THE GENERAL RADIO

Experimenter

A BETTER WAY TO ACOUSTICAL MEASUREMENTS: TAPE

ALSO IN THIS ISSUE:

EARPHONE COUPLERS FOR AUDIOMETER CALIBRATION

A-WEIGHTING ADDED TO OCTAVE-BAND ANALYZER

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Figure 1. The Type 1525-A Data Recorder.

A MAGNETIC TAPE RECORDER FOR ACOUSTICAL, VIBRATION, AND OTHER AUDIO-FREQUENCY MEASUREMENTS

Magnetic tape recorders are widely used in science and engineering for storing signals from transducers in a reproducible form. Although a remarkable variety of tape recorders is available, only one, the new Type 1525-A Data Recorder, is designed specifically for the important field of acoustic-noise measurement. It is an unusually useful tool in noise-control programs and a basic instrument for many acoustical measurements. The use of this recorder is, of course, not limited to recording signals from microphones only; electrical signals from other transducers, such as those from vibration pickups, can be measured, recorded, and reproduced, as can any signals in the audio-frequency range.

APPLICATIONS OF RECORDERS IN ACOUSTICAL MEASUREMENTS

Owing to the widespread use of tape recording, the general principles of operation are well known, and some applications to acoustic-noise studies are obvious. But in order to discuss the features that make the Type 1525-A Data Recorder particularly well suited for acoustic-noise measurements, it will be helpful first to review a number of these applications.

Non-Steady-State Sounds

Tape-recording a noise is sometimes an obvious first step in getting the information needed to solve a noise problem. For example, if the sound is of relatively short duration, as in a rocket blastoff, many machining operations, a single note from a musical instrument, and speech syllables, a recording for later playback and analysis is often almost essential. One can then form a section of the recorded tape into a loop for continuous playback to facilitate the frequency analysis.

Similarly, impact or explosive sounds, such as those produced by blasting, gun shots, drop forges, and typewriters, can be easily studied after they are made repetitive by means of tape loops.

The analysis of intermittent sounds or signals can be a helpful step in tracking down the sound sources. By means of tape recording, one can monitor the noise from a device for long periods to catch these intermittent sounds, which can then be separated out for analysis.

Some sounds vary significantly in level and character with time. Appliances that go through a cycle of different operations (dishwashers and clothes washers, for example) produce such sounds. Aircraft flyby is another example. Although an appliance can be programmed to stay in the same phase of the cycle for long periods, it is usually more convenient to make a recording of each phase. Sections can then be separated out for detailed analysis.

Some devices, for example a gas engine, drift slowly but significantly in speed. As a result, the basic noise pattern changes, and the drift is often serious enough to preclude direct, detailed analysis of the noise spectrum at a variety of speeds with the usual slow-scan techniques. One can, however, run the engine for a reasonable period at each of a number of selected nominal speeds and record short samples, say two seconds, at each of these speeds to form a series of tape loops. Each loop is played back and is analyzed by a wave analyzer. Since the inertia of the rotating system is often so large that serious fluctuations in speed do not occur in the short interval of the tape loop, the engineer obtains a series of frequency spectra that can be related to shaft speed. He may then be able

Figure 2. Recorder, showing loop mechanism.

to deduce much about the noise producing mechanisms from the relations between amplitude, frequency and shaft speed.

On-Site Recording

The complex instruments used in studying a noise can be installed and operated most conveniently in an acoustical laboratory set up for that purpose. If the noisy machine cannot readily be brought to the laboratory for study, the noise can be recorded at the site and later analyzed under laboratory conditions.

When it is expensive, impractical or inconvenient to run a noisy device for long periods or repeatedly for short periods, tape-recording simplifies the problem of studying the sound. Jets, rockets, turbines, compressors, and other large machines are expensive to run, and tape recordings of the noise they generate will save money.

An experienced engineer can often decide quickly just what information he needs to produce an economical solution to a noise problem. Occasionally, however, he may find that he needs more information than he at first expected. If he still has the original source to test, he can proceed to get the added information. If he has gone to some distant place to make the measurement, however, he may not have brought with him the equipment that he needs for a more detailed test. If he makes a tape recording of the noise, he can later make as detailed a study as he wishes at his home base.

Avoiding Ambient Noise Interference

Background noise may make noise studies of machines impractical when acoustically isolated rooms are not available. Often, however, the background noise is much less during lunch periods or outside normal working hours, particularly early in the morning, and measurements may then be practical. Even during such periods a complete study of the noise may be awkward or inconvenient, but, if tape recordings can be made during the quiet periods, the recorded signal can be analyzed at any convenient time.

Frequency and Time Scaling

Tape recording has also been used for frequency translation to bring a sound into the optimum operating range of particular instruments used for the analysis. Although dramatic changes of scale are not possible in one step, the Type 1525-A Data Recorder does make possible a two-to-one shift. Both the frequency and time scales are changed.

When recording and playback are at different tape speeds (this is discussed under Time and Frequency Translation, page 12), the frequency shift for wave analyzers of the constant-hertz-bandwidth type results in an apparent change in effective bandwidth, which may also be useful. The time-scale shift can be particularly useful in effectively doubling the speed of graphic recorders.

Impact sounds have a very rapid rise in sound level following the impact, but the subsequent decay of the sound is much slower. If one desires to record graphically the peak level, the task is less demanding of the instrumentation when the time scale of such a transient is reversed. The tape recorder makes this inversion possible. Incidentally, one can dramatically illustrate the significance of attack, or initial transient, on the subjective response to a sound by playing backwards a tape recording of a piano selection.

Comparisons of Recordings

Tape recorders are used to keep reproducible records of progressive changes in a sound. These changes may be a result of the application of successive noise-control procedures, for example. Such a series of records may be particularly useful for demonstrating to a consultant's client or to the management of a plant what has been accomplished in reducing noise. From an engineering viewpoint, these recordings are valuable when a change in plans requires a change in analysis procedure.

The recordings of noisy devices constitute a useful library of reproducible sounds. They can be a convenient means of demonstrating comparisons between different makes of the same product or of demonstrating the probable effects of contemplated noise-control procedures.

The tape recorder permits one to make subjective comparisons of the noise from different devices when the devices themselves may not be available at the same time or place, or when they cannot be conveniently operated in such a fashion that easy and psychologically valid comparisons can be made.

The Second Channel

By virtue of its two channels, the Type 1525-A has a number of additional advantages and uses.

Source and Detector

The recorder can function as a measurement system with one channel used to play a recorded test signal and the other channel used to record the results of the application of the signal to the device under test. The recorded source signals may be a series of third-octave or octave bands of noise, a pure tone swept over the audio range, or any of a wide variety of audio signals. Reverberation measurements can be facilitated by this technique.

A recorded signal can also be played back and measured on the main amplifier to obtain an A-weighted level, for example.

Narration

The second channel is often used as a "talk-in" channel to describe the conditions of the test, the settings of the controls, any changes that occur during the test, and other pertinent details. This procedure, when prompted by a check list, helps one to avoid mistakes in the original recording procedure and also ensures that a recording does not become useless if the written summary of the original test conditions is mislaid.

Timing

The signal recorded on the second channel can be a timing signal that is related to the information recorded on the first channel. For example, in studies of the vibration of rotating machinery, one may wish to relate the vibration at a particular instant to the angular position of a rotating shaft. A signal controlled by a contactor or a photoelectric pickoff can be recorded on the second channel for this purpose.

