THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

DISTORTION MEASUREMENT IN THE BROADCASTING STATION

● **THE MEASUREMENT** of audio fidelity, distortion, and noise in the broadcasting station has long been considered desirable in order to maintain the high quality service of which modern transmitting equipment is capable. This measurement takes on new importance with the requirement for proof-of-performance checks to comply with the amendments to the Federal Communications Commission Rules and Regulations, Sections 3.254 and 3.46, effective August 1, 1949. These amendments call for a determination of the over-all noise and distortion of the complete broadcasting station at least once a year, with one such measurement to be made during the four months immediately preceding the date of application for renewal of license. Many stations already make these measurements at frequent intervals as a routine maintenance operation.

The measurement of over-all distortion and noise requires the use of an audio test oscillator of low inherent distortion, a distortion and noise meter, and a demodulator for conversion of the transmitted r-f wave back into audio-frequency voltages. This demodulation facility is generally provided by the modulation monitor (TYPE 1931–A Amplitude Modulation Monitor, TYPE 1170–A F–M Monitor).

Figure 1. Panel view of the Type 1932-A Distortion and Noise Meter.

RECOMMENDED EQUIPMENT

The TYPE 1301–A Low-Distortion Oscillator is a convenient and reliable source of audio voltage for test purposes, with distortion less than 0.1% over the range from 40 to 7500 cycles, and less than 0.15% distortion up to 15,000 cycles. The general features of this oscillator are described on page 6.

The TYPE 1932–A Distortion and Noise Meter provides means for the measurement of sine-wave voltages, distortion, and noise throughout the audio range. The over-all pass-band of the voltmeter circuit extends to 45,000 cycles, thus including all noise and distortion products contained in this range. In particular, the third harmonic of a 15,000-cycle test signal is included.

The continuously tunable null network covers the range from 50 to 15,000 cycles. The voltmeter circuit makes use of a half-wave rectifier and is calibrated in root-mean-square volts. The meter receives all the uni-directional pulses coming from the rectifier and acts as an electro-mechanical integrator. The half-wave rectifier with un-bypassed meter is the equivalent of a full-wave rectifier for noise and distortion measurements, and is somewhat more convenient to use.

With the audio test source connected, combined distortion and noise are measured by (1) setting the voltmeter circuit for full-scale deflection, (2) balancing out the fundamental frequency of the test oscillator, and (3) reading the value of the residual distortion and noise. Details of the TYPE 1932–A Distortion and Noise Meter are given on page 5.

A typical installation for measuring the audio linearity, distortion, and noise in a broadcasting station is shown in the diagram. The modulation monitor supplies the necessary low-distortion demodulation device. As will be apparent from this diagram, a large broadcasting plant with several studios, or more than one transmitter site, may find it desirable to use more than one set of distortion-checking equipment.

ACCURACY

The TYPE 1932–A Distortion and Noise Meter, together with the TYPE 1301–A Low-Distortion Oscillator, makes a combination which will perform the measurements required in both f-m and a-m stations. All the required audio check frequencies are covered for both services. The f-m requirements for maximum allowable distortion are the

Figure 2. Panel view of the Type 1301-A Low-Distortion Oscillator.

most stringent. The maximum total allowable distortion is 2.5% between 100 and 7500 cycles, no more than half of which, or 1.25%, may be contributed individually by (a) the transmitter, (b) the studio-transmitter circuit, or (c) the audio facilities. With only 0.1% distortion in the source (TYPE 1301–A) and the distortion meter able to measure distortion and noise down to below 0.1%, it is fair to assume that the error in measurement of distortion cannot be greater than the arithmetic sum of these two quantities or 0.2%. Hence the allowable distortion of 1.25% may be measured easily without the necessity for subtracting a large amount of distortion contributed by the test source and the distortion meter.

