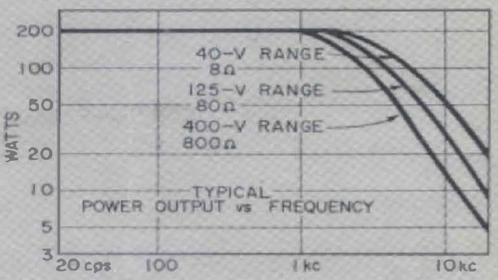
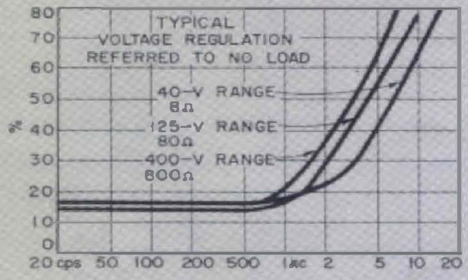
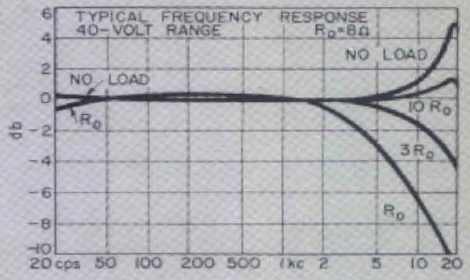
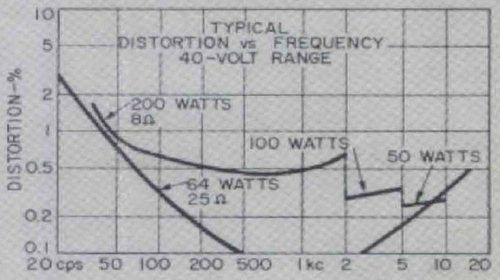
THE GENERAL RADIO EXPERIMENTER









Type 1308-A

AUDIO OSCILLATOR AND POWER AMPLIFIER

VOLUME 38 NUMBER 1 **JANUARY, 1964**

IN THIS ISSUE

200-VA Audio Generator
Digital Analog Converter
VARIAC® Autotransformers

THE GENERAL RADIO EXPERIMENTER

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A NEW 200-VA AUDIO GENERATOR

(see cover photograph)

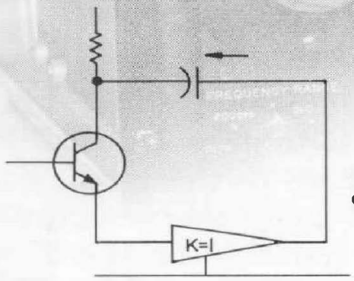

Figure 1. Guarded emitter follower.

One of the primary uses of high audio power is in the testing of electronic devices over a range of power-supply frequencies. The new Type 1308-A Audio Oscillator and Power Amplifier is well suited for this function and, in addition, has a number of features that fit it for other applications, many of which are not possible with previously available generators.

Among these features are all-solid-state circuitry, low distortion, low dynamic output impedance, and separate meters for output voltage and current. Maximum output of 200 voltamperes can be delivered to matched load impedances of 8, 80, and 800 ohms and a maximum of 5 amperes into lower impedances. The output circuit will pass up to 5 amperes of dc.

The generator is an excellent power source for the measurement of the properties of ferromagnetic materials with the Type 1633-A Incremental-Inductance Bridge at high levels of ac and dc excitation. Other uses include driving shaketables and acoustic transducers, testing servo systems and magnetic amplifiers, and testing regulated power supplies.

For specialized testing, the power amplifier can be driven from an external source, such as a high-stability signal, random noise, or square waves.

CIRCUIT

Oscillator

The small size and good reliability of solid-state circuitry are important advantages for laboratory equipment.