GENERAL DESCRIPTION OF THE INSTRUMENT

The Type 1525-A Data Recorder operates on the same principles as other magnetic-tape direct-recording systems

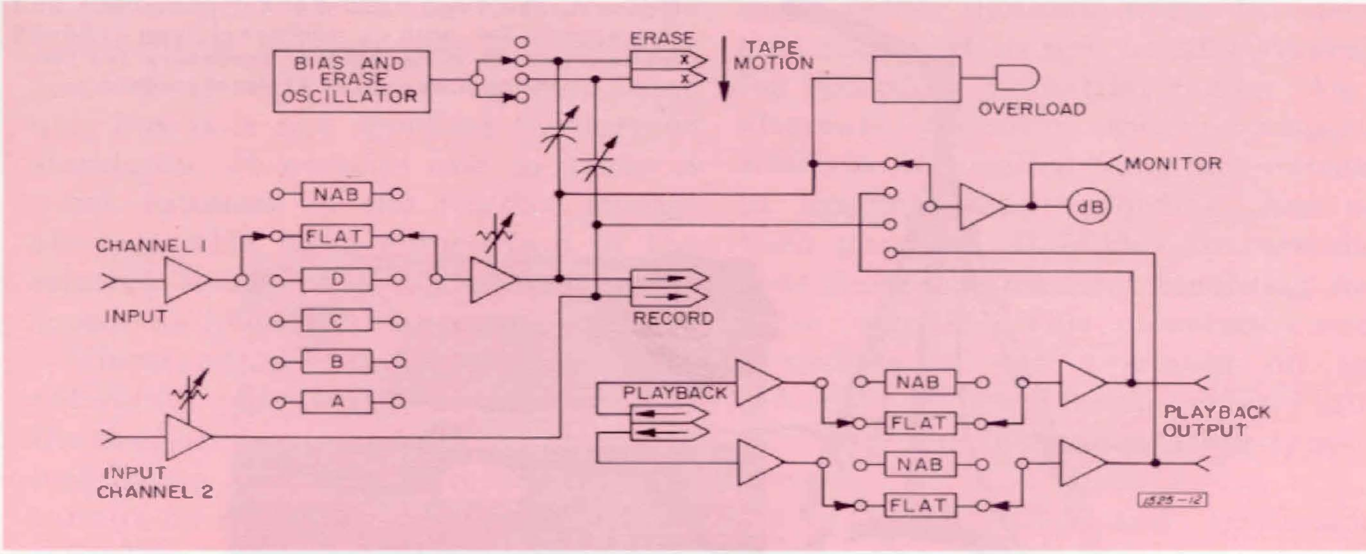


Figure 3. Block diagram of the recorder.

already described in detail in other publications, and a review of these principles is therefore unnecessary here. It does, however, differ from other tape recorders in a number of details that make it better suited for acoustic noise measurement and noise-control applications. These details will be discussed after a brief summary of the elements that make up the recorder.

Tape Transport

The TYPE 1525-A Data Recorder uses an Ampex PR-10-2 tape-transport mechanism, a widely used, professional-quality unit. This transport has two tape speeds, 15 and 7½ in/s. The tape speed is exceptionally constant, with low flutter and wow.

Electronic System

The various elements of the electronic system are shown in the block diagram of Figure 3. The main amplifier, called channel 1, has a field-effect input stage, followed by a series of weighting networks and a high-gain amplifier, whose gain is controlled by an accurate step attenuator and a continuous control. This amplifier supplies a signal to one of the windings on the record head and to an overload indicator. The signals to the record heads can be disconnected by a selector switch.

The second record amplifier is a simple two-stage transistor unit that supplies a signal to the other winding on the record head. This channel can be used in combination with the first to provide binaural recording.

When additional gain is needed, the TYPE 1560-P40 Preamplifier[1] (20 dB) or an auxiliary TYPE 1551-C Sound-Level Meter[2] (100 dB) is recommended.

When the instrument is recording, the bias-and-erase oscillator at about 95 kHz is energized, and it supplies an erase signal and a bias signal for the erase and record heads, respectively, for the selected channel or channels.

The outputs of both windings of the playback head are amplified by two identical amplifiers, and the outputs

[1] C. H. Woodward, "A New Low-Noise Preamplifier," *General Radio Experimenter*, June 1965.
[2] E. E. Gross, "TYPE 1551-C Sound-Level Meter," *General Radio Experimenter*, August 1961.

Figure 4. The Type 1560–P40K Preamplifier and Microphone Set, with an additional Type 1560–P5 Microphone, is a convenient accessory for two-channel operation of the recorder.

of the amplifiers are always available at jacks on the front panel, even during recording. Each amplifier includes the equalization circuits for NAB recording and for constant-current recording at 7½ and 15 in/s.

A monitoring amplifier that drives an output jack and an indicating instrument with the characteristics specified for sound-level-meter instruments can be switched to monitor the signals either at the record head or at the outputs of the playback amplifiers.

IMPORTANT FEATURES

The field-effect input stage for the main amplifier has so high an input impedance that a Type 1560-P5 piezoelectric ceramic measurement microphone or a vibration pickup can be used directly at the input. Sufficient gain is provided to make possible a setting of the calibration control for direct reading of sound level over a range of 34 to 140 dB (re 0.0002 μbar), even with 25 feet of cable between the microphone and the data recorder. These circuits, with the Type 1560-P5 Microphone, meet the requirements for sound-level meters as specified in American Standard S1.4-1961 and the International Electrotechnical Commission 123-1961.

If the best signal-to-noise ratio is desired at low-to-moderate sound levels, use of the Type 1560-P40 Preamplifier is recommended. Very long cables can be used between this preamplifier and the recorder without significant loss in signal. The recorder supplies the dc power required by preamplifiers for both channels.

The frequency response of the weighting networks provided in the main amplifier is shown in Figure 5. The A-, B-, and C-weighting characteristics of the sound-level meter permit one to make the usual weighted-level readings. The A-weighting network is particularly popular as a means for obtaining a single number for rating a noise. The D-weighting network has a decreasing response above 1 kHz. It has seen some use, but it is not specified by current standards. It permits one to make a quick estimate of the relative energy above 1 kHz by a comparison of the relative levels of the C-weighted response and the D-weighted response.

The standard sound-level-meter characteristics provided here make possible the measurement of a noise by approved techniques before it is recorded. This cannot be done directly on other tape recorders.

In addition to these sound-level-meter weighting characteristics, a flat, or uniform, response and NAB-weighting characteristics are provided. The NAB responses are those specified by the National Association of Broadcasters for tape recorders, and they have been designed for good results with speech and music signals. The responses, as shown in Figure 5, have rising characteristics at both high and low frequencies. Although such responses are generally helpful in obtaining a better dynamic range for speech and music, it is not usually desirable for recording industrial noises. As an alternate, therefore, the flat response, which is often called "constant-current" in magnetic-tape recording, has also been provided. It is this characteristic that should be used for recording most noise signals. This constant-current recording is not available on tape recorders designed for speech and music but only on instrumentation-type recorders.

On high-fidelity and professional types of magnetic-tape recorders designed for speech and music recording, the metering system monitors the signal level before any modification of the response characteristic is made. This modification, usually called pre-emphasis, affects a signal in a manner that depends on the spectrum of the signal. One cannot therefore be certain, without knowing much about the signal, what happens to the recorded signal. On such recorders it is possible for some types of signals to have the recording approach saturation of the tape even

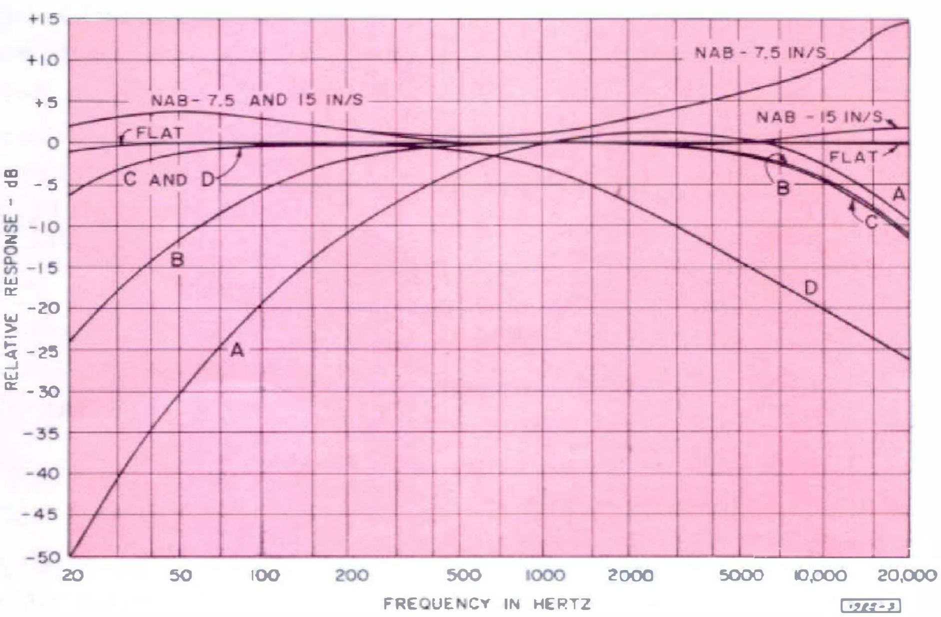


Figure 5. Frequency response of weighting networks.