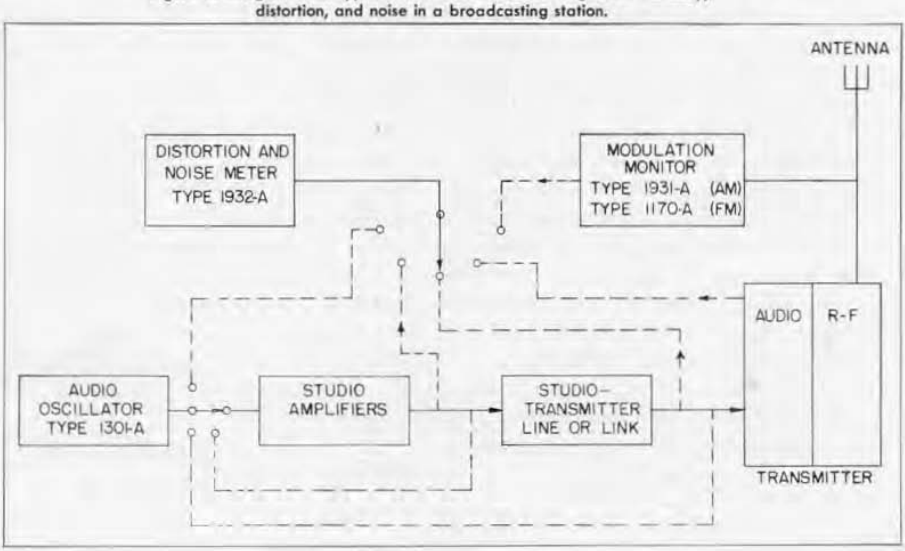
Since the TYPE 1932–A Distortion and Noise Meter does not require a separate simultaneous connection to the test oscillator, it is possible to make remote measurements. Because the distortion in the test oscillator is so low, these measurements can be made with the assurance that the distortion observed is in the equipment under test and not in the test source.

The distortion indicated by the TYPE 1932–A Distortion and Noise Meter is proportional to the average value of the wave that remains after the fundamental component is suppressed. The difference between this average value and the root-mean-square[1] value of distortion is small, and the distortion percentage indicated may be considered to be identical with the r-m-s distortion percentage within the accuracy specification of the distortion and noise meter. The catalog specification on accuracy is ±5% of full scale, which allows both for this difference between the average and r-m-s values and for the usual accuracy limitations of the metering system.

The percentage distortion can be based on the amplitude of the fundamental alone or on the amplitude of the total signal. The total signal is used as a reference in the TYPE 1932–A Noise and Distortion Meter. The difference between the two reference values is negligible for values of distortion less than 10%, but should be considered when higher values of distortion are measured.

[1] The r-m-s distortion is identical with the quantity designated as root-sum-square distortion by the FCC.

Figure 3. Diagram of a typical installation for measuring audio linearity, distortion, and noise in a broadcasting station.



ALTERNATIVE EQUIPMENT

Some broadcasters prefer to use the beat-frequency type of audio oscillator for checking frequency response, and consequently they would like to use the same oscillator as a test source for distortion measurements. The TYPE 1304–A[2] Beat-Frequency Oscillator is one of the lowest distortion models commercially available and has a satisfactorily low value of distortion over the audio range from 50 to 15,000 cycles when operated with NORMAL output. Between 100 and 7500 cycles, distortion will not exceed 0.25%, with approximately 0.5% at 50 cycles. For f-m, at the required frequencies of 10,000 cycles and 15,000 cycles, the distortion will be less than 0.5% and 0.75% respectively on the NORMAL output range. As is apparent from the data above, the TYPE 1301–A Low-Distortion Oscillator, owing to its lower inherent distortion, is preferable for use as a test source in distortion measurements.

Another aspect of the problem of distortion measurement is related to the type of circuit used to suppress the fundamental of the test frequency. The null-circuit in the TYPE 1932–A Distortion and Noise Meter is quite sharp and hence demands good frequency stability in the test source. Although the TYPE 1304–A Beat Frequency Oscillator and the TYPE 913–C (and most of the older TYPE 913–A's and 913–B's) are stable enough for satisfactory use, some beat-frequency oscillators may exhibit enough instability in frequency to be difficult to use. This is especially true at the 50-cycle test frequency, where the excellent stability of the TYPE 1301–A is most apparent.

