THE General Radio EXPERIMENTER

VOLUME XXVI No. 11 APRIL, 1952

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE SOUND-SURVEY METER

A Simple, Pocket-Size Instrument for Noise-Level Measurements

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MANY SOUND MEASUREMENTS do not require the accuracy and versatility of a standard sound-level meter,[1] and many others are economically feasible only with a low-cost meter. For these applications, the Type 1555-A Sound-Survey Meter, shown in Figure 1, has been developed. It is similar in operating characteristics to the standard sound-level meter and is comparable in accuracy, stability, and frequency response to the commercially available sound-level meters of only one year ago. At the same time it is smaller, lighter in weight, easier to use, and much lower in cost than standard instruments.

The Sound-Survey Meter has a wide range of applications in nearly all fields of sound measurement. For example, it can be used for determining the noise level from machinery, for preliminary surveys of environmental

[1] E. E. Gross, "Type 1551-A Sound-Level Meter," *General Radio Experimenter*, XXVI, 10, March, 1952.

Figure 1. View of the Sound-Survey Meter, held in hand, with thumb in position to operate level control.

noise levels, for simple acoustic measurements, and as a teaching and laboratory aid in education.

Description

The photograph of Figure 1 shows that the instrument has been designed particularly for ease of use. It is shaped to fit the hand but can also be set on a table or mounted on a tripod. The indicating meter is large for a hand-size instrument, so that it can be easily read. The controls and the meter are all on the face of the instrument. Controls are simple, a function switch at the left and a continuous level control at the right, both arranged for easy, finger-tip operation. Total weight with batteries is only 1 pound, 14 ounces.

Although the instrument is small enough to be carried in the coat or trousers pocket, many users will find it convenient to have the carrying case shown in Figure 2, which is available as an accessory.

The Sound-Survey Meter is shown partially disassembled in Figure 3. The entire unit is mounted in a simple, two-piece, aluminum case. The microphone cartridge is visible at the top, fastened to the case. The amplifier chassis is in the middle, showing the four sub-miniature tubes, and this chassis is readily removed from the case for ease in servicing. The batteries are one size-C flashlight cell and one 30-volt hearing-aid B-battery.

Figure 2. Convenient carrying case is made of brown, blister-proof, top-grain cowhide and has a shoulder strap. Space is provided for two spare flashlight cells and one spare plate battery.

Circuit

As shown by the simplified schematic of Figure 4, the instrument consists of a microphone, a calibrated potentiometer, a four-stage amplifier with weighting networks, and an indicating meter. A voltage proportional to the current in the meter circuit is returned to the grid of the second stage as negative feedback, which maintains the gain of the amplifier reasonably independent of normal changes in battery voltage and aging of tubes. This stabilization makes it practical in this simplified instrument to dispense with the usual front-panel gain adjustments. An internal adjustment is provided, however, which can be used if tube replacements make it necessary.

Components

While low price was an important objective in the design of this instrument, high-quality components have been used throughout. For example, the capacitors are hermetically-sealed units; low-noise, low-microphonic tubes are used in the first two stages; the meter is rugged, accurate, and comparatively large; the switch used is a high-quality miniature one; and the potentiometer is of a type well known for stability and long life.

Level Control

The calibrated potentiometer is a continuous level control, which is an innovation in commercial noise meters. It permits one, when measuring noise, to adjust the level control so that the fluctuating reading of the meter balances about the zero-decibel mark on the meter. Then the level is given directly by the setting of the attenuating potentiometer, which covers the most often used range of from 50 to 100 decibels.[2] An additional 30-decibel attenuation is also provided, and this with the −10 to +6 decibel range of the meter makes the total sound-pressure-level range of the instrument from 40 to 136 decibels.[2]

The continuous level control also permits the full 16-decibel dynamic range of the meter to be utilized. For example, some noises have a fairly steady background level with occasional bursts to higher levels. The level control can then be set so that the background level is at −10 decibels on the meter, and bursts of noise up to 16 decibels higher can be observed directly on the meter. This freedom of adjustment is not possible with the usual 10-decibel step control.