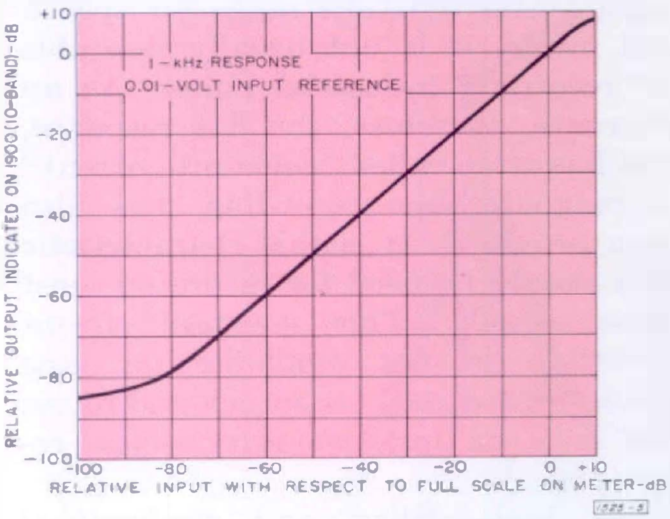


Figure 6. Amplitude-response characteristic of the complete instrument at 1000 Hz.

when the monitoring meter stays within the normal operating range. The Type 1525-A Data Recorder avoids this possibility, because its metering circuit is placed after all the weighting networks and just before the final stage driving the recording head.

In addition to supplying the meter monitoring circuit, the output of the main amplifier is applied to a peak-responding detector. When the output of this detector exceeds a preset value, which is near the point at which the recording-head current would saturate the magnetic tape, the output triggers a circuit that causes a light to turn on. It stays on until a reset button is pressed. This light functions as a monitor for impact-type sounds or vibrations, whose peak levels are not satisfactorily indicated by the relatively slow meter movement. It makes possible the selection of the proper amplifier-gain setting for such sounds without danger of overloaded and spoiled recordings.

Linearity

Linearity of response is an important characteristic when a tape recorder is used as a measurement device. The linearity at high levels is limited by magnetic saturation of the tape, and the apparent linearity at low levels is limited by tape noise. The results of some measurements of this linearity are shown in Figure 6. In this measurement the output of the playback signal was analyzed by the Type 1900-A Wave Analyzer,[3] set for a 10-Hz bandwidth. This reduced the effects of noise and eliminated the false improvement in apparent linearity that would result from including harmonics in the measured signal at high levels. The excellent linearity over a range of more than 70 dB is obvious from the plotted results.

Low-Frequency Response

The low-frequency response of the usual tape recorder designed for speech and music is not good below 40 or 50 Hz. In contrast with this performance, the response of this new tape recorder at the 7½-in/s, flat-recording condition is remarkably uniform down to 20 Hz with only a few dB drop in response at 15 Hz. This performance is important for many industrial noises that have maximum energy at these lower frequencies, and it increases the usefulness of the recorder for many applications in the field of vibration control, particularly where the ultimate goal is acoustic-noise control. Typical over-all response characteristics are shown in Figure 7.

The generally good response of this recorder can be illustrated in another way. The analyses of a test signal applied to the recorder and of the signal

[3] Arnold Peterson, "New Wave Analyzer Has 3 Bandwidths, 80-dB Dynamic Range," *General Radio Experimenter*, April 1964.

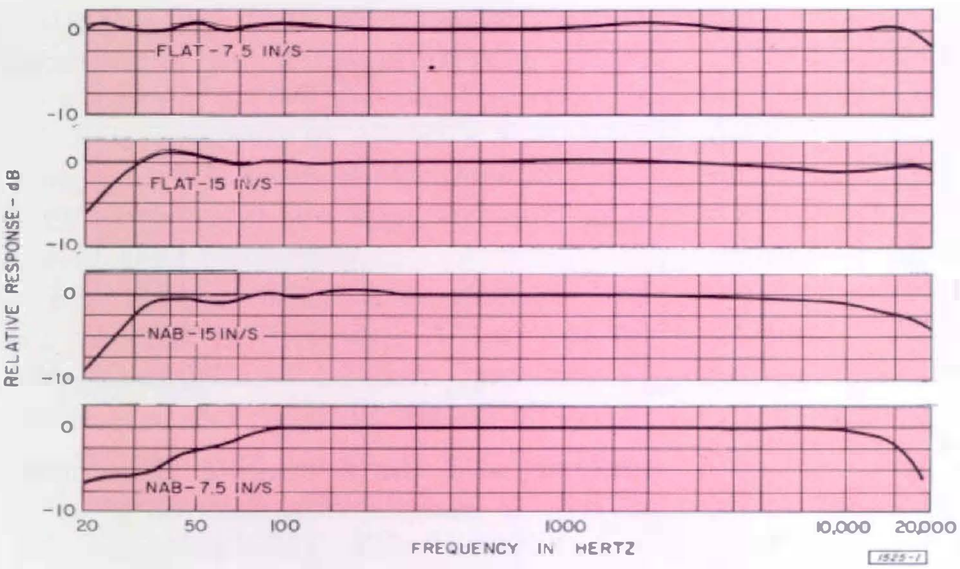


Figure 7. Typical over-all frequency response characteristics.

played back from the recorded tape are shown in Figures 8 and 9. This test signal was an 8-kHz tone burst of 4 cycles duration repeated every 2.5 milliseconds. This test tone has a wide range of component frequencies as shown by the analyses, and the good frequency response is shown by the close similarity of the before-and-after analyses.

Attenuator

The accurate step attenuator in the main amplifier has several advantages. It makes possible recordings over a wide range of levels with a good dynamic range. This feature is not provided on most tape recorders, and it is essential for handling the wide range of signal levels encountered in noise-control work. It also makes possible the use of a calibrating signal (such as that from a Type 1552-B Sound-Level Calibrator driving a measurement microphone or a Type 1557-A Vibration Calibrator driving a pickup) that is widely different in level from the signal to be studied. The difference in the settings of the step attenuator for the calibrating and the unknown signals is then used to relate the playback levels of the two signals. Expressed

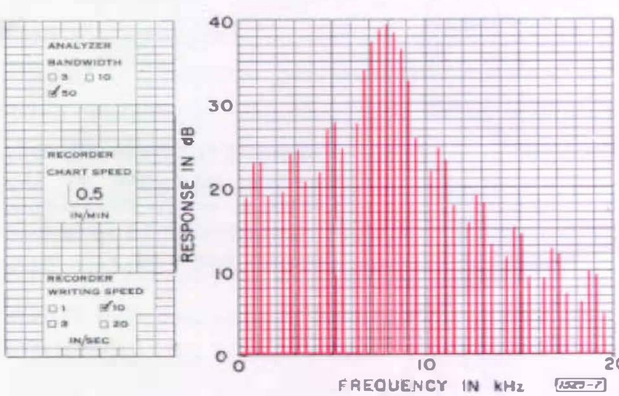


Figure 8. Analysis of an 8-kHz tone burst applied to the tape recorder. The tone burst was of 4 cycles duration repeated every 2.5 milliseconds.

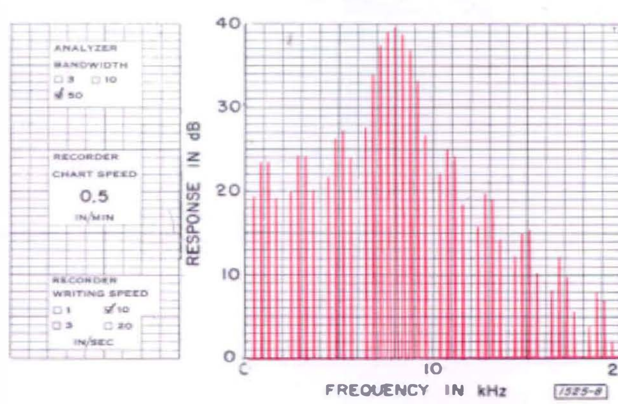


Figure 9. Analysis upon playback of the tone burst of Figure 8.

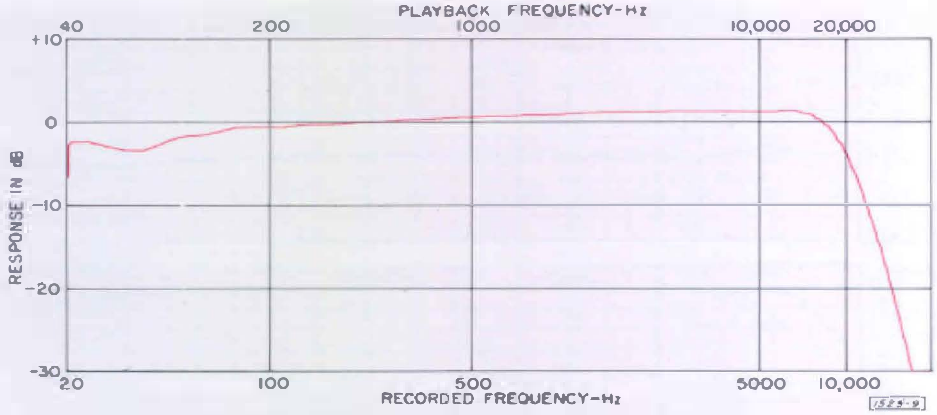


Figure 10. Over-all frequency response of the recorder when the signal is recorded at 7.5 in/s and played back at 15 in/s.

in another way, the accurate step attenuator is used to shift a calibrating signal to any convenient level before recording. This procedure is an essential element for accurate measurements on a recorded signal.