For one application, the measurement of distortion in recording systems, the sharpness of the null may be a considerable handicap because of "wow" or frequency instability in the recording-reproducing equipment, and the TYPE 1932–A Distortion and Noise Meter is not recommended for such uses. The slight variation in frequency of the test signal may result in imperfect suppression of the fundamental and hence an erroneous distortion reading. For measurements on recording systems, the older TYPE 732–B Distortion and Noise Meter is recommended, together with the TYPE 732–P1 Range-Extension Filters.[3]

The use of the TYPE 732–B Distortion and Noise Meter is possible with a test source having lower frequency stability since the fundamental is suppressed by a high-pass filter and not by a sharply tuned null circuit. Hence measurements on recording equipment, such as disk transcription, sound-on-film, and magnetic wire or tape recorders are easily carried out.

A number of a-m stations are already equipped with the TYPE 732–B Distortion and Noise Meter and TYPE 732–P1 Range Extension Filters, which were designed before f-m broadcasting started. These stations can meet all the requirements for proof-of-performance measurements in the a-m station, when an appropriate oscillator is used as a test-signal source. The range of measurement using this equipment is limited to 7500 cycles, which is all right for a-m, but is not sufficient for compliance with the f-m regulations.

The equipment mentioned in this article is designed to meet the requirements of broadcast station use and can be furnished, with the exception of the TYPE 1304–A Beat-Frequency Oscillator, in panel finishes to match the transmitter.

— FRANK D. LEWIS

[2] *Experimenter*, June, 1948.

[3] *Experimenter*, December, 1947.

TYPE 1932-A DISTORTION AND NOISE METER

Principles of Operation

The TYPE 1932-A Distortion and Noise Meter consists essentially of a null network continuously variable in frequency, followed by a calibrated vacuum-tube voltmeter, as shown in the elementary diagram below.

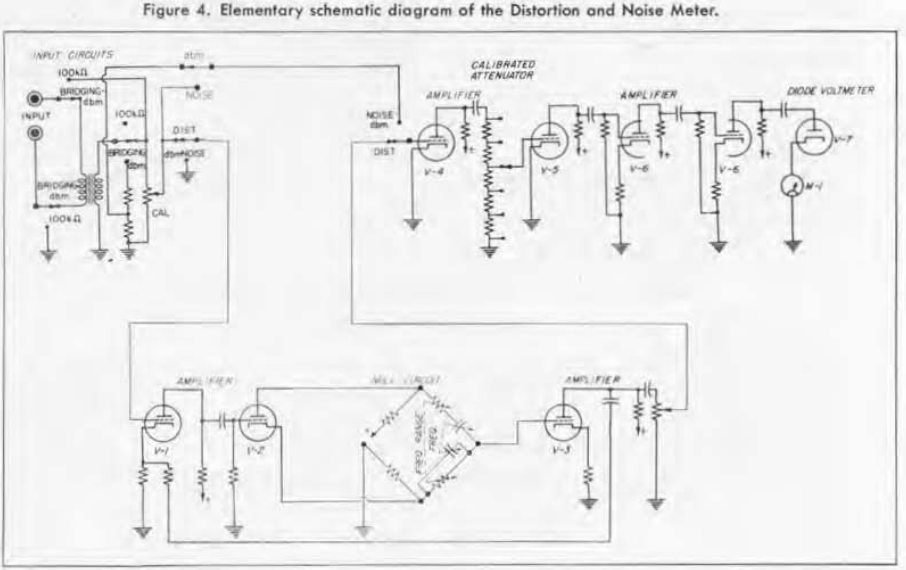
When the switches are set at NOISE, the instrument operates as a sensitive vacuum-tube voltmeter and can be used for noise measurements. The calibrated attenuator has a direct-reading dbm scale for the purpose of determining the program level in 600-ohm lines. Ratio scales, reading in db and per cent, are also provided.

For noise measurements, the instrument is set at 100% (0 db) for the desired reference level by means of the CAL control, and then upon removal of this reference signal, the attenuator is changed in known increments until a deflection of the meter is obtained. The ratio between the two settings, as read directly on the attenuator and meter scale, is the signal-to-noise ratio.

The null network attenuates the frequency, f, to which it is tuned, by more than 80 db, while $f/2$ and all frequencies below, and $2f$ and all frequencies above up to 45,000 cycles, are passed without attenuation. The instrument is calibrated, in the same way as for noise measurements, with the null network not in circuit and with a sine-wave signal applied to the device under test.

When the switches are set to DIST, the null network is introduced and must then be adjusted for a null at the frequency of the test source. Attenuation of the fundamental component by 80 db or more leaves a signal comprising distortion products, including power-line interference, and noise within a band of 30 to 45,000 cycles. The attenuator setting and meter reading now give a direct measure of the distortion level expressed as a percentage of the total signal. Note that the distortion includes all extraneous signals present and

Figure 4. Elementary schematic diagram of the Distortion and Noise Meter.



not just the harmonics of the fundamental test signal. For this reason the apparent minimum detectable distortion level may be limited by the residual noise level, should the latter be permitted to reach a comparable level.

SPECIFICATIONS

Distortion Range: Full-scale deflections for 0.3%, 1%, 3%, 10%, or 30% distortion.

Noise Measurement Range: 80 db below 100% modulation, when the distortion meter is operated from the TYPE 1931-A Modulation Monitor or the TYPE 1170-A F-M Monitor; or 80 db below an audio-frequency signal of zero dbm level.

Audio-Frequency Range: 50 to 15,000 cycles (fundamental) for distortion measurements; 30 to 45,000 cycles for noise and hum measurements.

Dbm Range: From + 20 to −60 dbm. Full-scale values of +20, +10, 0, −10, −20, −30, and −40 dbm are provided. Reference level is one milliwatt in 600 ohms.

Input Voltage Range: Between 1.2 and 30 volts for the 100-kilohm input, and between 0.8 and 30 volts for the 600-ohm bridging input.

Accuracy: For distortion measurements, ±5% of full scale for each range ± residual distortion as noted below; for noise and dbm measurements, ±5% of full scale.

Residual Distortion Level:

100-Kilohm Input: 0.05%, maximum, below 7500 cycles;
0.10%, maximum, above 7500 cycles.
Bridging Input: 0.10%, maximum, between 50 and 70 cycles;
0.05%, maximum, between 70 and 7500 cycles.
0.10%, maximum, above 7500 cycles.

Residual Noise Level: Less than −80 db.

Input Impedance: Two input impedances are provided — 100,000 ohms unbalanced and 600-ohm bridging input (10,000 ohms) balanced or unbalanced.

Vacuum Tubes:

4—6J5	1—6H6
1—6SN7-GT	1—6X5
1—6K6-GT/G	2—0D3/VR150

Accessories Supplied: Line connector cord and cable for connecting to the TYPE 1931-A Modulation Monitor.

Other Accessories Required: For measuring the distortion in oscillators and other audio-frequency sources, no additional equipment is required. For measurements on amplifiers, lines, and other communication networks, a low-distortion oscillator is required to furnish the test tone. TYPE 1301-A Low-Distortion Oscillator is recommended. When the modulated output of a radio transmitter is to be measured, a linear detector to produce the audio envelope is necessary. The TYPE 1931-A Modulation Monitor and the TYPE 1170-A F-M Monitor are recommended for this purpose. However, any detector system having minimum undistorted output of 1.5 volts rms can be used.

Terminals: Input terminals are provided at the rear of the instrument for direct connection to the modulation monitor. A Western Electric jack is provided at the panel also, as an auxiliary input circuit. Plugging into this jack automatically disconnects the rear connectors.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. The line input power is 65 watts. The power supply is voltage regulated. Line surges have no appreciable effect.

