THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

MAKING A GOOD INSTRUMENT BETTER

Also IN THIS ISSUE

● **THE TYPE** 913-A Beat-Frequency Oscillator[1], announced in 1942, established standards of performance not previously achieved by oscillators of this type. Its immediate widespread acceptance showed that frequency stability, low distortion, and constancy of output were truly important features in an audio oscillator. Experience with field use over the past six years, however, has shown several ways of improving the original design to provide better performance for the customer and greater convenience in manufacture. Changes have therefore been made from time to time that have been incorporated in the successive Type 913-B and Type 913-C models, culminating in the new Type 1304-A. These changes, in total, make the new instrument considerably different from the original and warrant mention as typical of the refinements that successively appear in instrument redesign.

[1]H. H. Scott, "Bringing the Beat-Frequency Oscillator Up to Date," *General Radio Experimenter*, Vol. XVII, No. 2, July, 1942.

Figure 1. Panel view of the Type 1304-A Beat-Frequency Oscillator. New features include an illuminated, precision-type, main dial, and an incremental frequency dial with a range of −50 to +50 cycles.

OSCILLATOR

The original oscillators used Type 6SK7 pentodes in tuned-plate tickler-feed-back circuits, with output pickup coils feeding the grids of the Type 6SA7 mixer directly. When properly constructed, these circuits gave excellent stability, but considerable difficulty was found in maintaining the high quality of fabrication necessary for satisfactory coils.

The coils were wound on slotted catalin coil forms and were adjusted to the correct inductance by iron-dust cores on a mounting constrained at each end. It was found that dimensional changes of the form material with time and temperature caused relative motion of the dust cores and coils, resulting sometimes in excessive drift, and sufficient trouble on this score was ultimately encountered to make it desirable to look into other constructions.

In the course of this investigation it was found that a Hartley or Colpitts oscillator using a simple single-winding coil was more stable than the tickler-feed-back oscillator using the three-winding coil, because the circulating current in the tuned circuit flowed through the whole coil, causing uniform heat distribution, and because the close coupling between grid and plate circuits minimized phase shift. The final coil design, therefore, turned out to be a single multilayer universal-wound coil on a simple, unslotted ceramic form. As a further simplification, it was found that the inductance could be held to a close enough tolerance that no iron-dust-core trimming was necessary. Simplification of construction, improvement of performance, and reduction of manufacturing cost were therefore simultaneously achieved.

BUFFER AMPLIFIERS

In the original design, no buffer amplifiers were interposed between the beating oscillators and the mixer. A pentagrid mixer tube was used, and it was felt that the isolation obtained by using two individual grids, fed from the low-impedance pickup windings on the oscillator coils, was adequate to minimize low frequency distortion caused by incipient locking of the oscillators.

With the new, simplified oscillator coils, no low-impedance pickup coil was available. To permit high-impedance capacitance voltage dividers to be used to feed the mixer grids without increasing the cross-coupling between oscillators to an intolerable amount, buffer amplifiers were necessary. These were obtained without increase in the tube complement by changing the oscillator tubes from pentodes to twin triodes. One half of each twin triode was used as the oscillator section, the other half as a cathode-follower amplifier.

The plates of both sections of the twin triodes are operated at r-f ground, with the cathode of the oscillator section tapped on the oscillator coil and the grid connected to the end of the coil at the highest r-f potential. This particular method of operation leads to two desirable results: first, the stator of the main tuning capacitor operates at d-c ground and, second, the plates of the twin-triode sections act as shields, eliminating the need for additional shielding of the tubes.

The grids of the buffer-amplifier sections are supplied through capacitance voltage dividers, which minimize loading of the oscillator circuits and permit adjustment of the voltages supplied to the mixer grids by varying the setting of small adjustable ceramic trimmer capacitors. Once the proper grid voltages for the mixer have been established, it is therefore possible to set these voltages to the same levels in all instruments. This simple adjustment, combined with the excellent isolation afforded by the buffer amplifiers, has effected very considerable improvement in the low-frequency distortion below 100 cycles and has reduced locking of the oscillators to a point where beats of less than 1 cycle can be sustained without pull-in.