Tape Loops

In many applications of a recorder in noise-control studies, a section of the tape is cut out and formed into a loop for continuous playback and analysis by a sweeping analyzer. The TYPE 1525-A Data Recorder includes tape loop guides that simplify the playback of these loops. (See Figure 2.)

Because of the type of noise usually encountered, the bandwidths used for analysis, and the averaging times employed, a sample duration of 2 to 3 seconds is convenient for acoustic and vibration studies. A length of loop that gives this duration is readily used on the TYPE 1525-A Data Recorder.

Time and Frequency Translation

The response characteristics given above apply for recording and playback at the same speed. If the frequency and time scales are modified by a change in speed between recording and playback, the apparent frequency response is somewhat different from that encountered in normal use, particularly at the frequency extremes.

Graphs of measured responses are shown in Figures 10 and 11. They illus-

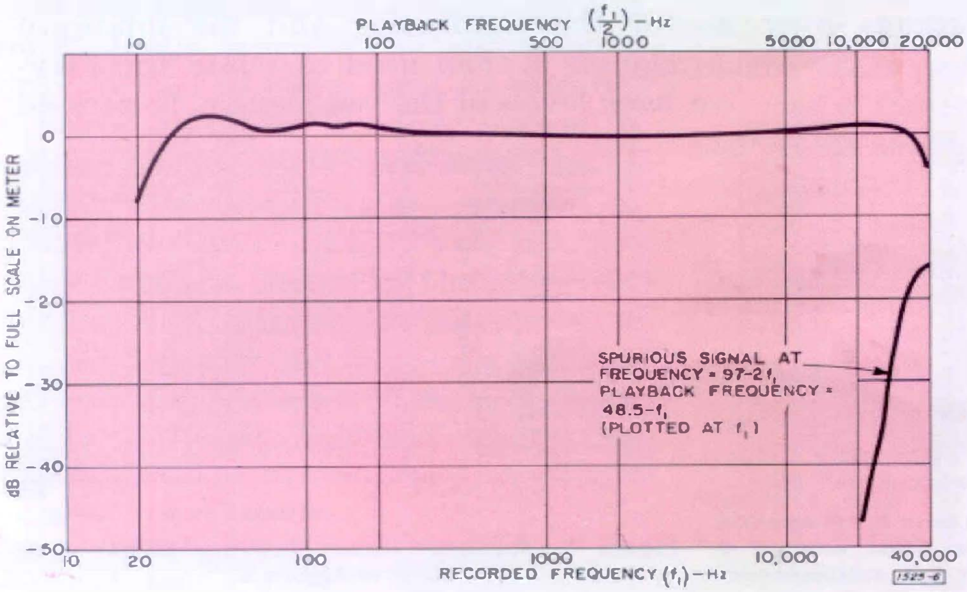


Figure 11. Over-all frequency response of the recorder when the signal is recorded at 15 in/s and played back at 7.5 in/s.

trate the fact that the playback characteristic is the dominating one. Thus, for example, a 15-kHz tone recorded at 7.5 in/s becomes at 15 in/s a 30-kHz tone, which is beyond the normal playback range, and the apparent output is low at that frequency.

The inverse effect also occurs when the process is reversed. A tone at 30 kHz recorded at 15 in/s becomes at 7.5 in/s a 15-kHz tone, which is within the reproducing range of the recorder, and satisfactory response is obtained. By this technique the apparent frequency range of the recorder for some measurement purposes can be doubled.

The extension of the frequency range is accompanied by another effect, however, which limits its usability. In the magnetic material on the tape, the mixing of the bias field and that from the incoming signal results in some spurious signals. The most important of these is at a frequency of f_B-$2f_1$, where f_B is the bias frequency (about 95 kHz for the TYPE 1525-A) and f_1 is the frequency of the signal being recorded. For frequencies up to 20 kHz this spurious component is at 55 kHz or higher, and no significant playback output of the spurious component results. When a 40-kHz tone is recorded, the spurious frequency is at 15 kHz, and a significant amount of the spurious signal is present as shown on the graph. The relative amount of this spurious signal drops rapidly with signal level. The value shown was measured at the normal maximum input level. When the input level is lowered 10 dB, the spurious signal drops about 20 dB. In addition, as shown on the graph, the level of the spurious signal drops rapidly as the frequency is reduced, becoming negligible at a recording frequency of 20 kHz.

This behavior shows the main reason for the use of a relatively high-frequency bias. For normal recording techniques, the bias frequency should be significantly higher than three times the highest signal frequency to be used if these spurious signals are to be avoided. For two-to-one frequency-scaling, the ratio of bias frequency to signal frequency should be greater than 4:1. But if this limitation of spurious signals is recognized, one can use this recorder for some applications at frequencies well above 20 kHz.

Incidentally, a number of hi-fi recorders use a bias-oscillator frequency in the range of 35 to 50 kHz. If an attempt is made to use such recorders at frequencies above 10 kHz, the spurious responses may be troublesome. Any attempt at frequency scaling downward would be even more subject to difficulty with spurious signals.

Modulation Noise

One limitation on the performance of a tape recorder is a form of noise known as modulation noise, which appears when a signal is recorded. The modulation-noise energy is concentrated in the frequency region immediately adjacent to that of the applied signal frequency components. The effect can be measured by an analysis of the playback of a recorded pure tone. The results of such a measurement on a TYPE 1525-A Data Recorder are shown in Figure 12. The level of the recorded 1-kHz tone is displayed as 0 dB, and the accompanying noise measured in the 10-Hz passband of the TYPE 1900-A Wave Analyzer is shown to peak in the vicinity of 1 kHz and to be more than 60 dB lower. A similar

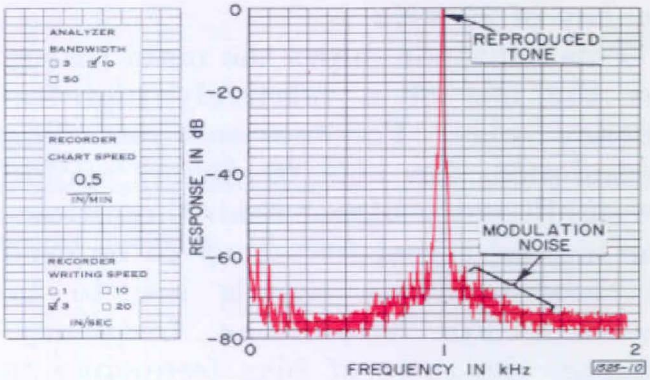


Figure 12. An analysis of the playback signal of a recorded 1000-Hz tone. The analysis on the Type 1900-A Wave Analyzer with a 10-Hz bandwidth shows the relative levels of the tone and the noise added in the recording and playback process. Note that the ordinate scale covers a range of 80 dB.

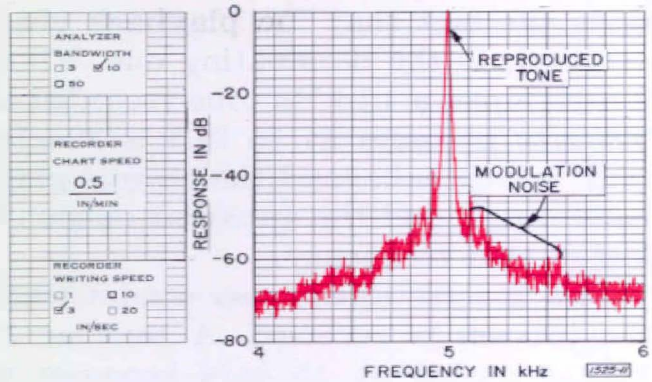


Figure 13. The same as Figure 12 except that the recorded signal was a 5000-Hz tone.

measurement for a 5-kHz tone is shown in Figure 13. The modulation noise measured here is significantly lower than that obtained on many other recorders, and it is so low that it does not ordinarily limit the performance of the recorder for acoustical and vibration measurements.

Modulation noise is dependent on the tape used, the transport tape drive and support mechanism, and the condition of the tape surface and heads. Use of high-quality tape, such as Ampex Type 641, careful control to avoid accumulation of dirt particles on the tape surface, and good maintenance of the transport mechanism are essential for obtaining this low level of modulation noise. Fortunately, for most applications in acoustical and vibration measurements, reasonable care in use, storage, and handling is adequate for satisfactory results.