Mounting: The instrument is relay rack mounted. Walnut end frames are available to adapt the instrument for table mounting. (See price list below.)

Panel Finishes: Standard General Radio black crackle. Certain standard grays which can be processed in quantity can be supplied at a price increase of $11.00.

Dimensions: Panel (length) 19 x (height) 7 inches; depth behind panel, 12 inches.

Net Weight: 37¾ pounds.

Type		*Code Word*	*Price*
1932-A	**Distortion and Noise Meter***	TABOO	**$575.00**
ZFRI-412-P1	**End Frames**	ENDFRAMDIG	**16.50 Pair**

*U.S. Patent No. 2,298,177.

TYPE 1301-A LOW-DISTORTION OSCILLATOR

Principles of Operation

The TYPE 1301-A Low-Distortion Oscillator was designed specifically for use as a test source of exceptionally pure waveform in the measurement of modulation distortion in transmitters and harmonic distortion in audio-frequency equipment. Its low hum level and symmetry of output waveform are of particular significance in the testing of modulation characteristics of a-m

and f-m transmitters, especially at high and low modulation frequencies.

Figure 1 shows the oscillator in simplified form.

The oscillator is essentially an RC type employing automatic gain control. The oscillating amplifier is arranged to have almost complete degeneration at all frequencies above and below the frequency of the null network, and consequently a small amount of regeneration will cause the circuit to oscillate at the frequency of maximum gain. This is the frequency of the null network, since degeneration is essentially zero at this frequency.

Since the circuit is highly degenerative at all other frequencies, harmonics of the oscillation frequency are suppressed. To control the oscillation level, the amount of regeneration is varied. This is done by the d-c bias applied to the "Regeneration Control Tube," a variable-μ type. The AVC amplifier has a fixed delay-bias applied to it. The oscillator amplitude must reach a critical level before this amplifier is effective. As the amplitude tends to increase above this point, the AVC amplifier applies a signal voltage to the AVC diode, whose output is connected to the "Regeneration Control Tube" in such a manner as to result in a reduction in net gain, thus opposing the original increase.

The power supply for the oscillator employs electronic regulation which reduces the effects of line-voltage variations upon the oscillator frequency and amplitude to a negligible value.

The oscillator is designed to have a high degree of frequency stability in order that it may be used effectively with the TYPE 1932-A Distortion and Noise Meter at low audio frequencies, when measuring extremely low distortion levels of the order of 0.1%.

SPECIFICATIONS

Frequency Range: 27 fixed frequencies between 20 and 15,000 cycles.

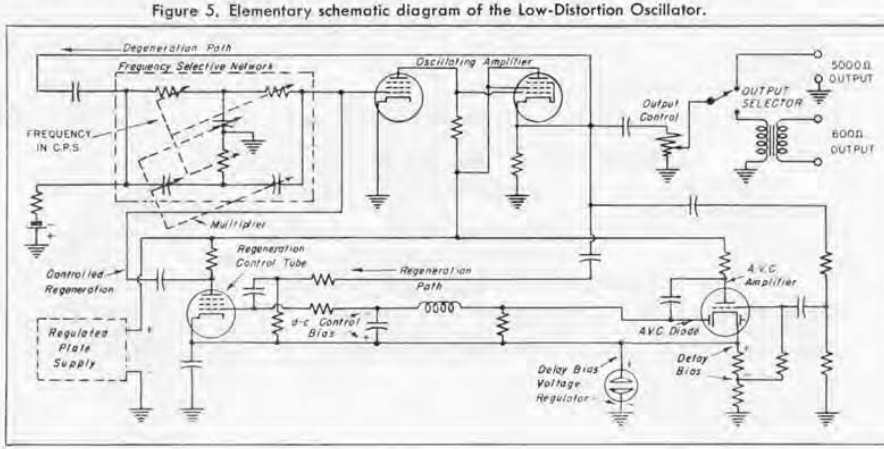
Frequency Control: The frequency is controlled by two push-button switches. The first provides frequencies of 20, 25, 30, 40, 50, 60, 75, 100, and 150 cycles, while the second multiplies these frequencies by 1, 10, and 100. The frequencies included cover practically the entire audible range in approximately logarithmic increments.