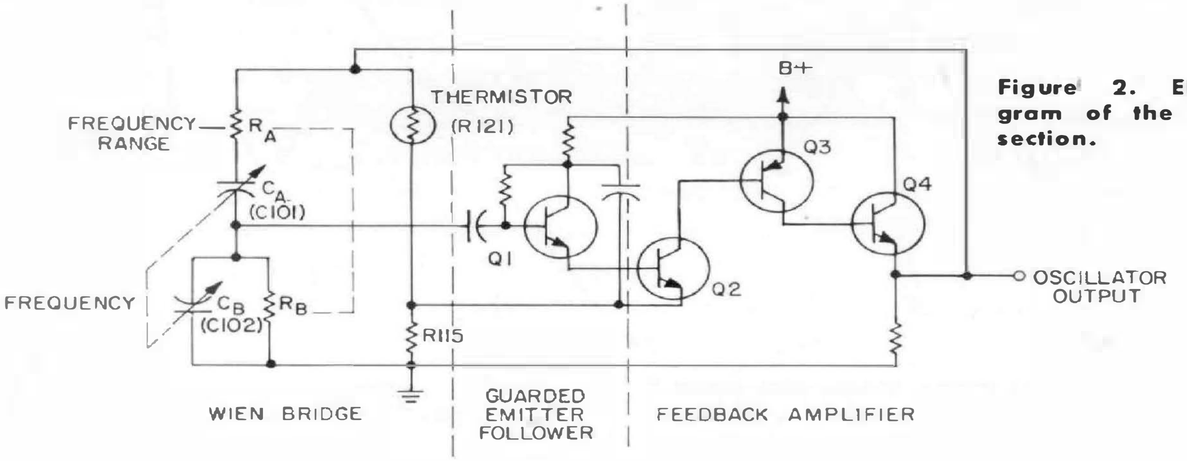

Figure 2. Elementary gram of the oscillator section.

The low impedance levels of transistors, however, are not usually considered compatible with the high impedance of variable air capacitors, which are used to provide infinite-resolution tuning in RC audio oscillators. A common alternative approach is to use ganged variable resistors. This has several disadvantages. From an economic standpoint, good quality, nonlinear potentiometers are expensive, and the limited resolution of wire-wound potentiometers often requires a separate vernier device. To combine the advantage of transistors and variable-capacitor tuning in the Type 1308-A Audio Oscillator and Power Amplifier, a novel feedback system is used. Since the impedance of practical-size variable air capacitors is of the order of 10 megohms at low audio frequencies, the associated amplifier should provide an input impedance of over 1000 megohms to avoid significant loading on the RC network.

Of course, feedback is often used to increase the input impedance of an amplifier. For example, the input impedance of an emitter-follower amplifier is usually approximated by the expression $R_{in} \cong \beta R_L$. It would appear that by an increase in the gain, β, of the stage, the input impedance could be increased indefinitely. However, the collector impedance of the first transistor shunts the input terminal and will limit the input impedance to the order of 10 megohms.

The only way to achieve an impedance in the 1000-megohm range with transistors is to degenerate all the residual impedances of the input transistor. A way of doing this is shown in Figure 1. The collector of the input emitter-follower is driven, or guarded, from the output of a unity-gain amplifier, so that all three terminals of the transistor are at the same potential, and therefore no current flows from the base lead through the transistor's collector-to-base impedance.

A practical realization of this technique is shown in Figure 2. The complete input stage and its bias network are driven from the unity-gain point at the emitter of *Q2*. The input impedance of the resulting amplifier is well over 1000 megohms for the ac signals involved. The three-stage feedback am-

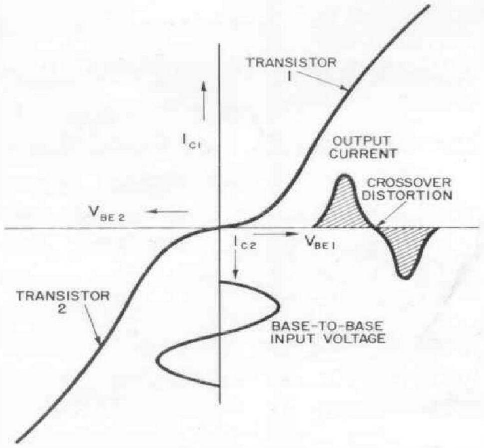

Figure 3 (*above*): Composite transconductance characteristic of a Class-B transistor amplifier.