MIXER

The chief problem in adjusting the mixer for proper operation in the Type 913-A and 913-B Oscillators was in obtaining independent settings for output voltage and minimum distortion. It was, however, found that, if the former arrangement of bias controls was changed so that the common cathode-bias for both grids was adjusted by a rheostat, and the bias for the signal grid (grid No. 3) by a potentiometer in parallel, the two adjustments for output voltage and minimum distortion could be made with no observable interaction. The improvement in performance from this change, from the adjustable oscillator voltages, and from the improved isolation of the buffer amplifiers has been very great. In previous models careful selection of the mixer tube had been necessary to maintain the low distortion desired. In the new design, on the other hand, nearly any tube will perform satisfactorily, and large numbers of tubes previously rejected for high distortion have been found completely satisfactory.

AMPLIFIER

Changes in the amplifier circuit and shelf were made principally because of difficulty with hum introduced from the heaters of the Type 6SF5 phase-inverter tubes. Replacement of these two tubes with a single Type 6SL7-GT Twin-triode has resulted in no further difficulty and has made it possible to rearrange parts to provide more convenience in assembly.

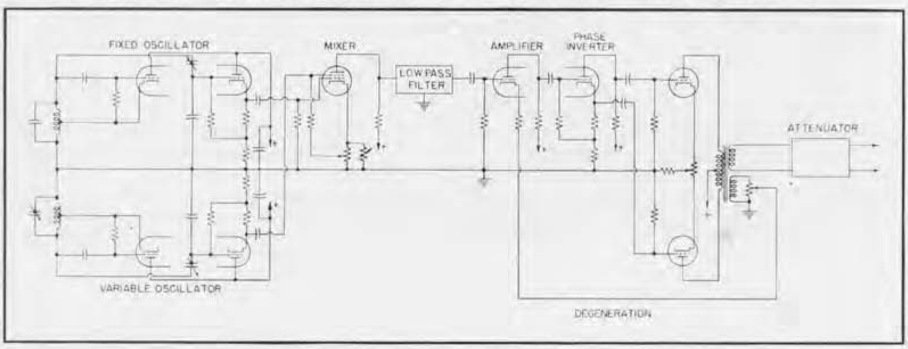
POWER SUPPLY

Rearrangement of the power-supply shelf and the substitution of a single 5V4-G for the two 6X5-GT tubes previously used have eliminated a difficult hum-reducing adjustment and improved heat-radiation conditions, the temperature rise in the oscillator compartment, for instance, being only 6 C.

MECHANICAL SIMPLIFICATION

Since these various changes necessitated a rearrangement of parts, considerable attention was given to utiliz-

Figure 2. Elementary schematic circuit diagram of the Type 1304-A Beat-Frequency Oscillator.



ing the available space most efficiently and to simplifying assembly. As a result, parts and circuit adjustments are more accessible, and wiring is simpler than in previous models.

NEW FEATURES

These variations have improved performance substantially, reduced the total number of tubes by two, simplified assembly and testing, and lowered manufacturing cost. As a result it has been possible to add new features at no increase in price.

The first of these is a cycles increment dial. This was first introduced in the TYPE 713-A Beat-Frequency Oscillator[2] and, since the discontinuance of this oscillator, many customers have requested that it be added to the TYPE 913 if it were ever redesigned. In the new TYPE 1304-A a better capacitor has been used than in the old TYPE 713-A, but the function and scale range remain the same. It is interesting to note that a considerable simplification in construction has been achieved by connecting the zero adjust capacitor across the variable-oscillator capacitor since no shield can for this capacitor is necessary and valuable panel space is conserved. The variation of capacitance required for zero adjustment is so small that no effect upon calibration accuracy results.

The second new feature is injection of line voltage into the beat-indicator circuit. As experience has been gained over the years with the adjustment of the variable capacitor used to give true logarithmic response over three decades of frequency, it has been found practical to furnish calibrations accurate to closer and closer tolerances. It has now become possible to adjust to $\pm(\frac{1}{2}$ cycle $+ 1\%)$, which is closer than zero beat can be established with the neon light. To translate this accuracy of adjustment into accuracy of readings, a more precise "zero" adjustment can be made at the line frequency by observing the waxing and waning of the neon light as the output of the oscillator beats with the line voltage. The improvement, of course, results from the fact that the beat is determined at a frequency where the amplifier has normal gain, as contrasted to the zero-beat condition where the amplifier has insufficient gain to operate the neon light until the deviation from zero beat is of the order of two cycles.

The third new feature is the improved gear-drive dial, patterned after the new TYPE 907-LA. This dial has better bearings than the old dial, smoother running gears and less backlash, and is simpler in construction and easier to make.

