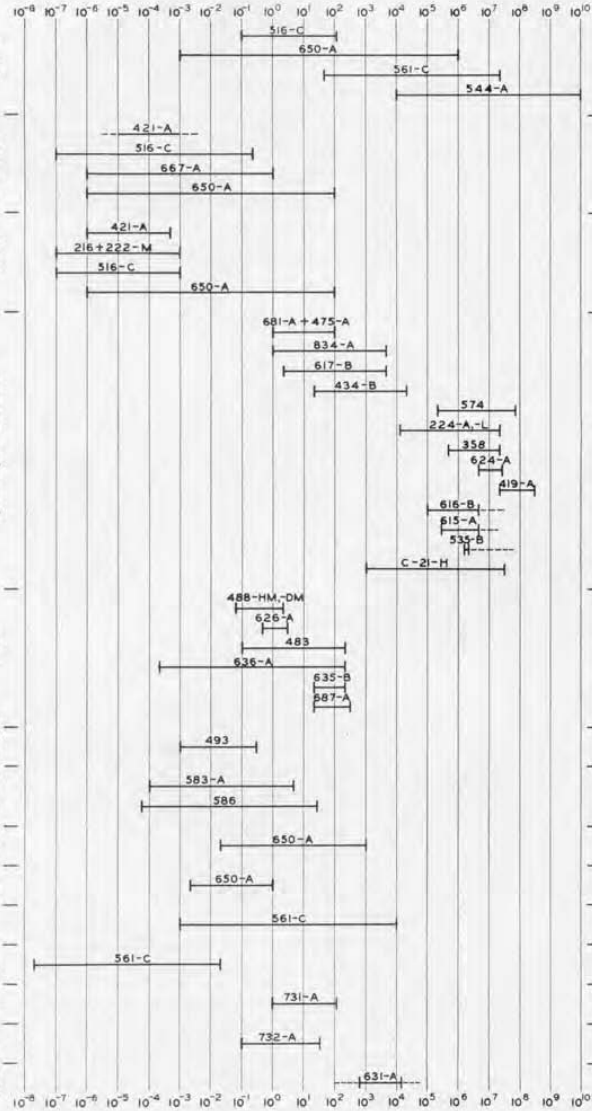
It is not the function of instrument makers to solve their customers' major problems, but rather to anticipate their minor ones. The worth of the instrument lies in the extent to which it supplies the desired information and leaves the worker free to achieve a guided solution to the primary problem. We all hesitate twice before using a spineless tape measure, yet are quite unperturbed by doubts while inspecting the fine graduations of a steel scale of a reputable manufacturer.

It is the belief of the Company that it has transferred many of the laboratory routine and secondary measurements from the tape-measure to the steel-scale class. The prerequisite that range and accuracy limits be known is no worse in simile than the few moments taken with the scale to ascertain its length and the fineness of its graduations.

The accompanying chart shows in brief outline the thorough coverage of all fields which have been achieved in the composite development of a line of measuring instruments, together with the frequencies at which the measurements may be made and the accuracy of the results. For extreme conditions of high impedances and high frequencies, it is to be expected that the accuracies will be somewhat less than the rated values shown.

The instruments are commercial products; price is therefore a factor. This is shown on the chart in that the wide ranges are in each case associated with a decrease in the rated accuracy, or with an increase in the cost above that of less accurate instruments in the same field. There stands out as well a clear demonstration of the restriction in working range previously necessitated by an increased range of operating frequencies. It is in this characteristic of the chart that the results of present investigations will be most evident. As the new instruments are announced, the inked-in lines will be longer than those they replace without an accompanying frequency restric-