Meter Characteristics

The negative feedback from the meter circuit to the second stage provides a high-impedance source for the rectifier-type meter. The resultant meter current is very closely proportional to the average value of the rectified signal, over the full calibrated range of the meter, with little dependence on temperature and individual rectifier characteristics. The scale distribution on the meter is correspondingly appreciably better than that obtained when a low-impedance source is used for driving the rectifier.

The metering system fails to meet the requirements of the two-signal test[3] for r-m-s reading by only ½ decibel. An investigation made during the development of this instrument showed, however, that this discrepancy is not important for a simple Sound-Survey Meter. It was checked experimentally that for almost all sounds the difference in reading that could be ascribed to the rectifier characteristic compared to that in standard sound-level meters was less than one decibel.

The meter meets the ballistic characteristics specified for sound-level meters, which includes a limit of one decibel on the overshoot. The speed of response is only slightly faster than a VU meter,[4] so that those familiar with the behavior of that instrument will find this one very similar.

Frequency Response

Typical over-all frequency response curves of the instrument are shown in Figure 5. These curves show the relative meter reading as a function of frequency for constant free-field sound pressure produced by a plane-wave source. The response curves include the diffraction effects of the instrument, but not those of the observer. Results are shown for two different angles of incidence and for the three different weighting networks. Those who are familiar with the usual microphone characteristics will realize that this over-all response is remarkably good.

[2]re 0.0002 μbar.

[3]American Standard for Sound-Level Meters, Z24.3 (1944), American Standards Association.

[4]A. S. A., "Volume Measurements of Electrical Speech and Program Waves," C16.5 — 1942.

Figure 3. View of Sound-Survey Meter partially disassembled to show construction.

The weighting characteristics are intended to approximate the relative response of the ear to pure tones at three different levels: the A network corresponding approximately to a 40-decibel level, the B network to a 70-decibel level, and the C network to a 100-decibel level. In this Sound-Survey Meter the minor differences at high frequencies have been ignored, and the weighting networks affect only the low-frequency response.

Maintaining uniform response at high frequencies for the different networks makes the instrument more suitable for preliminary surveys for determining possible hearing damage. It also makes it possible to estimate better the nature of the frequency spectrum being measured. For example, if a marked reduction in reading occurs when switching from the C to the B and from the B to the A networks, then most of the energy is concentrated at low frequencies. The extent of the reduction sometimes permits one to estimate the approximate frequency at which the energy is concentrated. In contrast, the usual weighting networks modify the high-frequency response as well, and this modification makes the estimate of the spectrum more uncertain.

Comparative Measurements

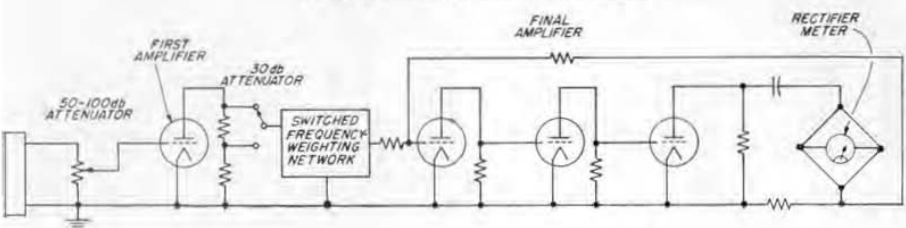
One important question that should be considered is: How does the noise-level reading as measured by the Sound-Survey Meter compare with that measured on a sound-level meter? There are many factors that enter into the answer to this question. The most important are the frequency spectrum of the noise and the frequency response characteristic of the instruments being compared. When these two factors are known, a fairly good estimate of possible differences can be made. This effect is important, not only when the Sound-Survey Meter is compared with a sound-level meter; it also is important when comparing two different types of sound-level meters that use different microphones.