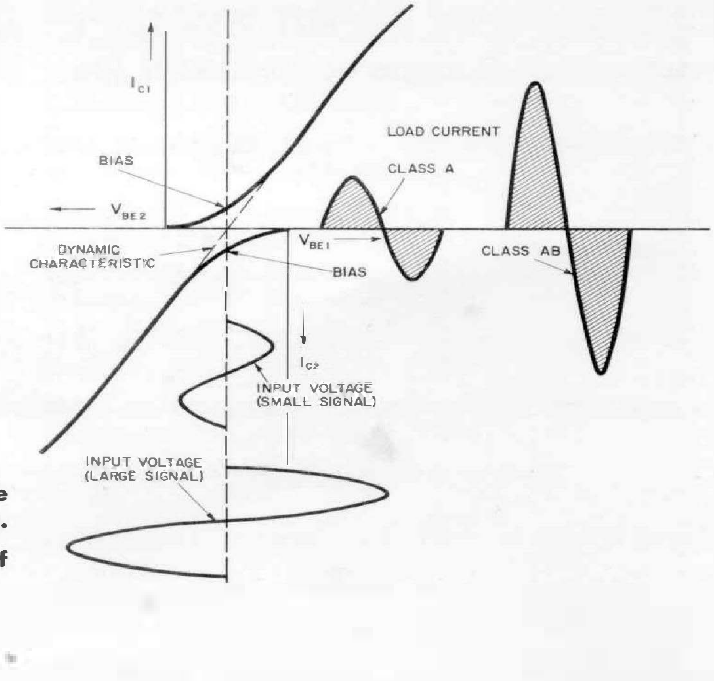

Figure 4 (*right*): Composite characteristic of Class-A and Class AB amplifier.

plifier provides sufficient loop gain so that the oscillator characteristics are not affected by changes in transistor characteristics.

Power Amplifier

The high power efficiency and the small size of transistor power amplifiers are well recognized. There are two serious problems, however, that have limited their widespread use in laboratory equipment — stability of the bias point with temperature and protection against overload and consequent failure. The voltage transfer characteristic, or transconductance, of a push-pull Class-B transistor amplifier is very nonlinear near zero current as shown in Figure 3. For this reason, a slight forward bias is usually used to shift the curves to a more nearly linear region, as in Figure 4. Unfortunately, the base-emitter bias voltage needed to keep the desired operating point varies with temperature, so that complicated temperature-sensitive bias networks are needed. It is not possible to keep the temperature-sensitive elements at the same temperature as the small transistor junction, and so some shifts in bias are inevitable.

If, instead, the output stage is driven from a high-impedance current source, the much more nearly linear current-gain transfer characteristic of the transistor is used[1] (see Figure 5). Under these conditions, no quiescent current is needed for distortion-free performance, so that much greater temperature stability can be achieved, and balancing adjustments for the output stage are not needed.

The circuit used is shown in Figure 6. The low dc resistance of the driver transformer assures bias stability of the output transistors. Ten output transistors are used and are mounted on a forced-air-cooled heat sink to provide the power-handling capability. The high-impedance drive is provided by *Q5*. The transistor *Q6* is used to balance the direct current in the drive transformer.

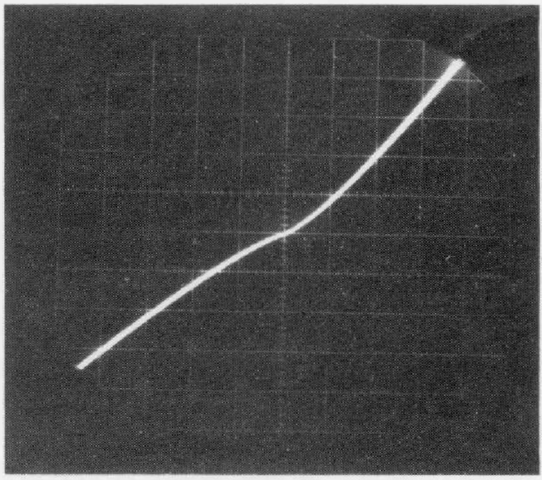

Figure 5. Output current (*vertical*) vs input current (*horizontal*) of the output stage of Figure 6.

The Class-A driver is also instrumental in protecting the output stage against overload by limiting the available drive current. Without this, a short circuit on the output could cause the output stage to draw very heavy current, probably with disastrous results. Two additional forms of protection are used—a thermal overload breaker on the output-transistor heat sink and a trip circuit that disconnects the input signal when the output current or voltage exceeds preset limits.