DIRECT MEASUREMENT RANGES
OF GENERAL RADIO INSTRUMENTS



Unknown	Unit	Instrument	Accuracy	Frequency Range
R	Ohms	516-C	1%	0–5 megacycles
		650-A	1%	0–10,000 cycles
		561-C	0.5%	1000 cycles
		544-A	3%	direct current
L	Henries	421-A	0.25%	125–4000 kilocycles
		516-C	1%	60 c.–5 megacycles
		667-A	0.2%	60–10,000 cycles
		650-A	2%	10–10.000 cycles
C	Mfds.	421-A	0.25%	125–4000 kilocycles
		216+222-M	0.1%	200–10,000 cycles
		516-C	1%	60 c.–5 megacycles
		650-A	1%	10–10,000 cycles
ω	Cycles per Second	681-A + 475-A	±5 c.	direct indicating
		834-A	2%	direct indicating
		617-B	±1 c.	direct reading
		434-B	0.5%	direct reading
		574	1%	direct reading
		224-A,-L	0.25%	by calibration
		358	0.25%	by calibration
		624-A	0.1%	by calibration
		419-A	1%	by calibration
		616-B	0.1%	by calibration
		615-A	0.1%	by calibration
		535-B	0.5%	by calibration
		C-21-H	0.00005%	with aux. equip.
E	Volts	488-HM,-DM	10%	10–10,000 cycles
		626-A	1–4%	0–4 megacycles
		483	10%	10–10,000 cycles
		636-A	5%	20–16,000 cycles
		635-B	waveform only	0–15 Mc.
		687-A	waveform only	0–50 Mc.
I	Amps.	493	2%	0–30 megacycles
W	Watts	583-A	4%	10–10,000 cycles
		586	2.5%	10–10,000 cycles
Q	X/R	650-A	15%	1000 cycles
D	R/X	650-A	15%	1000 cycles
μ		561-C	0.5%	1000 cycles
G_m	Mhos	561-C	0.5%	1000 cycles
Modulation	%	731-A	2%	50–50,000 kilocycles
Distortion	%	732-A	1%	400 cycles
Rpm		631-A	2%	direct reading

tion, and will tend to cluster to the sides of the chart.

Considering the individual sections, the outstanding position of the TYPE 650-A Impedance Bridge as a laboratory instrument is at once evident. Not only dominating each impedance field by its audio-frequency working range, its value is further enhanced by its triple appearance and its consequent general usefulness.

The narrowed working range of the TYPE 516-C Radio-Frequency Bridge for resistance and capacitance as shown on the chart is that within which the bridge is direct reading at all frequencies between sixty cycles and five megacycles. Measurement of impedances beyond these ranges is not a difficult matter, involving only the necessity of establishing series or parallel combinations that come within the direct-reading range of the bridge.

In the field of frequency measurements first appears the direct-indicating type of instrument previously available only for the measurements of voltage, current, and power. The TYPE 834-A Electronic Frequency Meter indicates directly the frequency of an applied audio-frequency voltage, while the combination of the TYPE 681-A Deviation Meter and a reference standard indicates directly the deviations from any desired point in the radio-frequency spectrum.

Harmonic extension methods are as useful as the fundamental ranges in heterodyne frequency meters and, where usable, are shown as dashed extensions on the chart.

The CLASS C-21-H Standard Frequency Assembly, together with its auxiliary interpolation equipment, constitutes a primary standard for the measurement of frequencies within the range and with the accuracy shown. Perfectly usable for secondary measurements, its range and accuracy are included on the chart for purposes of comparison.

For the measurement of current and voltage the instruments shown are those valuable beyond a-c and d-c meter movements because of individual advantages. These vary from the 10-megohm input impedance of the TYPE 626-A Vacuum-Tube Voltmeter to the single-frequency selectivity of the TYPE 636-A Wave Analyzer. The cathode-ray oscillographs are shown for their ability to give a visual picture of the waveform of voltages within the ranges marked. The value of the TYPE 493 Thermocouples is their ability to permit related measurements to be made with direct and radio-frequency currents, for the effect of frequency on their indications may be neglected over a wide frequency range.