For example, when the TYPE 759-P25 Dynamic Microphone is used with the TYPE 1551-A Sound-Level Meter to measure a 30-cycle signal, the reading will be about 7 decibels lower than when the Rochelle-salt microphone furnished with the instrument is used. For this frequency and the C network, the TYPE 1555-A Sound-Survey Meter reading would tend to be near that obtained when the TYPE 759-P25 Dynamic Microphone is used on the TYPE 1551-A Sound-Level Meter. Differences of similar magnitude can occur at the very high frequencies, while the differences will be appreciably less in the range from 100 to 2,000 cycles. That such differences are normal can be verified by checking the tolerances allowed in the ASA Specification on sound-level meters.[5]

Because of the limitations imposed by small size and low cost, more variation can be expected in the low-frequency response for the different networks in this simplified instrument than occur in the TYPE 1551-A Sound-Level Meter.

[5]See footnote 3.

Figure 4. Elementary schematic circuit diagram.



On the whole, however, the differences between readings taken on the Sound-Survey Meter and a commercial sound-level meter are not significantly greater than the differences that can be expected between sound-level meters of different manufacture.

Microphone

The microphone used in the Sound-Survey Meter is a Rochelle-salt-crystal diaphragm type similar in characteristics to the one supplied as standard with the TYPE 1551-A Sound-Level Meter. It operates into a high impedance, which limits the variation of sensitivity with temperature to about 0.03 db per degree F. Like all Rochelle-salt devices, it is limited to a maximum safe operating temperature of 46°C. or 115°F.; and the crystal is destroyed if kept above 55°C. or 131°F. Long exposure to extremes of humidity should also be avoided.

Maintenance

Routine maintenance checks are easily made. A battery check position is provided on the function switch. The plate battery is a 30-volt hearing-aid B-battery, which lasts for about 100 hours at two hours per day, while the filament battery operates for 20 hours at two hours per day. The filament battery is a size-C flashlight cell available in many local stores. The marked discrepancy in life of the two batteries serves to make less costly any oversight in failing to turn off the instrument. The inexpensive, readily-obtained filament battery runs down first and saves the plate battery.

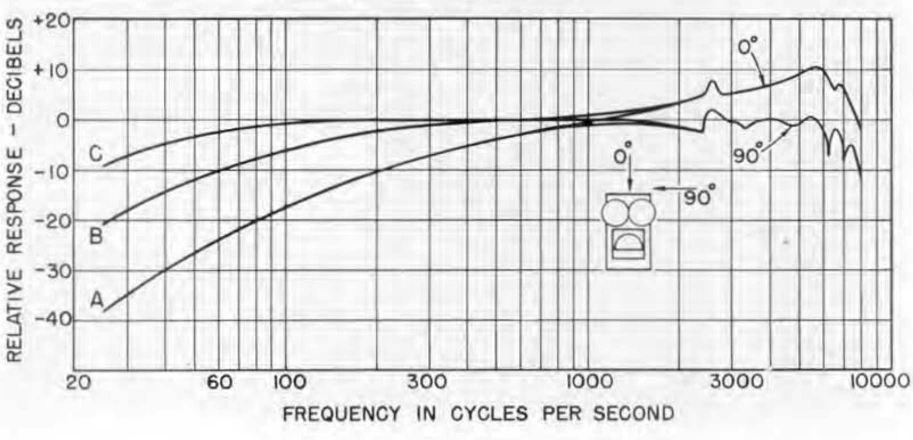
When necessary, the over-all calibration can be checked accurately with the TYPE 1552-A Sound-Level Calibrator[6] as shown in Figure 6.

Applications

The Sound-Survey Meter can be used in many measurements that have hitherto been made by the more expensive sound-level meter. For example, many noise surveys, appliance noise tests, and frequency response tests can be made satisfactorily with this new instrument. Some of these tests, however, must still be made with an instrument like the TYPE 1551-A Sound-Level Meter. When the noise must be analyzed or recorded, when a wide-frequency range system is necessary, or when a product-acceptance test requires the use of a standard sound-level meter, the

[6] E. E. Gross, "An Acoustic Calibrator for the Sound-Level Meter," *General Radio Experimenter*, XXIV, 7, December, 1949.

Figure 5. Typical frequency-response curves.