To achieve a low dynamic output impedance, two techniques can be used—negative voltage feedback, positive current feedback, or some combination of these. Negative feedback is used in this amplifier to avoid the stability and waveform problems that can result

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[1] James J. Faran, Jr. and R. G. Fulks, "High-Impedance Drive for the Elimination of Crossover Distortion," *The Solid State Journal*, December, 1961.

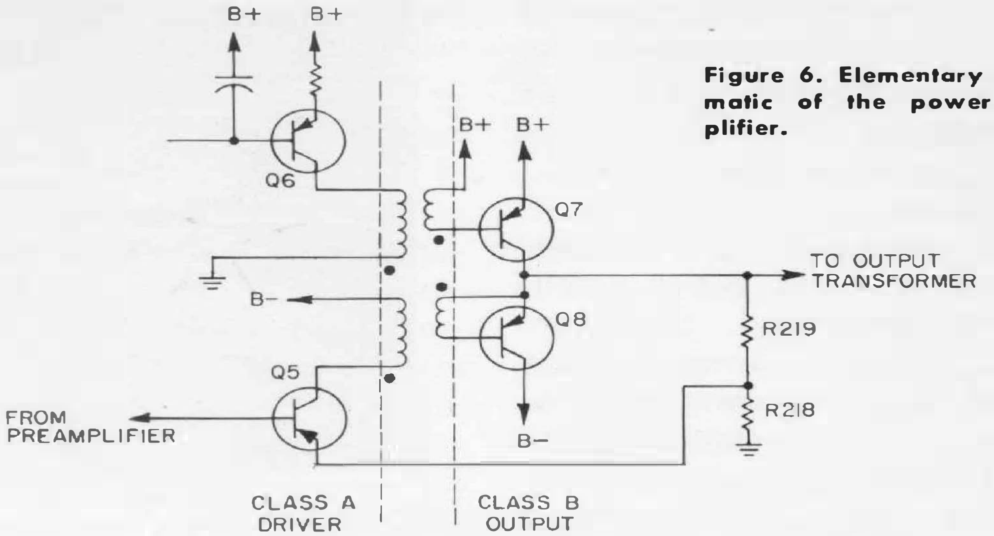

Figure 6. Elementary schematic of the power amplifier.

from positive feedback when reactive loads are used. The large negative feedback also greatly reduces harmonic distortion as well as dependence upon power-supply voltages. A single-ended push-pull configuration is used to provide a convenient point to sample the output and close the feedback loop. Thus, the output transformer is not inside the loop — a decided advantage with the large feedback factor used. Since the transformer is fed from a low-impedance source, its distortion is very low.

APPLICATIONS

Magnetic Measurements

One of the primary uses of this generator is as a signal source for the Type 1633-A Incremental-Inductance Bridge[2] in high-power-level measurements on iron-core inductors and transformers. These measurements require the simultaneous application of ac and dc signals to the inductor under test. Since this requirement could not be met by conventionally available power oscillators, new generators were required. The Type 1265-A Adjustable DC Power Supply[3] was designed for this purpose, as was the Type 1266-A Adjustable AC Power Source[4] which supplies an ac signal for measurements at power-line frequencies. The Type 1308-A Audio Oscillator and Power Amplifier can be used to supply the ac signal for measurements throughout the audio-frequency range. The output transformer of this generator provides voltage and current ranges to match the wide range of impedances that can be measured with the bridge, and direct current up to 5 amperes can be passed through the output circuit.

Meters are provided for both current and voltage, so that the excitation applied to the coil under test can be easily determined. The overload-trip circuit is arranged to trip at 50% above full scale on the current meter, so that, on the lowest output ranges, the power delivered to the load can be limited to as little as 80 milliwatts to avoid damage to the unknown inductor.

The ability to provide a low-distortion signal to a nonlinear reactive load is also important. In the measurement of an inductor on the Type 1633-A Incremental-Inductance Bridge, the load presented to the generator

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[2] R. G. Fulks and H. P. Hall, "A New System for Measuring the Inductance of Iron-Core Coils," *General Radio Experimenter*, 36, 5, May, 1962, pp 1–12.

[3] H. P. Hall, "The Type 1265-A Adjustable DC Power Supply," ibid, p 11.