The varied fields at the bottom of the chart illustrate the usefulness of General Radio instruments in specialized tests. Each of the quantities may be obtained as the result of the comparison of two or more measurements of the types listed above, but the use of the instruments results in an economy of apparatus, labor, and time. The uses are specialized, but the applications are not. Each unit performs the same measurement regardless of the primary purpose and under a variety of experimental conditions.

— F. IRELAND

THE FREQUENCY STANDARD AT GENERAL RADIO COMPANY

AMONG the important developments of modern communication engineering is the primary frequency standard. Frequency standardization, of vital importance to the user of communication measuring instruments, is even more essential to the manufacturer, who must be able to work to a far greater accuracy.

The frequency standardization laboratory at the General Radio Company has three important uses: First, it provides a central standard which is used throughout the plant for all frequency calibrations and frequency and time measurement. Secondly, it is used as a proving ground for all advances made in the design of frequency standards and associated equipment. Finally, it is an operating exhibit of a large number of the frequency- and time-measuring instruments manufactured by the Company. The complete frequency standard is shown in the photograph of Figure 1. A very brief listing of the equipment provided will be made here, the balance of the description being made from the functional viewpoint. Referring to the photograph, from left to right, the equipment in the various racks is as follows:

Rack 1: CLASS C-21-H, Series 690, Primary Frequency Standard with full alternating current operation. Crystal

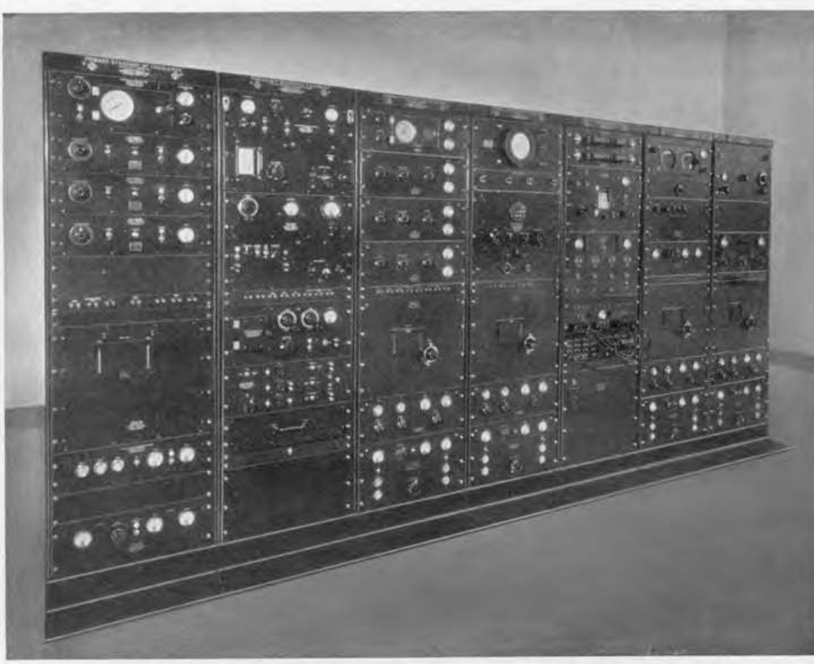


FIGURE 1. The primary frequency standard at General Radio Company

Oscillator No. 1 is in this rack.

Rack 2: Auxiliary and Interpolation Equipment for frequency measurements. Racks 1 and 2 constitute a complete frequency measuring system.

Rack 3: CLASS C-21-H, Series 590, Primary Frequency Standard, with floating battery operation. (Crystal Oscillator No. 2.) This unit was placed in service in the fall of 1929 and it has been in continuous service ever since, except for minor shutdowns to move the equipment from one location to another in the building.

Rack 4: Crystal Oscillator No. 3, Cathode-Ray Oscillograph equipment, and direct-reading audio-frequency meter (TYPE 834-A).

Rack 5: Power distribution panel, signal distribution amplifiers and line connections, beat-frequency recorder and integrator.