TYPE 1551-A Sound-Level Meter is recommended. In addition, some noise levels are beyond the range of measurement of the Sound-Survey Meter. For example, quiet electric clocks have a noise level well below 40 db, and the background level in a broadcast studio is usually in the range from 20 to 30 db on the A-weighting network. But these low levels are exceptional, and the usual noise levels to be measured are well within the operating range of the TYPE 1555-A Sound-Survey Meter.

In addition to these generally accepted applications for a noise meter, the low cost of the Sound-Survey Meter makes it economically practical to use for many applications that were not so feasible before. Some of these will be discussed briefly, and, because of its importance, the application of this meter for preliminary noise surveys with regard to deafness risk will also be considered.

Deafness-Risk Surveys

Much work is being done at present by industrial hygienists, otologists, psychologists, physicists, engineers, and others on the problem of hearing loss from long-period exposure to excessive noise.[7] This work will lead to essential information for judging when ear protection is necessary. Some preliminary conclusions have been reached, but, because the problem is very complicated and adequate data are not available, the present conclusions are tentative and will be modified when a better understanding of the problem develops. Some of the factors that make the problem difficult are (1) the large differences between individuals in their susceptibility to damage by noise; (2) the normal loss in hearing with age; (3) the effects of some diseases on hearing; (4) the much higher level of noise that can be tolerated without permanent damage for short exposures than for repeated long-time exposures; and (5) the higher levels that can be tolerated when the noise is dominated by low-frequency components rather than components in the higher audio-frequency range.

[7]Karl D. Kryter, "The Effects of Noise on Man," Monograph Supplement 1, September, 1950, American Speech and Hearing Association.

Leo L. Beranek, "Noise Control in Office and Factory Spaces," Transactions Bulletin 18, 1950, Industrial Hygiene Foundation, pp. 26-33.

Proceedings of the Second Annual National Noise Abatement Symposium, October 5, 1951, Technology Center, Chicago 16, Illinois.

Proceedings of the Course on the Acoustical Spectrum, February 5-8, 1952, School of Public Health, University of Michigan, Ann Arbor, Michigan.

(*Left*) **Figure 6.** Sound-Survey Meter with Sound-Level Calibrator in position for over-all calibration check.
(*Right*) **Figure 7.** Sound-Survey Meter being used to measure noise level produced by pneumatic rock drills.

Because of the importance of the problem, however, even the tentative conclusions available now are of value; and the Sound-Survey Meter is most helpful for preliminary surveys to determine if operating personnel need to wear ear defenders or if effort to reduce the noise level is justified. If the levels are sufficiently low, a check by the Sound-Survey Meter could be all that is needed. Otherwise, it can show whether or not detailed investigation using the TYPE 1551-A Sound-Level Meter and the TYPE 1550-A Octave-Band Noise Analyzer is necessary.

Sound Reproduction

The audio engineer should find the Sound-Survey Meter very useful for custom audio installations. Typical uses here are the following: adjusting the relative levels of the different speakers in a two or three-way speaker system; checking the dynamic range; setting the initial reference level for a compensated volume control; checking and adjusting low-frequency response to avoid boominess.

Speech Classes

The deaf person is obviously unable to judge the relative loudness of his own speech and that of others. A visible indication of level, such as that provided by the Sound-Survey Meter, can be a useful aid to the instructor of the handicapped in showing the student how to adjust this level. Training in adjusting the level of speaking is also needed when a hearing aid is first used, because this aid upsets the apparent balance of level between the user's voice and the background noise or other voices.

Even a person with normal hearing cannot correctly compare on a subjective basis his own voice level with that of others, because of the inherent difference between listening to himself and listening to others. The instructor in speech and drama classes may find the Sound-Survey Meter useful here for demonstrating to the student on an objective basis how his level compares with other voices, and it might be used as an aid to develop the ability of the student to project his voice to cover a reasonable audience without speech reinforcement.

After experience has been obtained with the instrument, it can be used as a guide at rehearsals. It can help in determining whether or not a given performer needs a close microphone pickup, or it may be useful in demonstrating to the performer and the director that such a pickup is necessary.