SUMMARY

Provision of sound-level-meter characteristics, a variety of weighting networks, an accurate step attenuator, an amplifier with high gain and high input impedance, a transient overload indicator, two-channel recording, simultaneous playback on recording, good low-frequency response, and tape loop guides make the versatile Type 1525-A Data Recorder particularly well suited for acoustic-noise and vibration measurements.

— Arnold Peterson

The Type 1525-A Data Recorder is based on one developed for the General Radio Company by G. W. Kamperman, D. Noiseux, and R. V. Jones of the firm of Bolt Beranek and Newman Inc.

Note: A brief biography of Arnold Peterson, author of the foregoing article, appeared in the August 1966 issue of the *Experimenter*. —Editor

SPECIFICATIONS

Channels: 2 channels with separate record and playback amplifiers and separate channel erase.

Measurement Range (Input Level): 10 μV to 1 V on channel #1 (40 to 140 dB sound-pressure level for microphone sensitivity of −66 dB re 1 V/μbar). About 0.7 V on channel #2 for full-scale meter indication. (For high sensitivity, channel #2 can be driven by the output of a separate sound-level meter.)

Frequency Response:

At 15 in/s (38.1 cm/s)

Constant Current: ±2 dB, 50 to 15,000 Hz. +2, −4 dB, 30 to 18,000 Hz.

NAB equalization: ±2 dB, 50 to 15,000 Hz.

At 7½ in/s (19.05 cm/s)

Constant Current: ±2 dB, 20 to 10,000 Hz. +2, −4 dB, 15 to 16,000 Hz.

NAB equalization: +2, −4 dB, 50 to 15,000 Hz.

Signal-to-Noise Ratio:
NAB equalization: Over 54 dB below 2% distortion point as measured according to NAB standard (A weighting).
Constant Current: Over 45 dB below 2% distortion point for noise band from 20 to 15,000 Hz (over 65 dB for octave band at 1 kHz) with input to channel #1 of greater than 10 mV.

Input Impedance: *Channel #1:* approx 20 pF shunted by 400 MΩ.
Channel #2: >100 kΩ.

Weighting Characteristics: NAB and constant current for both playback amplifiers; NAB constant current, and A, B, and C weighting (standard sound-level-meter characteristic) for record channel #2.

Monitoring: Electronic voltmeter with 16-dB range and sound-level-meter ballistic characteristics, switchable to monitor record or playback level on either channel. Peak monitor on record channel #1.

Tape Speeds: 15 in/s (38.1 cm/s).
7½ in/s (19.05 cm/s).

Tape: ¼ inch, professional quality.

Reel Size: 7-in reel (maximum).

Flutter and Wow: Below 0.2% rms.

Bias and Erase Frequency: 95 kHz nominal; separate erase for each channel.

Power Required: 105 to 125 V, 60 Hz, 135 W.

Accessories Supplied: Guides for tape loop; Type 1560-P99 Adaptor Cable; CAP-22 Power Cord; reel of tape; rack-mount hardware; maintenance kit.

Accessories Available: Type 1560-P5 Microphone and Type 1560-P34 Tripod and Extension Cable for sound measurements and recording. Type 1560-P40K Preamplifier and Microphone Set for sound measurements and recording at levels below 50 dB where the best signal-to-noise ratio must be maintained (the recorder supplies the necessary power to operate a Type 1560-P40 Preamplifier). For sound and noise analysis, Type 1900-A Wave Analyzer, Type 1564-A Sound and Vibration Analyzer, Type 1568-A Wave Analyzer, Type 1558 Octave-Band Noise Analyzers.

Dimensions: Portable model — width 21, height 16, depth 9 inches (540, 410, 230 mm); rack model — width 19, height 14, depth behind panel 7 inches (485, 355, 180 mm), over-all.

Net Weight: Portable model, 53 lb (25 kg); rack model, 50 lb (23 kg).

Shipping Weight: Portable model, 60 lb (28 kg); rack model, 57 lb (26 kg).

Catalog Number	*Description*	*Price in USA*
1525-9701	Type 1525-A Data Recorder	$1995.00

A STANDARD EARPHONE COUPLER FOR FIELD CALIBRATION OF AUDIOMETERS

There is much evidence that frequent calibration of audiometers in common use for industrial audiometry is a practical necessity. Cudworth[1] has emphasized the need for maintaining proper calibration of audiometers and has proposed a field calibration and audiometer evaluation system using the sound-level meter. Reports on audiometer performance presented at various hearing and noise symposiums of industrial hygiene and safety organizations have urged periodic calibration.

A published study[2] reports on the performance of five audiometers over a period of 42 months. At the start of the test period all were adjusted by the manufacturer to be within specifications. They were calibrated three times a month at first and then once a month unless the operator suspected trouble. A record was kept of calibration results, and a note made each time an audiometer performed outside its specification. The results are significant:

Defect in Performance	*Number of Occurrences*
Sound pressure at or beyond tolerance limits	63
Faulty earphone performance	11
Frequency outside limits	10
Excessive harmonic distortion	13
Extraneous instrument noise	19

References are listed on page 20.

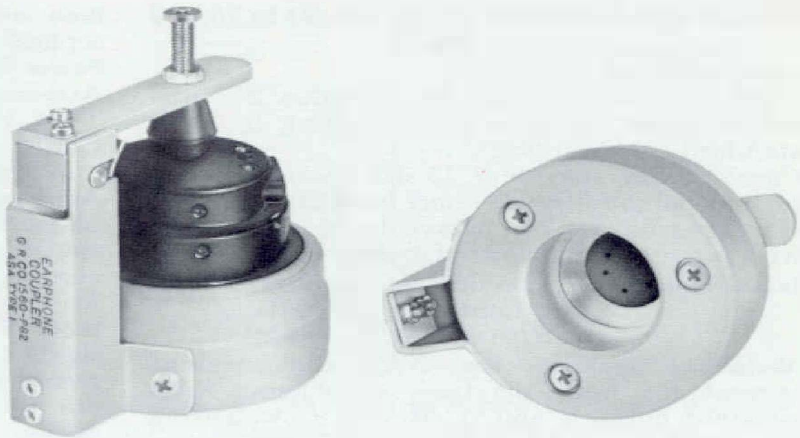


Figure 1. (Right) The Type 1560—P82 Earphone Coupler; (center) the coupler with earphone installed; (left) coupler with earphone, installed on sound-level meter.

Since incorrect sound pressure is the chief offender, it is apparent that a readily available, simple, convenient, and reliable acoustical calibration system for audiometers is needed. Since many industrial hygienists are responsible for noise surveys as well as for industrial audiometry, the sound-level meter or other sound-measuring instrument is usually readily at hand. The missing link has been a readily available standard earphone coupler.

Standard Earphone Coupler

An earphone coupler is a device for coupling an earphone to a standard-pressure microphone for the purpose of determining the acoustic characteristics of the earphone. It provides a tightly sealed chamber of specified volume to simulate the compliance of the human ear. An earphone coupler and a sound-level meter are all that is needed to evaluate the over-all performance of an audiometer.

There are two types of standard earphone coupler in use today: (1) the NBS Type 9A Coupler, specified in ASA Z24.5–1951 [3] and in ASA Z24.12–1952 [4]; and (2) the ASA Type 1 Coupler, specified in ASA Z24.9–1949 [5] and in ASA Z24.13–1953.[6]

The Type 1 Coupler is the newer design of the two and, because of its shape, has been found easier to use than the 9A for field calibrations [1]. According to the standards [3,4], there is but slight measurable difference between results obtained with the two couplers. This is confirmed by measurements reported by Morrical et al [7].

The Type 1560-P82 and Type 1560-P81 Earphone Couplers

Since the Type 1, specified by ASA Standard, is easier to use, we have chosen to manufacture a version of this coupler.

This new coupler is available in two models: (1) The Type 1560-P82 for use on 15/16-inch-diameter, piezoelectric, ceramic, sound-level-meter microphones, such as the GR1560-P5 and 1560-P6 Microphones (it will also fit Type L Laboratory Standard Microphones like the WE Type 640AA); and

(2) the Type 1560-P81 for use on the older 1⅛-inch-diameter, piezoelectric, ceramic, sound-level-meter microphones, like the GR1560-P3 or 1560-P4.