[4] Gilbert Smiley, "The Type 1266-A Adjustable AC Power Source," ibid, p 13.

can be almost purely reactive. A reactive load dissipates no power, of course, since the voltage and current are not in phase. Although the Class-B output circuit used in the generator is very efficient with a resistive load, the efficiency drops nearly to zero with a reactive load. Therefore, all the input power must be dissipated in the output circuit, a requirement that usually imposes severe power-factor limitations on the load impedance. In this generator the output circuits have been built to handle this power, so that, under most output conditions, no power-factor derating is required.

Power-Frequency Testing

Another application is in the testing, over a range of power frequencies, of equipment that may be used by the military or in overseas countries. Here, the Type 1308-A Audio Oscillator and Power Amplifier is particularly useful because of its low dynamic output impedance. For example, equipment that uses a capacitor-input rectifier system draws current from the line only near the peaks of the sinusoidal signal. With such a nonlinear load an undistorted signal is possible only when the dynamic output impedance of the oscillator is low — a feature not found on many power oscillators. The waveforms shown in Figure 7 are typical of this situation. With this generator, the output voltage remains sinusoidal even though the output current contains many higher-frequency components.

This oscillator also has many applications where immunity from power-line transients and noise is required. Because of the large amounts of negative feed-back used, the output signal is not sensitive to this type of disturbance. A 5% jump in line voltage will typically cause less than a 0.1% change in output at full power.

In the measurement of hum and other spurious outputs it is also helpful to use some frequency other than the power-line frequency to run equipment under test, so that the desired components can be distinguished from the line-frequency components in the measurement system itself.

Power Amplifier

The usefulness of this generator is greatly enhanced by its ability to function as a power amplifier, driven from an external source. Thus, it can be used to supply high power with extreme frequency stability when driven from a standard-frequency source.

Its good transient response permits its use with special-waveform signals, such as square waves and noise. Usable power output is necessarily reduced with random-noise excitation to avoid tripping of the overload circuits on noise peaks.

Other Uses

Some applications stem not from the high power rating but from other fea-

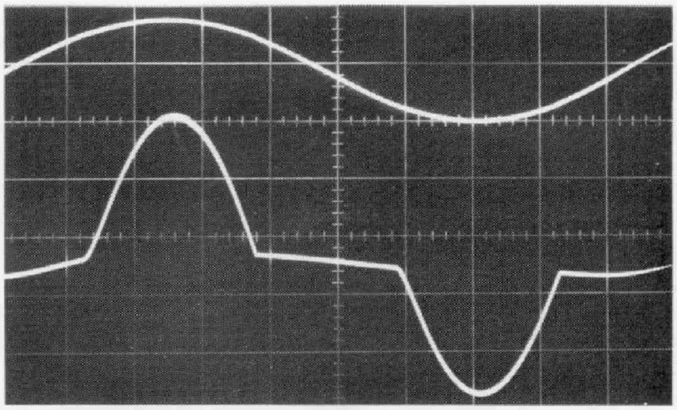

Figure 7. Output voltage (*top*) and output current (*bottom*) of the Type 1308-A Audio Oscillator and Power Amplifier when driving a device that has a capacitive-input rectifier filter. Current is drawn only near the peaks of the input waveform.

tures of the instrument. When the generator idles along at 60 watts or less, its harmonic distortion is well under 0.5% over most of the frequency range. This, combined with the wide output-voltage ranges, has been used for calibrating dynamometer-type voltmeters. The instrument has also been used as a signal source in series with a dc power supply to provide a dc source with adjustable ripple level and frequency for testing power-supply regulators.

Other applications where the multiple voltage ranges are useful are the test of servo systems and magnetic amplifiers, and driving shaketables and other acoustic transducers.

— R. G. FULKS

SPECIFICATIONS

OUTPUT

Power: 200 voltamperes, 50 cps to 1 kc. (See curves on cover.)

Full-Scale Output Ranges: 4, 12.5, 40, 125, 400 volts, rms; 0.5, 1.6, 5 amperes; in any combination up to 200 va.

Optimum Load Impedance: 0.8, 2.5, 8, 80, 800 ohms. Will operate satisfactorily with higher-impedance or nonlinear loads. Output transformer will pass dc equal to rated ac.

Regulation and Response Time: (See cover.) Less than 20% no load to full load—20 cps to 1 kc. (Bandwidth greater than 10 kc provides essentially instantaneous regulation.)