The TYPE 1301-P1 Range Extension Unit is available to provide a multiplying factor of 0.1 (see price list). This range extension unit plugs directly into jacks provided inside the oscillator.

Frequency Calibration: Each instrument is adjusted within $\pm(1\frac{1}{2}\% + 0.1$ cycle).

Frequency Stability: The internal voltage regulator eliminates frequency changes resulting from changes in plate supply. Changes in load

Figure 5. Elementary schematic diagram of the Low-Distortion Oscillator.



have no effect upon the frequency. The frequency drift is not greater than 0.02% per hour after the first 10 minutes of operation.

Output Impedance: Three output circuits are provided. Selection among them is obtained by means of a push-button switch on the panel. The output impedances are as follows:

1. 600-ohm balanced to ground.
2. 600-ohm unbalanced.
3. 5000-ohm unbalanced.

The volume control is a potentiometer in the 5000-ohm circuit. The actual output impedance of the 5000-ohm circuit will vary between 1000 and 6000 ohms, depending upon the setting of the volume control. Suitable resistance pads keep the impedance of the 600-ohm output circuit essentially constant, regardless of the volume control setting. The 600-ohm balanced output circuit is balanced at all frequencies when operating into a balanced load of any impedance.

Output Power: 18 milliwatts into 600-ohm load, or 6.6 volts open circuit; 100 milliwatts into 5000-ohm load, or 30 volts open circuit. The output voltage, for either impedance position, will remain constant within ±1 db throughout the frequency range.

Waveform Distortion:

5000-ohm output: — Not more than 0.1% between 40-7500 cycles.
Not more than 0.15% at other frequencies.

600-ohm output: — Not more than 0.1% between 40-7500 cycles.
Not more than 0.25% between 20-40 cycles.
Not more than 0.15% above 7500 cycles.

Power Supply: 105 to 125 (or 210 to 230) volts, 25 to 60 cycles ac. The total power consumption is approximately 45 watts.

Tubes:

1—6Y6-G	1—6X5
1—6SJ7	1—6B4-G
1—6SK7	1—6SL7-GT
1—6SQ7	1—0D3/VR150
1—NE-17	

Terminals: Jack-top binding posts with standard ¾-inch spacing and standard Western Electric double output jack are provided on the panel. A ground terminal is also provided. A standard multipoint connector provides duplicate output terminals on the rear of the instrument for relay-rack installation. These terminals are disconnected when a plug is inserted in the Western Electric-type panel jack.

Accessories Supplied: Line connector cord and multipoint connector.

Mounting: The instrument is relay-rack mounted. Walnut end frames are available to adapt the instrument for table mounting. (See price list below.)

Panel Finishes: Standard General Radio black crackle. Certain standard grays which can be processed in quantity can be supplied at a price increase of $11.00.

Dimensions: Panel (length) 19 x (height) 7 inches; depth behind panel, 12 inches.

Net Weight: 31½ pounds.

Type		*Code Word*	*Price*
1301-A	**Low-Distortion Oscillator***	OZONE	**$395.00**
1301-P1	**Range Extension Unit (2 to 15 c.p.s.)**	OVATE	**70.00**
ZFRI-412-P1	**End Frames**	ENDFRAMDIG	**15.60 Pair**

*U.S. Patent No. 2,173,427.

CORRECTION

The price of the TYPE 1532–P1 Replacement Lamp for Strobolume was incorrectly given in the May issue of the *Experimenter*. The price of this item is as follows:

Type		*Code Word*	*Price*
1532-P1	**Replacement Lamp**	TOWEL	**$30.00**

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