The Type 1560-P82 Earphone Coupler, shown in Figure 1, is a precision-machined, aluminum device designed to provide the proper acoustic coupling medium between a microphone and an earphone. The coupler also includes a toggle clamp to apply the prescribed force of 500 grams to the earphone under test. The clamp has an adjustable pressure foot to accommodate earphones of various heights and to maintain the lever arm in the horizontal position necessary for the proper applied force. The top part of each coupler model is designed to accept the Telephonics TDH-39 Earphone, which seems to be most commonly used on American audiometers. The Permoflux PDR series and Western Electric 705-A earphones will also fit these couplers.

In appearance, the Type 1560-P81 Earphone Coupler is the same as the Type 1560-P82. The cross-section views (Figure 2) show how the two GR couplers differ from each other and from the prototype ASA Type 1 Standard Earphone Coupler. The Type 1560-P82 Coupler has a small step added to provide positive and accurate location of the microphone.

The Type 1560-P81 Coupler, in addition to the small locating step, has a larger diameter recess to accept the 1⅛-inch-diameter microphones, and the height of the acoustic coupling cavity is reduced to maintain the required 6-cm³ coupling volume with the large microphone and its larger effective volume.

These modifications add measurably to the convenience of use but in no way impair the acoustical performance.

New Coupler Performance

Measurements made in the General Radio Laboratories verify that there is only a slight difference in the response of a TDH-39 Earphone as measured with an NBS 9A Coupler and with the ASA Type 1 Coupler. Our measurements also show that the differences are negligible when the earphone response is measured in the NBS 9A Coupler and the Type 1560-P82 or Type 1560-P81 Earphone Coupler. Figure 3 shows the responses of two Telephonics TDH-39 Earphones, each

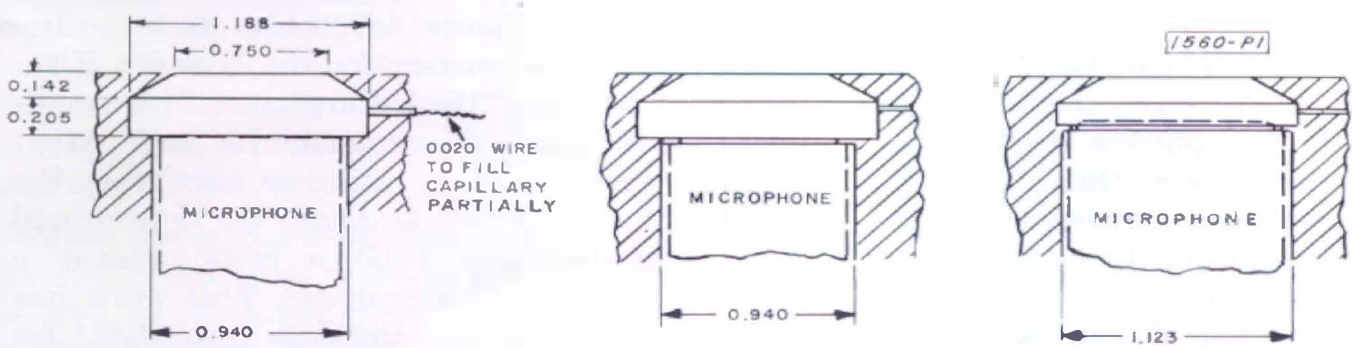
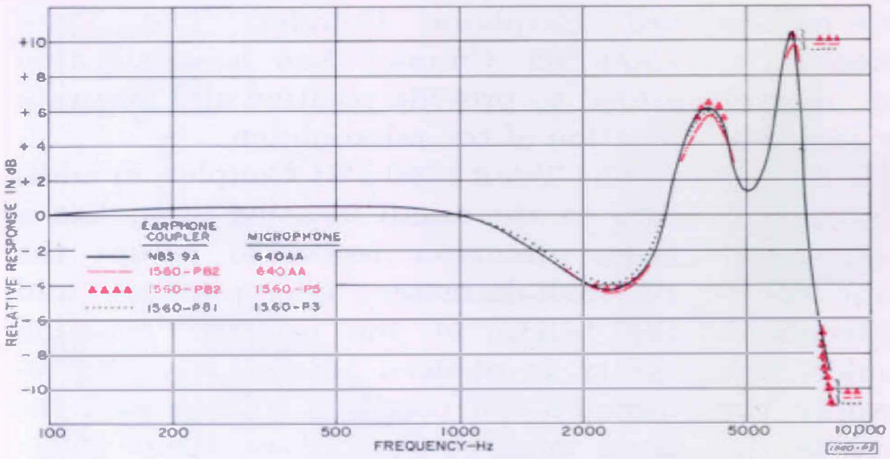


Figure 2. Standard Earphone Couplers. (a) ASA Type 1 (Z 24.9—1949); (b) Type 1560—P82 ASA Type 1 (modified to accept 15/16-inch diameter, piezoelectric, ceramic, sound-level-meter microphone); (c) Type 1560-P81 ASA Type 1 (modified to accept 1⅛-inch diameter, piezoelectric, ceramic, sound-level-meter microphone). Note that the General Radio couplers make possible accurate and repeatable positioning of the microphone.



(a)

(b)

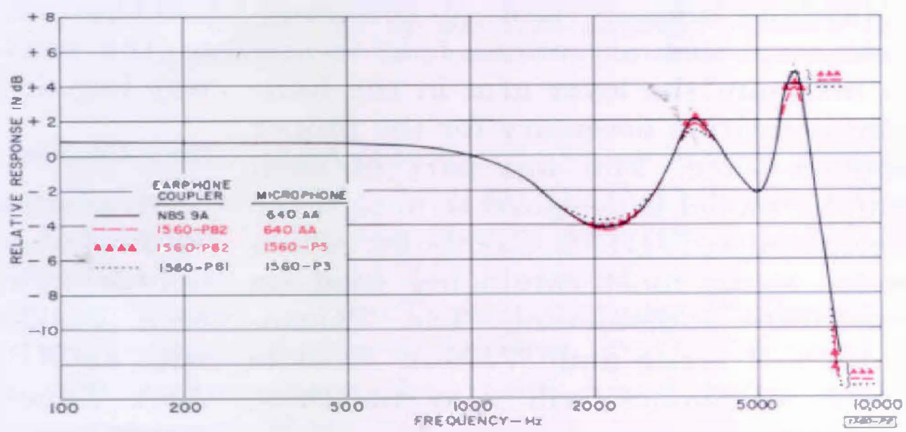


Figure 3. Frequency response. (a) Telephonics TDH-39 Earphone No. 3; (b) Telephonics TDH-39 Earphone No. 101.

measured in the NBS 9A Coupler with a Western Electric 640AA Microphone, then in the Type 1560-P82 Coupler with the 640AA and with a Type 1560-P5 Microphone, and finally in the Type 1560-P81 Coupler with a Type 1560-P3 Microphone. Earphone No. 3 has had intermittent use over four or five years; earphone No. 101 is a new unit. We have measured a number of other earphones in this manner, and, in each case, there has been excellent agreement between the responses as measured in the various couplers.

Application

To use a coupler to evaluate an audiometer frequency characteristic, one measures the sound-pressure level developed in the coupler by the audiometer earphone. This is usually done at a hearing-level dial setting of 60 dB. If the audiometer is calibrated in accordance with Z24.5–1951 [3], the sound-pressure levels that should be developed in the coupler are derived from Table 2 in that standard, which lists the threshold (0 dB hearing level) sound-pressure levels at each audiometric frequency for the Western Electric Type 705-A Earphone. The standard then states that, for any other type or configuration of earphone, the threshold levels must be determined by loudness balance tests against a Type 705-A Earphone. This work has been done and the data published [8] for the Telephonics TDH-39 Earphone with MX41/AR cushion. The data in lines 1 and 3 of Table I, below, are derived from the data of Reference 8.

TABLE I

Sound-pressure levels (dB re 2×10^{-4} μbar) at audiometric frequencies in the Type 1560-P82 or Type 1560-P81 Earphone Coupler corresponding to a 60-dB hearing level for a TDH-39 Earphone with MX41/AR cushion as read on typical sound-level meters.

Coupler Type No.	*Sound-Level Meter* *Type*	*Sound-Level Meter* *Weighting Position*	*Audiometer Reference Threshold*	*Frequency-Hz* *125*	*250*	*500*	*1000*	*1500*	*2000*	*3000*	*4000*	*6000*	*8000*
1560-P82	1551-C*	C	ASA 1951	112	99.5	84	77	78	78	74.5	71	75	83 dB
1560-P82	1551-C*	C	ISO 1964	105.5	85	71	67	67	68.5	69.5	67	70	69 dB
1560-P81	1551-B	20 kc	ASA 1951	112	99.5	84	77	78.5	79	77.5	76	79	80 dB
1560-P81	1551-B	20 kc	ISO 1964	105.5	85	71	67	67.5	70	72	72	74	66 dB

* Also Type 1565-A Sound-Level Meter

New audiometers may be calibrated to the new international audiometric zero.[9,10] Data for the TDH-39 Earphone, though not in the international standard at present, are available[11], and, apparently, some efforts are being made to add the TDH-39 data to the international standard.[12,13] The data for lines 2 and 4 of Table I are derived from the data of Reference 12.