Frequency: Internal oscillator covers 20–20,000 cps in four bands.

Harmonic Distortion at Rated Output: (See cover.)
1%, 100 cps—10 kc
2%, 50 cps—100 cps

Hum: More than 50 db below maximum output.

GENERAL

Overload Protection: Electronic overload circuit trips at approximately 1½ full-scale current (manual reset); thermal protection on transistor heat sink (automatic reset).

Load Power Factor:
0 to 1.0 for continuous operation to 30 C ambient.
0 to 1.0 for intermittent operation to 50 C ambient.
0.7 to 1.0 for continuous operation to 50 C ambient.

Meters: 0 to 5, 15, 50, 150, 500 volts.
0 to 0.05, 0.16, 0.5, 1.6, 5 amperes.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 60 cps, 70 to 500 watts, depending on load. For 50-cycle supply, maximum output must be reduced 20%.

Amplifier:
Input Impedance—10 kilohms.
Sensitivity—Approximately 2 volts needed for full output.

Terminals: Binding posts and 4-terminal connector at rear.

Cabinet: Rack-bench.

Dimensions: Bench model—width 19, height 7, depth 16¼ inches (485 by 180 by 414 mm), over-all; rack model—panel 19 by 7 inches (485 by 180 mm), depth behind panel 15 inches (385 mm).

Net Weight: 91 pounds (42 kg).

Shipping Weight: 105 pounds (48 kg).

Type		*Code Number*	*Price*
1308-AM	**Audio Oscillator and Power Amplifier, Bench Model**	1308-9801	**$1150.00**
1308-AR	**Audio Oscillator and Power Amplifier, Rack Model**	1308-9811	**1150.00**

U.S. Patent No. D187,740.

NEW GRO REPRESENTATIVE FOR GREECE

We announce the appointment of the Greek firm of Marios Dalleggio as exclusive General Radio Company (Overseas) representative for Greece, succeeding the firm of K. Karayannis, who have represented us in that country for many years. Effective January 1, 1964, Marios Dalleggio took over these responsibilities and is now directly serving our customers in Greece with competent technical assistance and advice.

All inquiries, whether technical or commercial, concerning General Radio products, should be addressed to:

Marios Dalleggio
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OPERATION OF VARIAC® AUTOTRANSFORMERS ON 208/120-VOLT LINES

Users of Variac® autotransformers should seriously consider the advantages inherent in the increasingly popular 208/120-volt, 3-phase distribution system. Because the wye voltage of this system is 120 volts (rather than 139 volts as in a 240-volt system), certain restrictions on Variac autotransformers in 3-phase circuits no longer apply. The 208/120-volt, 60-cycle system allows the use of Types W5L and W8L; other models can be connected for overvoltage, or step-up, as shown in the accompanying table. This tabulation points out the possibility of trading voltage range for KVA on 208-volt circuits. Note that Types W5L and W8L increase the available KVA per dollar at a sacrifice of overvoltage operation and with operation limited to 60 cps only.

The step-up connection makes possible outputs adjustable to 485 volts from a 208-volt source, but it should be noted that, for this connection, regulation is not so good as for the line and overvoltage connections.