The TYPE 1304-A Beat-Frequency Oscillator furnishes an outstanding example of the painstaking development work that goes into instrument redesign over a period of years. As a commercial product in its own right, we believe this oscillator to be the finest now obtainable.

—D. B. SINCLAIR

[2] L. B. Arguimbau, "TYPE 713-A Beat-Frequency Oscillator," *General Radio Experimenter*, Vol. X, No. 10, March, 1936.

SPECIFICATIONS

Frequency Range: 20 to 20,000 cycles.

Frequency Control: The main control is engraved from 20 to 20,000 cycles per second and has a true logarithmic frequency scale. The total scale length is approximately 12 inches. The effective angle of rotation is 240°, or 80° per decade of frequency. The frequency-increment dial is calibrated from +50 to −50 cycles.

Frequency Calibration: The calibration can be standardized within 1 cycle at any time by setting the instrument to the line frequency or to zero beat. The calibration of the frequency control dial can be relied upon within ±(1%+0.5 cycle) after the oscillator has been correctly set to zero beat. The accuracy of calibration of the frequency-increment dial is ±1 cycle.

Zero Beat Indicator: A neon lamp is used to indicate zero beat at the line frequency or at zero scale.

Frequency Stability: The drift from a cold start is less than 7 cycles in the first hour and is essentially completed within two hours.

Output Impedance: The output impedance is 600 ohms, either grounded or balanced-to-ground, and is essentially constant regardless of the output control setting. With load impedances of 2000 ohms or less, the output is balanced for all settings of the output control. With higher load impedances, unbalance may occur at low settings of the output control.

Output Voltage: Approximately 25 volts open circuit. For a matched resistive load the output voltage varies by less than ±0.25 db between 20 and 20,000 cycles. The open-circuit output voltage is approximately 40 volts with the output switch in the HIGH position.

Output Control: The output control is calibrated from +25 to −20 db, referred to 1 milliwatt into 600 ohms.

Output Power and Waveform: NORMAL output 0.3 watt maximum when operated into a matched load, with total harmonic content approximately 0.25% between 100 and 7500 cycles. Below 100 cycles the harmonic content increases, and may reach 0.5% at 50 cycles. A panel switch allows an increase in the output power to a maximum of 1 watt. For this HIGH position of the OUTPUT switch the distortion is less than 1% between 100 and 7500 cycles and increases to 2% at 50 cycles. With the OUTPUT control turned fully on, the harmonic content is approximately doubled when the oscillator is operated into a very low impedance. With the OUTPUT control turned 3 db or more below maximum load, impedance has very little effect upon the waveform.

A-C Hum: For NORMAL output the a-c hum is less than 0.1% of the output voltage.

Terminals: Jack-top binding posts with standard ¾-inch spacing and standard Western Electric double output jack are provided on the panel. A standard multipoint socket and plug provide duplicate output terminals on the back of the instrument for relay-rack installation.

Mounting: 19-inch relay rack panel; removable wooden ends are supplied so that it may be used equally well on a table.

Power Supply: 105 to 125 volts, 50 to 60 cycles a-c. A simple change in the connections to the power transformer allows the instrument to be used on 210 to 250 volts. The total consumption is about 100 watts.

Tubes:

3—6SL7-GT	2—6V6-GT
1—6SA7	2—OD3/VR150
1—5V4-G	1—991

All are supplied with the instrument.

Accessories Supplied: A seven-foot line connector cord and a multipoint connector.

Dimensions: 19⅜ x 14¼ x 7½ inches, over-all.

Net Weight: 41½ pounds.

Type		*Code Word*	*Price*
1304-A	**Beat-Frequency Oscillator**	CAROL	**$450.00**

PATENT NOTICE: U. S. Patent No. 2,298,177. Licensed under patents of the American Telephone and Telegraph Company.

GR POWER CORD NOW AVAILABLE

There has been a considerable demand lately for replacement power cords of the type supplied with General Radio instruments and, because of this, we are making the power cord available as a standard catalog item.

The cord is 7 feet long and has the plug and socket ends molded in rubber directly to the two-conductor, No. 18, Type S5, stranded cord. Net weight is 8 ounces.

Type		*Code Word*	*Price*
CAP-35	**Power Cord**	CORDY	**$1.75**

A NEW MODEL OF THE MICROVOLTER*

The audio-frequency Microvolter is a very useful accessory for the electronics laboratory. Used in conjunction with an oscillator, the Microvolter converts it to a standard signal generator, capable of such measurements as gain or loss, frequency characteristic, overload level, and hum level on amplifiers, networks, and other low-frequency equipment.

This combination is also useful for the measurement of the generated voltage of microphones, vibration and phonograph pickups, and other transducers by the insert-voltage method. The Microvolter supplies the standardizing voltmeter and the calibrated adjustable attenuator which is necessary for providing an accurately known voltage over the range from 1 microvolt to 1 volt.

The Type 546-B Audio-Frequency Microvolter, which has been widely used for such measurements, has recently been replaced by a new model, the Type 546-C. Chief improvements in the new instrument are (1) a voltmeter which is more sensitive and has a better frequency characteristic, and (2) the adoption of the standard 600-ohm level for the input and output impedances.

The voltmeter uses a miniature copper-oxide rectifier designed, as in the earlier Microvolter, to have a negligible frequency error over the audio-frequency range. In addition, a compensation circuit corrects for frequency error (at the reference level labeled "0 db") up to 100 kilocycles per second to within ±5%. This compensation accordingly extends the usefulness of the meter to cover the full frequency range of the attenuator. The increased sensitivity reduces the non-linear loading of the rectifier on the input with a reduction in the waveform distortion introduced by the unit to less than 0.2% for a 600-ohm source. This low level of distortion brings the Microvolter in line with the low-level generally required from modern instruments, and, if the source impedance is reduced to much less than 600 ohms, its distortion is even less. The meter scale is calibrated in db with respect to the reference level so that an approximate correction for output level can be made when a reduced input level is desired.

The attenuator settings are made by

*Reg. U. S. Patent Office.

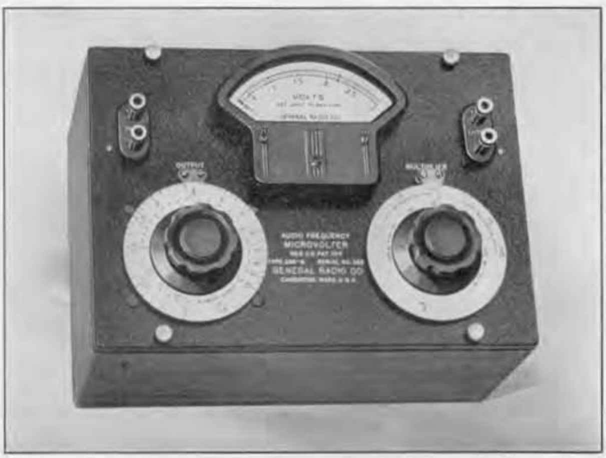


Figure 1. Panel view of the Microvolter. Photograph shows previous model, Type 546-B. New model differs very little in appearance.

means of two panel controls, one a six-step decade multiplier and the other an individually calibrated dial which gives continuous variation over each decade. The dial carries both voltage and decibel calibrations. The voltage scale is approximately logarithmic and the decibel scale approximately linear.

The output voltage is expressed as the open circuit voltage in microvolts or millivolts, and the open circuit level in decibels is expressed in db above one microvolt. This reference level is used for the convenience of having almost all positive decibel readings over the range of the instrument. By subtracting 123.8 db, this level can be transferred to dbm (decibels with respect to one milliwatt) into a 600-ohm load.

The decibel calibration makes it possible to obtain gain or loss values directly in decibels for amplifiers, transformers, lines, and other networks without the necessity of converting voltage ratios.

—ARNOLD P. G. PETERSON

SPECIFICATIONS

Output Voltage Range: From 0.1 microvolt to 1.0 volt open circuit, when the input voltage is set to the standardized reference value.

Accuracy: For open-circuit output voltages the calibration is accurate within $\pm(3\% + 0.5$ microvolt) for output settings above 1 microvolt and for all frequencies between 20 and 20,000 cycles. For higher frequencies up to 100 kc the calibration is accurate within $\pm 5\%$ for output settings above 100 microvolts. These specifications apply only where waveform and temperature errors are negligible (see below).

In calculating ratios of output voltages, at a given frequency, the accuracy of any given reading can be considered to be within $\pm(2\% +$ 0.5 microvolt), at frequencies up to 100,000 cycles. At the higher frequencies this accuracy applies only at levels above 100 microvolts.

The microvolter can be used on dc if an external meter is used or if the internal meter has been calibrated for dc.

Output Impedance: The output impedance is approximately 600 ohms and is constant with setting within $\pm 5\%$. This impedance is sufficiently low so that no correction on the output voltage is necessary for load impedances of the order of 100,000 ohms and greater.

Input Impedance: Approximately 600 ohms, substantially independent of output setting on all but the highest multiplier position.

Waveform Error: The accuracy of the microvolter as a calibrated attenuator or voltage divider is independent of waveform. The absolute accuracy of the output voltage calibration depends on the characteristics of the input copper-oxide rectifier voltmeter, which has a small waveform error that depends in turn on both the phase and the magnitude of harmonics present in the input. This error in the voltmeter can, in general, be neglected when the microvolter is used with ordinary laboratory oscillators. The rectifier-type voltmeter itself introduces some distortion unless the source impedance is very low. With a 600-ohm source the distortion introduced is about 0.2%.

Temperature Error: The accuracy of the calibration is independent of temperature when the microvolter is used as an attenuator or voltage divider. The absolute accuracy is affected slightly by temperature because of change in the voltmeter characteristics. The necessary correction for temperatures from 65° to 95° Fahrenheit is furnished with the instrument. The effects of humidity are negligible.

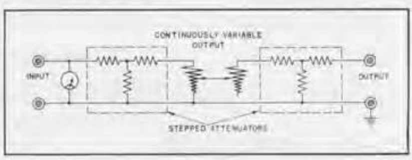
Power Source: The driving oscillator must be capable of furnishing about 2.2 volts across 600 ohms, or about 8 milliwatts.

Terminals: Jack-top binding posts are mounted on standard ¾-inch spacing.

Mounting: The instrument is mounted on an aluminum panel in a shielded walnut cabinet.

Dimensions: (Length) 10 x (width) 7 x (height) 6⅜ inches, over-all.

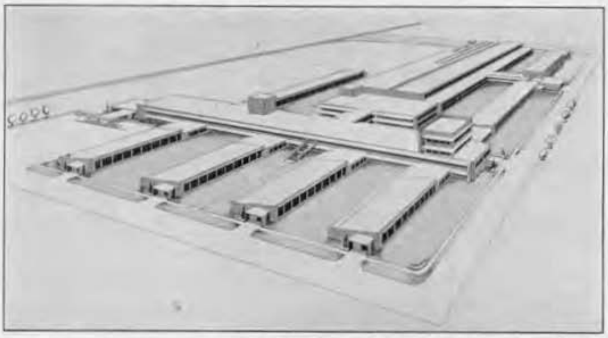
Net Weight: 6½ pounds.



Type		*Code Word*	*Price*
546-C	**Audio-Frequency Microvolter***	CROWN	**$110.00**

*Reg. U. S. Pat. Off.

MISCELLANY



NAVY DEDICATES NEW LABORATORY Aerial view of the new $8,000,000 Michelson Research Laboratory, dedicated on May 8, at the Naval Ordnance Test Station, Inyokern, California. Named in honor of the noted physicist, Dr. Albert A. Michelson, the new laboratory contains 410,000 square feet of floor space. It includes facilities for research and development in all branches of physical science, extensive modern shop facilities, and a mathematics section for theoretical work.

TECHNICAL PAPERS — "Determination of the Loudness of Noise from Simple Measurements," by Leo L. Beranek, Acoustics Laboratory, M.I.T., and Arnold P. G. Peterson, Engineer, General Radio Company; at the Washington, D. C., Meeting of the Acoustical Society of America, April, 1948.

—"A Standard-Signal Generator for F-M Broadcast Service," by Donald B. Sinclair, Assistant Chief Engineer; at the New England Radio Engineering Meeting, May 22, 1948.

— C. T. Burke spoke on the "Need for Improved Quality in Electron Tubes for Instrumentation and Industrial Use" at the Electron Tube Conference held by the A. I. E. E. Joint Subcommittee of Electronic Instruments, at Philadelphia, March 29.

RECENT VISITORS — Mr. Hayward C. Parish, Distributor of General Radio products in Australia; Mr. Ching Yi Sui and Mr. Hsiung Hsu, Central Broadcasting Administration, Shanghai; Mr. Mei-Lian Cheng, Central Radio Corporation, Nanking.

CREDITS — As is usual in instrument development, several engineers collaborated in producing the finished design of the TYPE 1304-A Beat-Frequency Oscillator. S. R. Larson was responsible for many of the new ideas and seeing the job through, while F. D. Lewis supplied the detailed criticism of the previous design as a guide to improvement. The project was carried out under the supervision of D. B. Sinclair, author of the article that appears in this issue.

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