Table I lists the sound-level-meter readings that should be produced by an audiometer set to the 60-dB hearing level and coupled to a typical sound-level meter by a Type 1560-P82 or Type 1560-P81 Earphone Coupler.

In place of the sound-level meters listed in the table, the earlier Type 1551-A Sound-Level Meter or one of the Type 1558 Octave-Band Analyzers can be used, when equipped with the appropriate microphone.

Most industrial hygienists and others concerned with noise measurement as well as audiometry have a sound-level meter or an octave-band analyzer; one of these couplers is the only additional equipment necessary to check the acoustic output of an audiometer.

For those who wish to make complete acoustical and electrical tests on an audiometer, the Type 1564-A Sound and Vibration Analyzer, with a Type 1560-P40 Preamplifier, a Type 1560-P5 Microphone, a Type 1560-P82 Earphone Coupler, and an audio oscillator, is recommended.

— E. E. Gross

Figure 4. Type 1560-P82 Earphone Coupler used on Type 1565-A Sound-Level Meter.

Ervin E. Gross received his B.S.E.E. degree from Northeastern University in 1936 and has been with General Radio ever since. As a development engineer in General Radio's Audio Group, he has specialized in the design of sound and vibration measuring instruments. He is a Senior Member of the IEEE and a member of the Acoustical Society of America and has been active in standards work for both organizations.

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2. E. L. Eagles, S. M. Wishik, L. G. Doerfler, W. Melnick, H. S. Levine, *Hearing Sensitivity and Related Factors in Children*, University of Pittsburgh Graduate School of Public Health. Published by Laryngoscope, St. Louis, Missouri, 1963.
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4. *American Standard Specifications for Pure Tone Audiometers for Screening Purposes*, Z24.12–1952, American Standards Association, New York, 1952.
5. *American Standard Method for the Coupler Calibration of Earphones*, Z24.9–1949, American Standards Association, New York, 1949.
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10. ISO Technical Communication 43—Acoustic, No. 554, "A Standard Reference Zero for the Calibration of Pure Tone Audiometers," (1964). (Note: See Reference 9).
11. TABLE — "Recommended Reference Equivalent Threshold Sound Pressure Levels in the 9A Coupler," Proposed for the International Organization of Standards by the National Bureau of Standards, Washington, USA, 1963.
12. C. G. Rice and R. R. A. Coles, "Normal Threshold of Hearing for Pure Tones by Earphone Listening with a Self-Recording Audiometric Technique," *Journal of Acoustical Society of America*, 39, 1185–1187 (L) (1966).
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16. A. Glorig, *Noise and Your Ear*, Grone and Stratton, New York (1958).

SPECIFICATIONS

Type Coupler: ASA Type 1.

Volume: 6 cm^3 including equivalent volume of microphone (TYPE 1560-P5 Microphone for TYPE 1560-P82 Coupler; TYPE 1560-P3 Microphone for the TYPE 1560-P81 Coupler).

Axial Holding Force: 500 grams.

Frequency Range: 100 Hz to 8000 Hz; ±1 dB from 100 Hz to 6000 Hz, increasing to ±3 dB at 8000 Hz (with corrections for pressure response of microphone).

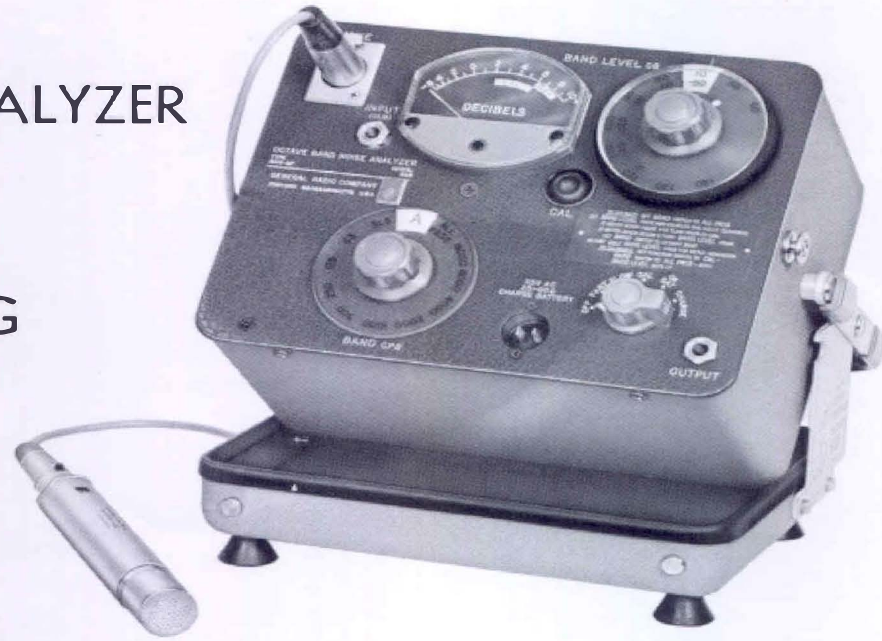
Dimensions: Coupler, diameter 2¼ by height $1\frac{1}{16}$ inches (5.7, 2.5 mm); over-all, width 2¼, length 3, height 3 inches (5.7, 7.7, 7.7 mm).

Net Weight: 8 oz (230 g).

Shipping Weight: 2 lb (1 kg).

Catalog Number	*Description*	*Price in USA*
1560-9682	**Type 1560-P82 Earphone Coupler**	**$30.00**
1560-9681	**Type 1560-P81 Earphone Coupler**	**30.00**

OCTAVE-BAND ANALYZER WITH A-WEIGHTING



An A-weighted sound level is now often used to rate similar types of noise, because a good correlation has been found for many noises between A-weighted sound levels and loudness, speech interference, and "noisiness."

A-weighted sound level is often measured in lieu of or as a supplement to an octave-band analysis. To make both measurements, the noise sleuth has needed two instruments: a sound-level meter and an octave-band analyzer.

The Type 1558-BP Octave-Band Analyzer provides both capabilities in a single instrument. It is identical to the Type 1558-AP Octave-Band Noise Analyzer[1] except for the inclusion of an A-weighting network. A-weighting is selected by the BAND switch, which also selects ten octave bands at frequencies specified by ASA S1.6–1960 Preferred Frequencies for Acoustical Measurements. Both this instrument and the Type 1558-AP Octave-Band Noise Analyzer conform with the requirements of the new *American Standard Specification for Octave, Half-Octave, and Third-Octave-Band Filter Sets S1.11–1966 for Type E, Class II octave-band filters.*

The new analyzer is shown in Figure 1 together with the Type 1560-P40 Preamplifier and Microphone. This combination measures levels ranging from 24 dB to 150 dB, the same range as the Type 1551-C Sound-Level Meter.

An existing Type 1558-AP Octave-Band Noise Analyzer can be converted to a –BP model. For details, write to our Service Department.

[1] W. R. Kundert, "New, Compact, Octave-Band Analyzer," *General Radio Experimenter*, October 1962.