Physics Laboratories

While many college physics laboratories have sound-level meters, large numbers of high-school physics laboratories and even some of the smaller colleges have not been able to afford one. Now these can consider this new, low-cost meter. It can replace or supplement

Figure 8. Measuring the level of reproduced sound in a theatre.

some of the classical powder or flame experiments. For example, standing waves in rooms, the effects of baffles or obstructions, the attenuation of doors and partitions, the comparative intensity of various noise sources as well as other phenomena can be demonstrated.

When schools have a serious noise problem, this instrument can help in determining how to correct it. Simple sound surveys will indicate quickly which classrooms are too noisy and likely to affect the efficiency of the teachers. Experience has indicated that when the noise level exceeds 45 db on the A-weighting network, the students are likely to have difficulty in understanding the teacher.

Architects

The architect can use the Sound-Survey Meter in the study of sites for office buildings, homes, and factories. The builder often considers noise in his selection of a proper place to put a building, in the same way that he considers other environmental factors such as prevailing winds, smoke, and schools.

Field Engineers

The instrument is so convenient to carry that sales engineers of some products should find it a useful accessory on their field trips. For example, the applications engineer for acoustical materials can determine with this instrument much about the nature of any noise problem. He can determine the levels involved, and, by using the weighting networks, he can also learn something about the spectrum, which is often a crucial factor in the problem.

— ARNOLD PETERSON

SPECIFICATIONS

Range: From 40 db to 136 db above the standard sound-pressure reference level of 0.0002 μbar.

Frequency Characteristic: Three different frequency characteristics can be selected by the main control switch. (See Figure 5.) In the *C* and *C* +30db weighting positions substantially equal response to all frequencies between 40 and 8000 cps is obtained. This characteristic is ordinarily used for all levels above 85 db.

The *B*-weighting position is used for levels between 55 and 85 db. Its response follows the 70 db contour established as the standard of weighting for sound-level meters. The *A*-weighting position is usually used for levels between 40 and 55 db. Its response follows approximately the 40-db contour established for sound-level meter weighting. In addition to providing means for making the usual weighted level measurement, these characteristics permit one to estimate, by comparative measurements with different weighting characteristics, the relative importance of low-frequency components in the sound being measured.

Microphone: The crystal diaphragm-type microphone cartridge is mounted at the top of the instrument. Temperature coefficient of sensitivity is about 0.03 db per degree F.

Meter and Attenuator: For levels below 100 db the noise level is given by the sum of the readings of the meter and attenuator.

For levels above 100 db the main control switch is set to "*C* +30db." Then the noise level is given by the sum of the readings of the attenuator and the meter plus 30 db.

The ballistic characteristics of the rectifier-type meter simulate those of the human ear and agree with those for standard sound-level meters.

Stability: The amplifier and level indicator are stabilized by feedback. The change in gain with battery voltages is thereby reduced to moderate values.

The behavior of the instrument is not noticeably affected by temperature and humidity over the ranges of room conditions normally encountered. The maximum safe operating temperature is 115° F. Temperatures above 130° F. will permanently damage the Rochelle-salt crystal in the microphone cartridge.

Accuracy: The gain of the amplifier is set initially so that the sensitivity of the instrument is correct at 1000 cps within ±1 db. The *B* and *C* frequency characteristics are essentially within the tolerances allowed by the American Standards Association specification on Sound-Level Meters. The *A* frequency characteristic is similar to that required by the ASA specification, but it provides only the low-frequency roll-off below 1000 cps.

When the *B*- and *C*- weighting networks are used, the reading of this meter for most types of sounds does not differ from that of a meter meeting the ideal characteristics given in the ASA specification on sound-level meters by more than the standard ASA tolerances increased by 1 db.

Batteries: One 1½-volt size-C flashlight battery (Eveready 935 or equivalent) and one 30-volt hearing-aid battery (Eveready 413E or equivalent) are supplied.

Tubes: Two CK512AX and two CK533AX tubes are supplied.