Rack 6: Crystal Oscillator No. 4, power supply equipment for stroboscope, recorder, etc., and high-speed stroboscopic clock.

Rack 7: Crystal Oscillator No. 5; selective amplifier (for 1 kc multiples), time signal receiver, and automatic time switch.

The five 50-kc crystal oscillators are maintained in continuous operation, with two of them operating complete multivibrator and timing systems. These two syncro-clocks are checked several times each day against the U. S. Naval Observatory Time signals as transmitted hourly through N.A.A. on 113 kc. If desired, the timing systems may be connected to any other pair of crystal oscillators.

Time comparisons between syncro-clocks, or between the syncro-clocks and the time signals, are made by means of the high-speed stroboscopic clock. This clock has two high-speed hands, one turning once per second, and the other ten times per second. This latter hand travels over a scale of 100 divisions, each division representing one millisecond. The slower hand travels over a scale of ten divisions, each one-tenth of a second, or each one representing a complete revolution of the high-speed hand. These high-speed hands are viewed in the light from a stroboscope lamp permanently mounted in the clock case.

FIGURE 2. The dial of the high-speed stroboscopic clock. The right-hand dial carries two hands, the shorter rotating once each second, the longer ten times per second

The stroboscope lamp is flashed each dot of time signal, the flash lasting but a few microseconds. When seen in the flash, the high-speed hand appears perfectly stationary, and its position may be read to one-fifth of a division or 0.0002 seconds.

The five crystal oscillators constitute the hearts of five frequency standards, two of which are checked against time, the others being checked in terms of these two by beat-frequency methods. One oscillator (No. 5, actually) is purposely maintained about eight parts in a million low in frequency, so that definite beat frequencies can always be obtained between this oscillator and each of the other four.

In the intercomparing recorder system four detectors and amplifiers are

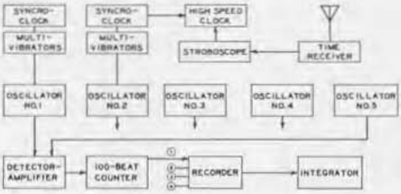


FIGURE 3. Block diagram of the primary standard. For convenience, only one beat recording channel is shown in detail. Beats between Oscillator No. 5 and each of Nos. 2, 3, and 4 are counted and recorded in the same way

provided, one for each of the four pairs of crystals. Each beat-frequency output operates a counter, which counts 100 beats. At the end of each 100-beat interval a dot is printed on the paper strip in the recorder. A point is printed on the record for each beat frequency during every five-minute interval throughout the twenty-four hours. The record is really a *time* record (the time of 100 beats of the beat frequency) but is easily converted into frequency. A time record is used because all four records may be made simultaneously on the recorder. A change of frequency of one part in ten million, in any five-minute period, is easily seen on the record. The record gives a continuous check on the performance of any crystal in terms of the others. If any crystal changes frequency, the record indicates which one changed, how much it changed, and in which direction.

The integrator adds up the successive times of the 100-beat intervals for each of the four pairs of crystals. It is simply a system of four revolution counters arranged to record seconds. The integrator gives a very sensitive indication so that small frequency differences are measurable with high accuracy and in a short time. The integrator is particularly useful in detecting either a very small slow drift in frequency or in studying the small frequency changes resulting from arbitrary changes in circuit parameters, such as changes in filament or plate voltages.

The frequency distribution system consists of a bank of amplifiers, four channels being provided for each main output frequency of 1, 10, and 50 kilocycles. A system of about 30 tone circuits, extending to laboratories and shops, permits the use of the frequency standard at any required point in the building. As required, outputs at multiples of 1 kc, essentially free of other harmonics and of the fundamental, may be distributed from the selective amplifier. Other frequencies, up to 5000 cycles, are available from the linear beat-frequency oscillator. These may be monitored, if necessary, against the standard by means of the cathode-ray oscillograph. — J. K. CLAPP.

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts