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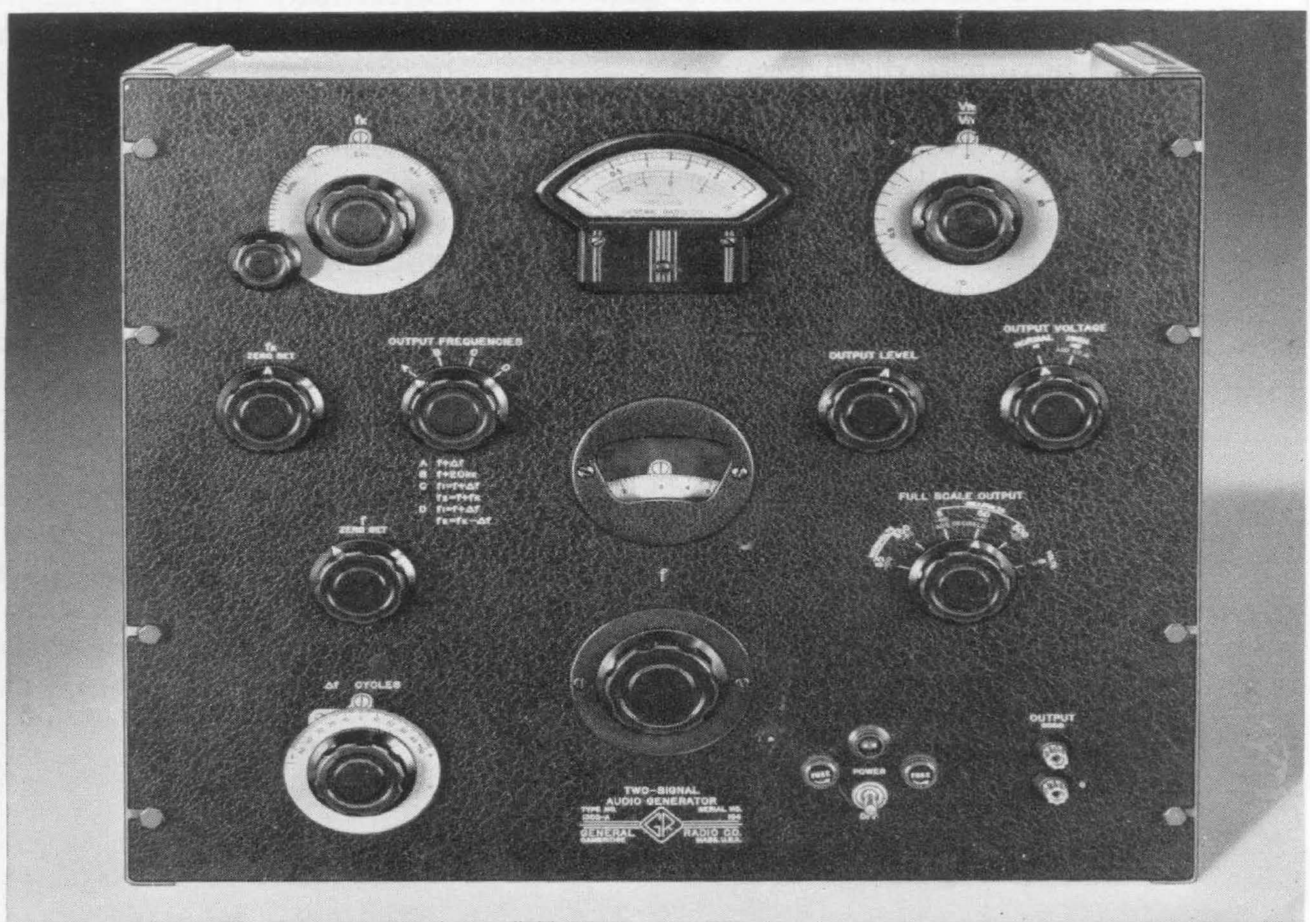
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

AN AUDIO-FREQUENCY SIGNAL GENERATOR FOR NON-LINEAR DISTORTION TESTS

● **MODERN METHODS** of testing audio-frequency devices require a test-signal generator of considerable versatility. In addition to a single, low-distortion, sinusoidal signal for the relatively simple harmonic-distortion and amplitude-frequency response tests, it must also be capable of supplying simultaneously two signals of differing frequencies for the intermodulation measurements that yield important information about the production of unwanted inharmonic difference tones, to which the ear is very sensitive.

These requirements are met by the TYPE 1303-A Two-Signal Audio Generator, which is particularly designed for intermodulation measure-

Figure 1. Panel View of the Type 1303-A Two-Signal Audio Generator.



ments but is also an extremely useful and adaptable instrument for any laboratory where audio-frequency measurements are made. It will supply any of the following signals:

1. A single low-distortion sinusoidal voltage adjustable in frequency from 20 c to 40 kc in two ranges, 20 c to 20 kc and 20 kc to 40 kc.

2. Two low-distortion sinusoidal voltages, each separately adjustable, one to 20 kc and the other to 10 kc.

3. Two low-distortion sinusoidal voltages, with a fixed difference in frequency maintained between the two as the frequency of the one voltage is varied. The fixed difference frequency is adjustable up to 10 kc, and the lower of the two frequencies is adjustable up to 20 kc.

The output is continuously adjustable and is calibrated both in volts and in db with respect to 1 milliwatt into 600 ohms.

These different output combinations make the Type 1303-A Audio Signal Generator an excellent signal source for the three standard non-linear distortion tests. These tests are: (1) The widely used harmonic distortion test.[1] (2) The intermodulation method that evaluates distortion in terms of the resultant modulation of a high-frequency tone by a low-frequency tone[2,3,4] (standardized by the SMPE).[5] (3) The difference-frequency intermodulation method, which evaluates distortion in terms of the amplitude of the difference-frequency components produced by intermodulation of two sinusoidal test signals of equal amplitude (recommended by the CCIF).[6,7,8] The Type 736-A Wave Analyzer is a convenient detector for any of these tests.

This versatile source is necessary for distortion testing because frequently tests by a single method do not show up all the non-linear distortion that can occur in a system.[8] Tests by different methods are particularly necessary in development work, where performance data must be obtained over a wide range of operating levels and frequencies. Later, in production testing, one system can usually be selected as the most satisfactory for checking faults.

Several methods are needed, even in testing audio amplifiers, particularly when large amounts of feedback are used. Some other devices that require tests by a method other than the standard harmonic method are hearing aids, high-efficiency speech-reproducing systems, magnetic and other recording systems,[9,10] f-m systems with pre-emphasis, noise suppressors, filter networks (particularly of the feedback type), loudspeakers, and, in general, any system of restricted frequency range.

The two-frequency signals supplied by this oscillator are also useful in cross-modulation studies on carrier and telemetering systems, meter testing,[11,12] differential phase measurements and psychoacoustic tests. The single-frequency signal can be used for any of the usual tests that require a signal in the frequency range from 20 c to 40 kc. Representative uses are for tests on audio-frequency lines, networks, and amplifiers; for modulating signal generators and test oscillators; and as a voltage source for acoustic tests, recording tests, and bridge measurements. It can also be used for measuring other small audio voltages by substitution methods; for the measurement of generated voltage of microphones, vibration and phonograph pickups, and other transducers by the insert voltage method;[13] and for the measurements of gain or loss, amplitude response, and harmonic distortion, as a function of frequency.

DESCRIPTION

The Type 1303-A Two-Signal Audio Generator generates the signals delivered at the output by a beat-frequency method, using the same type of oscillators and mixers that were developed for the Type 1304-A Beat-Frequency Oscillator.[14] Three oscillators and three mixers are used to provide the various signals listed above, and the outputs of the mixers are combined in a linear adding network. This combined signal is applied to a low-distortion power amplifier. The output voltage is obtained from the power amplifier through a 600-ohm attenuator system with a voltmeter to monitor the voltage level at the input of the attenuator.

Particular care has been taken to keep the harmonic content and the intermodulation products in the output of the signal generator at a very low level. This feature is, of course, necessary when the generator is used in non-linear distortion measurements. The low level of distortion has been achieved by careful design of the oscillator and mixer system and by using a degenerative, low-distortion, power amplifier.

The high stability characteristics of the Type 1304-A Beat-Frequency Oscillator have been duplicated here, so that the generator is well suited for applications that demand a signal source having high stability of voltage and frequency. The frequency drift from a cold start is only a few cycles.

Output System

The output level is adjustable by an *L*-pad output-level control. This level is indicated by a voltmeter calibrated in voltage and in decibels with respect to an output of one milliwatt into a 600-ohm line (dbm). Following the voltmeter is a six-position 600-ohm attenuator also calibrated in decibels. The open-circuit output voltage is adjustable from 5 microvolts to 5 volts on the low-distortion output and up to 50 volts on the high-level output.

The combination of oscillator, voltmeter, and attenuator makes the instrument a standard-signal generator that can be used to measure other small audio voltages by substitution methods and to determine gain and attenuation. In addition, the output voltage of the oscillator is practically constant over the entire frequency range, a feature which greatly facilitates tests of amplitude response and distortion as a function of frequency.

Frequency Controls

The scale of the main frequency-control dial is logarithmically divided over the range from 20 c to 20 kc. It is a duplicate of the scale used on the Type 1304-A Beat-Frequency Oscillator, so that the recording systems and recording paper used with that oscillator can also be used with this new generator.

This standard audio-frequency band of the instrument has been extended by a second range, 20 kc to 40 kc, which is selected by a panel switch. This frequency range is an important one for ultrasonic work.

The cycles-increment control permits small variations in frequency to be obtained above and below the setting of the main dial for frequencies up to 20 kc. The span of the cycles-increment dial is −50 to +50 cycles. This control is useful for checking small changes in frequency, for some psychoacoustic tests, and for manually producing a small warble in output frequency.

THE TWO-SIGNAL OSCILLATOR SYSTEM

The method used for generating the two-frequency signals[15] can be understood by reference to the block diagram of Figure 2. When the switches are in the positions C and D, the two signals are available at the output. In position C, oscillator No. 1 and oscillator No. 2 are applied to mixer No. 1 to produce a signal (indicated on the diagram as $f+f_k$) which is filtered and applied to the fader control, labeled $\frac{Vf_2}{Vf_1}$. At the same time oscillator No. 2 and oscillator No. 3 are applied to mixer No. 3 to produce a filtered signal, labeled $f+\Delta f$. This signal is applied to the other half of the fader system, and the generator output is obtained from this fader after being amplified in the low-distortion amplifier and attenuated in the attenuator.

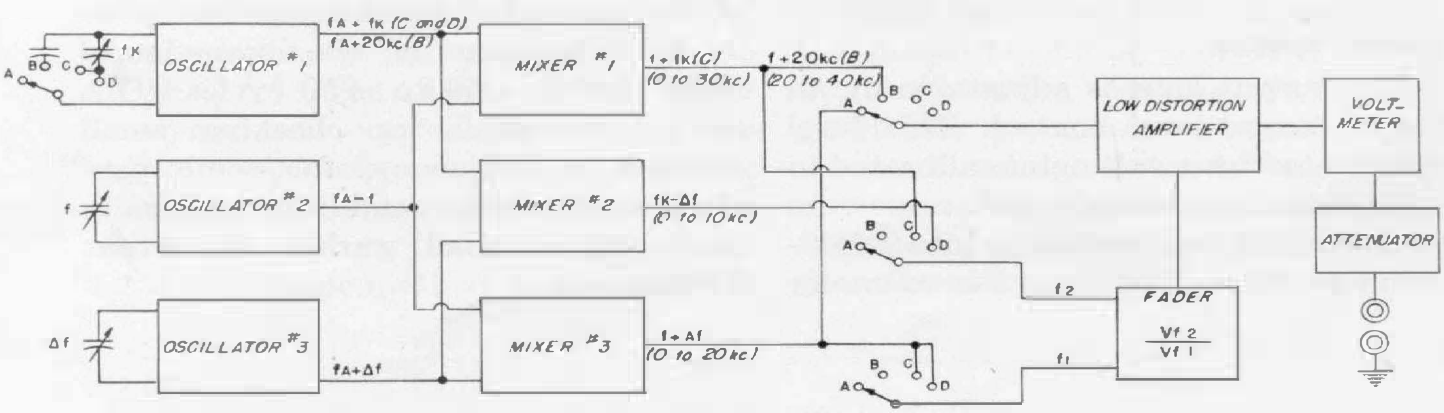
The controls labeled f_k, f, and Δf are initially set to zero, and adjustments are then made so that all three oscillators are operating at the same frequency, labeled f_A. Then the control, f_k, can be set to a desired difference frequency, say 400 cycles, which means that oscillator No. 1 is operating at a frequency of f_A+400. As oscillator No. 2 is adjusted by the control, f, its frequency becomes f_A-f, where f is the reading of the main frequency-control dial. The frequency of the signal from mixer No. 1 is the difference between the two applied frequencies, f_A+400 and f_A-f. This difference is $f+400$. At the same time the frequency of the signal from mixer No. 3 is the difference between the two applied frequencies, f_A and f_A-f. This difference is f. The frequencies of the two signals that make up the output are then $f+400$ and f. As the control, f, is varied, these two signals vary in frequency but the difference in frequency is maintained constant at the value set by the control, f_k, in this case, 400 cycles.

In position D, oscillator No. 1 and oscillator No. 3 are applied to mixer No. 2, and oscillator No. 2 and oscillator No. 3 are applied to mixer No. 3. In this case, two beat-frequency generators result with oscillators No. 1 and No. 2 beating with the common fixed oscillator No. 3. The two signals are then separately adjustable in frequency by the controls, f_k and f.

OPERATION — CCIF METHOD

The constant-difference-frequency feature of the two-signal output is particularly convenient for the CCIF type of distortion test. This feature simplifies checking the even-order distortion that produces a distortion component equal in frequency to the difference in frequency between the two applied frequencies. The Type 736-A Wave Analyzer connected at the output of the device under test can be tuned to this constant difference-frequency. Then,

Figure 2. Functional block diagram illustrating the method of generating two-frequency signals.



with the Type 1303-A Two-Signal Audio Generator as a source, this component of distortion can be determined as a function of frequency by turning the main frequency control over the required range. No retuning of the wave analyzer is necessary, and the measurement of this component of distortion is simpler than any other test of distortion over a wide frequency range. The other components of distortion are determined by retuning the wave analyzer as the frequency of the source is changed. However, by using a special analyzer system with a carefully designed square-law rectifier, Thilo and Koschel[7] have reported it possible to extend the above simplicity of observation to determine approximately the other important difference-frequency components.

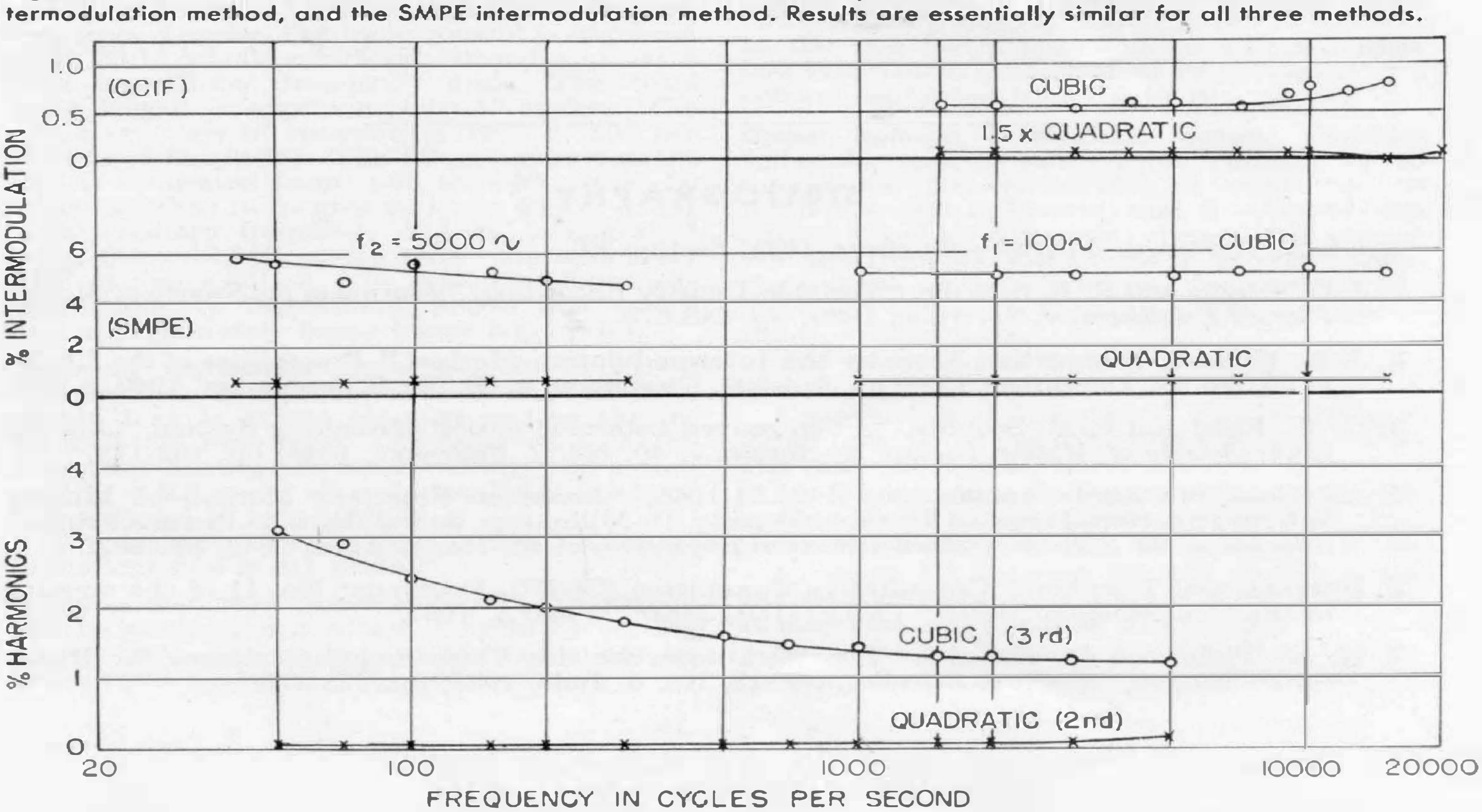
The individual components of the two-signal output are set equal in amplitude for the CCIF test. However, the amplitudes can be set by means of a calibrated control to have any ratio over the range from 0.1 to 10.

OPERATION — SMPE METHOD

The provision of a two-signal output with the frequencies of the two signals separately adjustable makes this generator very convenient for the SMPE type of intermodulation test. With this method, a low-frequency signal, usually about 100 cycles, and a high-frequency signal, often about 5 kc, are used. The low-frequency signal is set by the calibrated control to have an amplitude of four times that of the high-frequency one. Here one uses a wave analyzer to measure the amplitudes of the side-band components spaced about the high-frequency signal at frequency intervals equal to the low-frequency signal frequency. These side-band components are produced by non-linear distortion that causes modulation of the high-frequency signal by the low-frequency signal.

When a Type 736-A Wave Analyzer is used as the detector system for this method, a wide range of input signal frequencies can be used with the Type

Figure 3. Non-linear distortion in an audio amplifier as measured by the harmonic distortion method, the CCIF intermodulation method, and the SMPE intermodulation method. Results are essentially similar for all three methods.



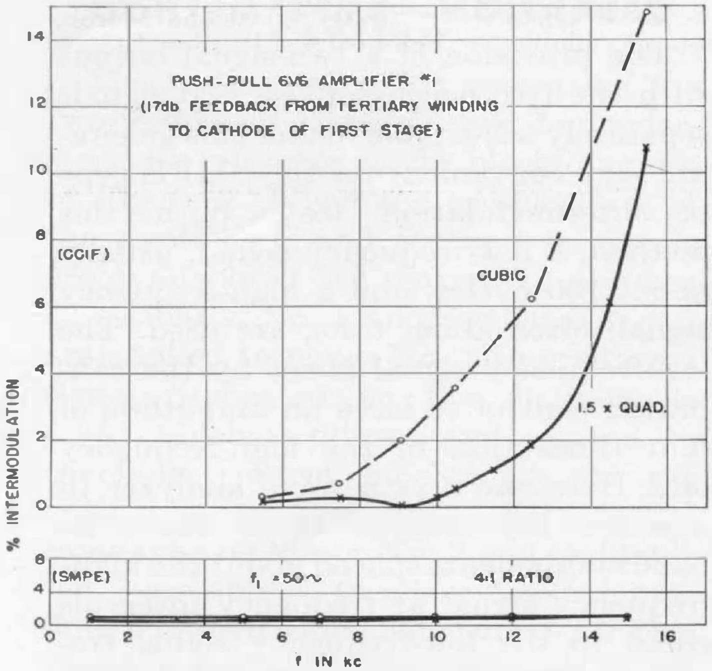


Figure 4. Results of measurements by the two intermodulation methods on an amplifier that shows marked differences for the two methods.

1303-A Two-Signal Audio Generator as the source. If one of the commercially available intermodulation detector systems is used, the range of signal frequencies that can be used is more limited, but the measurements for this SMPE test can be made more quickly.

TYPICAL MEASUREMENTS

Some results of measurements of nonlinear distortion are shown in Figures 3 and 4. The audio amplifier which was measured and gave the results shown in Figure 3 uses four 6B4 tubes in push-pull parallel in the output stage. The operating level was 16 watts in the single-signal case, and the measurements using two signals were made with the same peak-to-peak signal voltage with correspondingly reduced output power level. The results are plotted with the ordinate scales adjusted to show the essential similarity of results by all three methods.[8]

However, this similarity occurs only in some systems; the results shown in Figure 4 show marked differences for the two intermodulation methods. At high frequencies the CCIF method here shows the presence of distortion that is not indicated by the SMPE method. The two amplifiers used here were each uniform in gain as a function of frequency within one decibel from 40 c to 16 kc so that this variation in distortion measurements is not a result of a poor response characteristic.

—A. P. G. Peterson

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SPECIFICATIONS

Frequency Range: Single frequency output: 20 to 40,000 cycles in two ranges, *A*, 20 to 20,000 cycles, and *B*, 20,000 to 40,000 cycles. Double frequency output: There are two combinations of double-frequency output, *C* and *D*.

C: One frequency, f_1, of 20 to 20,000 cycles and a second frequency, f_2, higher than f_1 by a fixed amount, which may be between 0 and 10,000 cycles. As f_1 is varied, the difference frequency remains constant.

D: One frequency, f_1, of 20 to 20,000 cycles and a second frequency, f_2, of 20 to 10,000 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. 20 kc is switched in to give 20 kc to 40 kc. A 3¼ inch auxiliary frequency dial, f_k, is engraved from 0 to 10,000 cycles over approximately 180° of dial rotation. The scale distribution is approximately logarithmic above 500 cycles and approximately linear below 500 cycles.

Frequency Calibration: Main dial, 20 to 20,000 cycles: The calibration can be standardized within 1 cycle at any time by setting the instrument 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.

Auxiliary dial, 20 to 10,000 cycles: The frequency can be standardized within 1 cycle by setting to zero beat. The calibration of the dial can be relied upon within ±(3% +10 cycles).

Zero Beat Indicator: The output voltmeter can be used to indicate zero beat.

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 Attenuator: The output attenuator has six steps from −100 to 0 db with an accuracy of ±1% of the nominal attenuation.

Output Control: For each step of the attenuator the output voltage can be continuously varied from zero to maximum voltage. With two-frequency output, the ratio of the voltages at the two frequencies can be adjusted from less than 0.1 to greater than 10 by means of a control calibrated from 0.1 to 10.

Output Voltage: NORMAL output provides full-scale, open-circuit output voltages of 50 microvolts, 500 microvolts, 5 millivolts, 50 millivolts, 500 millivolts, and 5 volts. HIGH output provides full-scale, open-circuit output voltages from 500 microvolts to 50 volts. When the output voltage is of two frequencies, the indicated voltage is the sum of the voltages at the two frequencies.

The variation of output voltage with frequency is as follows:

f, range *A*, and f_1, ranges *C* and *D:* Between 20 and 20,000 cycles the output voltage varies less than ±0.25 db.

f + 20 kc, range *B:* Between 20 and 35 kilocycles the output voltage varies less than ±0.3 db. It may drop 1 db at 40 kilocycles.

f_2, range *C:* Between 20 and 20,000 cycles the output voltage varies less than ±0.3 db. It may rise 0.75 db at 30 kilocycles.

f_2, range *D:* Between 20 and 10,000 cycles the output voltage varies less than ±0.25 db.

Output Voltmeter: The output voltmeter is calibrated in volts at open circuit and in dbm. Above 10% of full scale, the calibration is accurate within ±5% of the reading.

Output Impedance: The output impedance is 600 ohms resistive within ±2%. One side of the output circuit is grounded.

Output Power: HIGH output is 1 watt maximum into a matched load. NORMAL output is 10 milliwatts, maximum, into a matched load.

Harmonic and Intermodulation Distortion: Distortion of NORMAL output is not affected by the load impedance. Distortion of HIGH output is not affected by the load impedance except in the 0 db attenuator position. Settings of the output control and attenuator have no effect on the distortion.

Harmonic Distortion: For NORMAL output the total harmonic content is less than 0.25% from 100 to 8000 cycles. Below 100 cycles the harmonic content increases and may reach 0.5% at 50 cycles. For HIGH output the total harmonic content is less than 1% from 100 to 8000 cycles. Below 100 cycles the harmonic content increases and may reach 2% at 50 cycles.

Intermodulation Distortion: (1) CCIF: Quadratic and cubic distortion for frequencies above 1000 cycles and a difference frequency greater than 100 cycles are each less than 0.15% on NORMAL output and less than 0.5% on HIGH output.

(2) SMPE: The square root of the sum of the squares of the quadratic and cubic distortion for f_1 between 40 and 300 cycles and f_2 between 1000 and 15,000 cycles is less than 0.5% on NORMAL output and less than 3% on HIGH output.

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

Terminals: Type 938 Binding Posts on panel. 4-terminal socket in back.

Mounting: 19-inch relay rack panel with walnut end pieces.

Power Supply: 105 to 125 v., 210 to 250 v., 50 to 60 cycles. Power consumption 135 watts.

Tubes:

4—6SL7-GT	1—5R4GY
3—6SA7	1—6Y6-G
2—6V6-GT	1—6SJ7
2—6SN7-GT	1—OD3/VR-150
1—6J5	1—3-4
1—6H6	

Accessories: Power cord, multipoint plug.

Other Accessories Required: For measurements of harmonic and intermodulation distortion the Type 736-A Wave Analyzer is recommended as a detector.

Dimensions: (Width) 19¼ x (height) 17⅞ x (depth) 14⅞ inches overall.

Net Weight: 80 pounds.

Type		*Code Word*	*Price*
1303-A	**Two-Signal Audio Generator**	BEGET	**$1050.00**

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