Case: Aluminum, finished in organic black, with standard ¼-20 tripod socket. Aluminum panel is finished in black crackle lacquer.

Dimensions: 6 x 3⅛ x 2½ inches, over-all.

Net Weight: 1 pound, 14 ounces, with batteries.

Type		*Code Word*	*Price*
1555-A	Sound-Survey Meter*	MISER	$125.00
1551-P1	Carrying Case		10.00

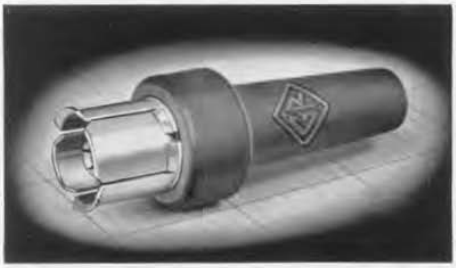
*Licensed under patents of the American Telephone and Telegraph Co.

CREDITS — The development of the Sound-Survey Meter was carried out under the direction of Dr. Arnold P. G. Peterson. Credit is also due to Henry C. Littlejohn for the mechanical design, to Robert J. Ruplenas for his assistance in the electrical development, and to Dr. Leo L. Beranek, Dr. Donald B. Sinclair, and Ervin E. Gross for their many helpful suggestions.

COAXIAL CONNECTORS FOR RG-58/U AND OTHER CABLES

We have recently had several requests for a Type 874 Connector for use with RG-58/U and other cables of small diameter. Accordingly, we are making available the Type 874-C58 Cable Connector and the Type 874-P58 Panel Connector for this purpose. A complete list of Type 874 Cable and Panel Connectors, with the coaxial cables for which they are suitable, is given on page 10.

(*Left*) Cable Connector; (*right*) Panel Connector.



Type		*Code Word*	*Price*
874-C	Cable Connector	COAXCABLER	$2.00
874-P	Panel Connector	COAXPEGGER	2.50
874-C8	Cable Connector	COAXCORDER	2.00
874-P8	Panel Connector	COAXPUTTER	2.50
874-C58	Cable Connector	COAXCALLER	2.00
874-P58	Panel Connector	COAXPANNER	2.50

AN Number	Impedance in Ohms	Jacket Diameter-inches	Shields	O.D. of Dielectric	Inner Conductor	Capacitance $\mu\mu f$/foot	Maximum Operating Volts-rms	ATTENUATION DB/100 FT. MEGACYCLES 100	300	1000	3000	Cable Connector	Panel Connector
GR 874–A2 CABLE	50	.365	DOUBLE SHIELD TINNED COPPER	.244	41/30T	32	3500	2.6	5.1	10.5	20.5	874–C	874–P
RG–8/U	52	.405	COPPER	.285	7/21	29.5	4000	2.1	4.2	9.0	18	874–C8	874–P8
RG–29/U	53.5	.184	TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–55/U	53.5	.206	DOUBLE SHIELD TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–58/U	53.5	.195	TINNED COPPER	.116	20	28.5	1900	4.2	7.9	16	32	874–C58	874–P58
RG–58A/U	50	.195	TINNED COPPER	.116	19/.0068	29	1900	5.3	9.6	22	45	874–C58	874–P58

A NOTE ON THE SINGLE-ENDED PUSH-PULL AMPLIFIER

Much interest has been shown in the article on the push-pull amplifier circuit in the October, 1951, issue of the *Experimenter*. Some of our correspondents have cited earlier work in which series-connected output tubes have been used. Since others may also be interested, we reproduce here their combined references, all of which are U. S. Patents.

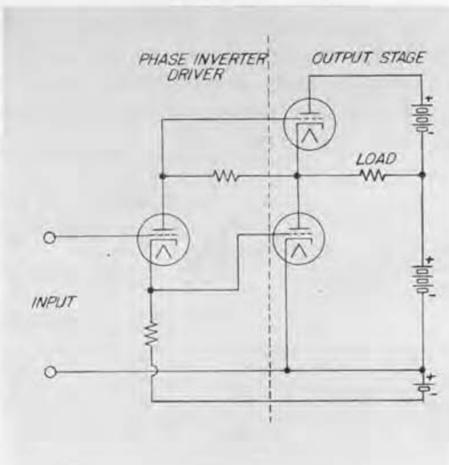
Holden	1,999,327
Gubin	2,235,677
Smith	2,247,316
Artzt	2,310,342
White	2,358,428
Etter	2,423,931
Rockwell	2,446,025
Stodola	2,488,567
Stachura	2,561,425

A study of these patents appears to show that none of them have anticipated the basic circuit of Figure 1 of the October, 1951, *Experimenter*, which is reproduced here. The essential element of this circuit is the symmetrical drive of the series output tubes without the use of a transformer. Each output tube is driven with a voltage from cathode to grid so that the two tubes operate in the same fashion. The usual attempts at driving these series tubes without a transformer result in one being driven as a cathode follower, while the other is driven as a straight amplifier or in the drive of one tube by some portion of the output voltage. With either of these systems the true push-pull symmetry of Figure 1 is lost.

Another point raised by several of our correspondents concerns the heater-to-cathode voltage of the upper output tube. When the series circuit is used, this voltage is usually so high that a separate heater winding must be used for the upper output tube. This winding should then be connected to a d-c potential corresponding to the average potential of the upper cathode. Sometimes, because of the high a-c voltages developed, this separate winding must be connected directly to the cathode rather than to a derived d-c potential. Then it is desirable to use a shielded, twisted pair for the connection from the transformer to the heater. When tubes like the Type 6AS7 Twin Triode are used in the output, however, this separate heater winding is not usually necessary.

The connection of one side of a separate heater winding to the cathode adds a capacitance across the output load. The effect of this capacitance is usually insignificant. For example, it can usually be kept to less than 200 $\mu\mu$f; and then for two Type 6L6 Pentodes as output tubes the frequency at which the reactive current is equal to the load current is 500 kc. This figure applies for a 1650-ohm load and, if lower-impedance tubes

Figure 1. The basic single-ended push-pull amplifier circuit, showing the series-connected output tubes supplying a common load and driven by a cathode-follower phase inverter.



are used or if more care is exercised in reducing the stray capacitance, the effect is even less important.

Those who want additional information on the amplifier should find the paper on "A Single-Ended Push-Pull Audio Amplifier" in the January, 1952, issue of the *Proceedings* of the Institute of Radio Engineers helpful. Reprints of this paper are available on request from the Editor of the *General Radio Experimenter.*

MISCELLANY

ELECTED — Kipling Adams, Manager of our Chicago office, has been named Chairman of the Board of the 1952 National Electronics Conference. Mr. Adams is also Secretary of Region Five of the Institute of Radio Engineers.

William M. Ihde, of our Chicago office, has been elected Secretary of the Chicago Audio and Acoustic Group.

RECENT VISITORS: Mr. E. Garthwaite, Chief Engineer, Marconi Instruments Co., St. Albans, Herts., England; Mr. Jurg Keller, Manager, Seyffer and Co., our representatives for Switzerland; Prof. Andrea Pinciroli, National Electrotechnical Institute, Turin, Italy; Mr. Giuseppe Fidecaro, Physicist, Instituto di Fisica, Universitaria Rowe, Italy; Prof. E. W. Kimbark, Instituto Tecnológico de Aeronáutica, Sao Paulo, Brazil; and Dr. Hideo Seki, Radio Regulatory Administrative Office, Tokyo, Japan.

PUBLICATIONS AVAILABLE

The series of articles entitled "The Versatile Voltage Divider," which appeared in the *Experimenter* in 1950, is now available in reprint form with some new material. These articles discuss the design, characteristics, and applications of variable three-terminal resistors, commonly called "potentiometers."

Reprints are also available of "Apparatus for Noise Measurement" by Leo L. Beranek. This paper describes a sound-measuring system and discusses the various components.

We shall be glad to send you a copy of either paper on request.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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PRINTED IN U.S.A.