Catalog Number	*Description*	*Price in USA*
1558-9890	**Type 1558-BP Octave-Band Noise Analyzer, Portable Model**	**$850.00**
1558-9848	**Type 1558-BP Octave-Band Noise Analyzer, Rack-Adapted Model**	**850.00**
1560-9520	**Type 1560-P40K Preamplifier and Microphone Set**	**251.00**

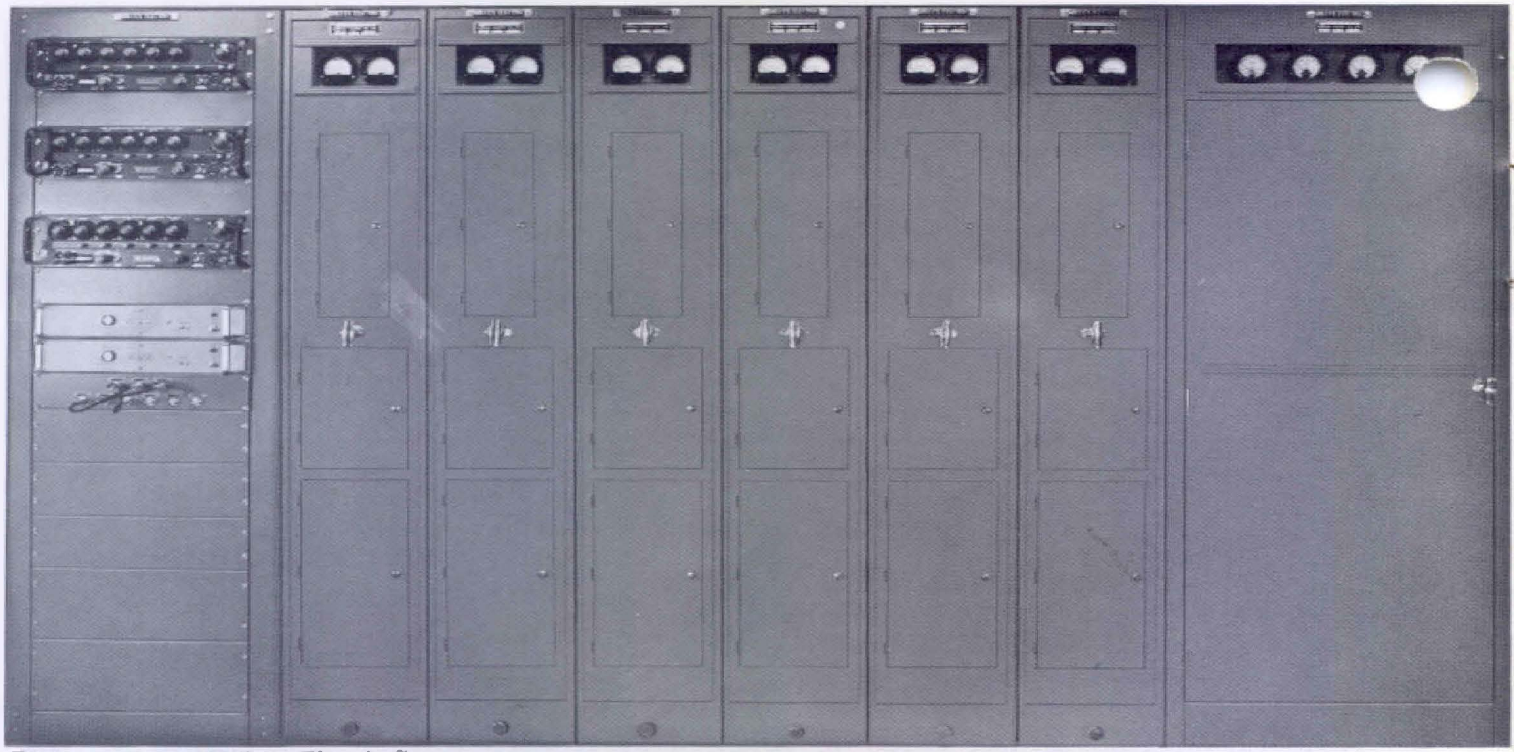


Photo courtesy of Wilcox Electric Company

Wilcox Type 96 transmitter, with GR frequency synthesizers installed in far-left rack.

VERSATILE TRANSMITTER USES GR SYNTHESIZERS

Those whose dark business it is to jam radio transmissions are not likely to welcome the increasing use of frequency synthesizers to control transmitter frequencies. The engineer at the transmitter has, in a typical synthesizer, the equivalent of several million crystals and can jump from one hertz to the next with the abandon of a grasshopper.

The Wilcox Electric transmitter system shown above was designed and built by Wilcox Electric for a government anxious to maintain communications in the face of interference, intentional or otherwise. Each of six transmitters in the system can be fired up instantly on any one or two of 32 preset channels. Primary frequency control is by crystal oscillator, but three GR frequency synthesizers stand ready to take over if a crystal fails or if the operator wants to set up new frequencies without grinding new crystals. The total number of channels that can be set by means of the synthesizer is high enough to make any would-be jammers take up another profession.

A SIMPLE WAY TO SYNCHRONIZE MAGNETIC TAPE WITH OSCILLOSCOPE TRACE

During some recent investigations of transient sound pulses in our Engineering Department, it was necessary to synchronize the starting of an oscilloscope trace with the position of the pulse on a magnetic recording tape. The Type 1536-A Photoelectric Pickoff [1] proved very well suited to this task.

[1] "Using a Photocell Where it Counts," *General Radio Experimenter*, October 1962.

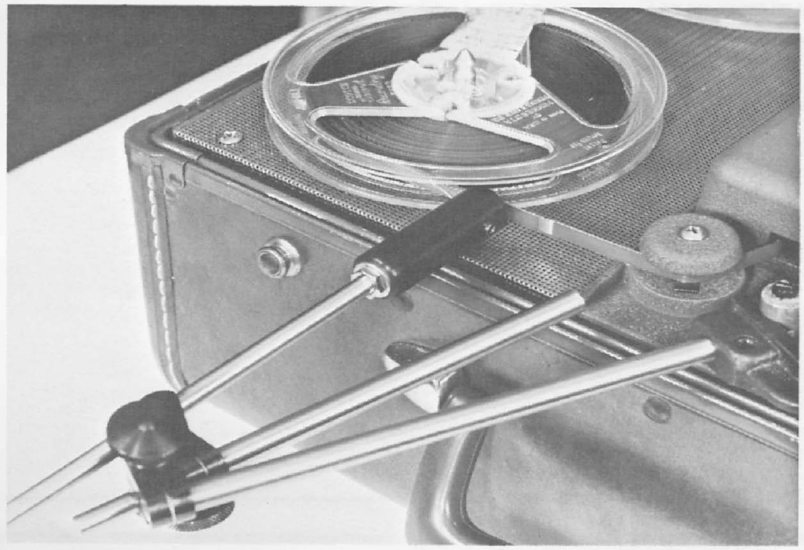


Figure 1. Photoelectric pickoff shown mounted in tape recorder. Note piece of reflective foil attached to tape.

The pulse was located on the magnetic tape by trial-and-error to within an inch or two, and a bit of aluminum foil was fastened to the back of the tape at this spot by cellophane tape. The photoelectric pickoff was clamped to the recorder and positioned so that the light beam shone across the width of the tape. The passage of the aluminum foil through the light beam initiated the oscilloscope trace.

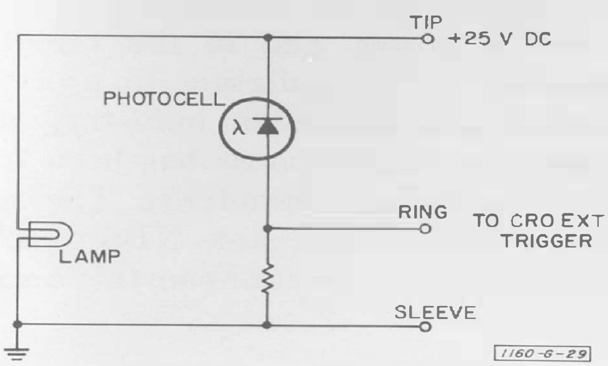


Figure 2. Electrical connections to pickoff plug.

Figure 1 shows the photoelectric pickoff mounted on the tape recorder. A piece of aluminum tubing was screwed to the chassis to provide a convenient gripping surface for the mounting clamp. For final positioning of the pickoff, the mounting rods were adjusted until the sound pulse occurred coincident with the start of the trace. If greater precision were required, the photoelectric pickoff could have been mounted on a micrometer carriage.

Electrical connections are shown in Figure 2. It is necessary only to supply dc voltage of approximately +25 volts for the exciter lamp and to connect the ring of the TYPE 1536-A plug to the oscilloscope external trigger terminal. The scope itself, of course, should be adjusted for single-sweep operation.

— GORDON R. PARTRIDGE

NEW NBS LABORATORIES TO BE DEDICATED

The new laboratory complex of the U. S. Department of Commerce's National Bureau of Standards, located in Gaithersburg, Maryland, will be dedicated on November 15. Secretary of Commerce John T. Connor will head the list of dignitaries participating in the ceremonies. *(Cont'd)*

the GR Experimenter

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NBS LABORATORIES *(Continued)*

In conjunction with the dedication, the Secretary is sponsoring a two-day Symposium on Technology and World Trade, to be held November 16 and 17 on the NBS grounds. About 500 distinguished experts from all over the world have been invited to participate.

Among the important new facilities at Gaithersburg are a nuclear research reactor and a powerful linear electron accelerator (linac). In the field of nuclear physics, in the nuclear generation of electric power, and in the rapidly expanding use of radiation to process materials and products in industry, one of the most urgent needs has been for measurements and standards. The reactor and linac will enable NBS to fulfill its important functions in this area.

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