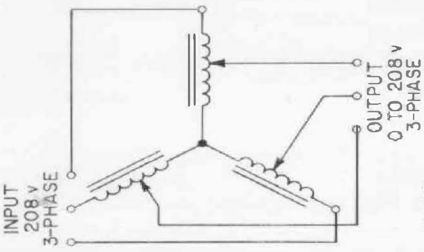

Figure 1

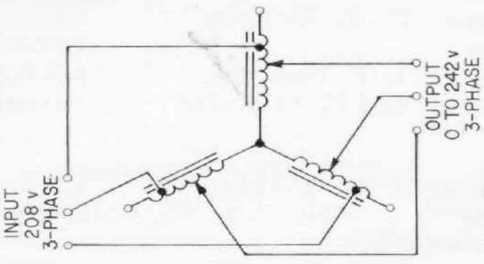

Figure 2

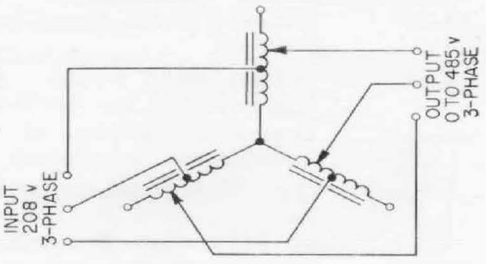

Figure 3

Type	*Circuit* *	*Input Volts*	*Frequency, Cps*	*Output Volts*	*KVA at Max. Volts*	*Price*	*KVA/$*
W2G3	Line	208	50-60	0-208	1.12	$ 52.00	0.0215
W2G3	Overvoltage	208	50-60	0-242	1.00	52.00	0.0192
W5G3	Line	208	50-60	0-208	2.81	61.00	0.0460
W5G3	Overvoltage	208	50-60	0-242	2.52	61.00	0.0413
W5LG3	Line	208	60	0-208	3.96	59.50	0.0666
W8G3	Line	208	50-60	0-208	3.96	70.00	0.0566
W8G3	Overvoltage	208	50-60	0-242	3.57	70.00	0.0510
W8LG3	Line	208	60	0-208	4.68	70.00	0.0668
W10G3	Line	208	50-60	0-208	4.68	108.00	0.0433
W10G3	Overvoltage	208	50-60	0-242	4.20	108.00	0.0389
W20G3	Line	208	50-60	0-208	9.36	156.00	0.0600
W20G3	Overvoltage	208	50-60	0-242	8.40	156.00	0.0538
W30G3	Line	208	50-60	0-208	12.96	264.00	0.0510
W30G3	Overvoltage	208	50-60	0-242	12.60	264.00	0.0478
W50G3	Line	208	50-60	0-208	18.00	397.00	0.0454
W50G3	Overvoltage	208	50-60	0-242	21.00	397.00	0.0529
W5HG3	Step-up	208	50-60	0-485	0.84	71.50	0.0117
W10HG3	Step-up	208	50-60	0-485	1.68	114.00	0.0147
W20HG3	Step-up	208	50-60	0-485	3.36	162.00	0.0207
W30HG3	Step-up	208	50-60	0-485	5.04	264.00	0.0191
W50HG3	Step-up	208	50-60	0-485	10.50	397.00	0.0264

* Line, Figure 1; Overvoltage, Figure 2; Step-up, Figure 3

REPRINTS

Reprints are available of a number of articles by General Radio engineers published in technical journals. Recent papers include:

Reprint No.	Title	Author	Publication	Date
A-79	A New Look at the Phase-Locked Oscillator	H. T. McAleer	Proceedings of IRE	April, 1959
A-80	VHF Matching Network Design	A. E. Sanderson	Proceedings of IRE	July, 1959
A-81	A New Design Procedure for Optimum Matching Networks	A. E. Sanderson	Electronic Industries	July, 1959
✓A-82	A Novel Method of Frequency Multiplication	H. T. McAleer	Electronic Industries	August, 1959
✓A-83	A Standard Program Cuts Costs	H. C. Littlejohn	Electronic Industries	Oct., 1959
A-84	Design Trends Increase Versatility of Standard-Signal Generators	W. R. Byers and G. P. McCouch	Canadian Electronic Industries	March, 1960
✓A-85	How to Design Scales that Humans Can Read	H. C. Littlejohn	Electronic Design	Sept., 1960
A-86	Plastic Cutouts Help Design C Boards		Electronics	July, 1960
✓A-87	Mixer Circuit Has Clean Output	H. T. McAleer	Electronic Industries	Oct., 1960
✓A-88	A Simplified Noise Theory and Its Application to the Design of Low-Noise Amplifiers	A. E. Sanderson and R. G. Fulks	NEREM 1960 Record	Nov., 1960
A-89	The Measurement of Impedance from Very-Low to Very-High Frequencies	C. E. Worthen	Electrical Design News	Nov., 1960
✓A-90	Industry's Watchdog: The Stroboscope	F. T. Van Veen	Safety Maintenance	Jan., 1961
A-91	High-Impedance Drive for the Elimination of Crossover Distortion	James J. Faran, Jr. and R. G. Fulks	The Solid State Journal	Dec., 1961
A-92	A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors	A. E. Sanderson	IRE Transactions on Microwave Theory and Techniques	Nov., 1961
A-93	R-F Leakage Characteristics of Popular Coaxial Cables and Connectors, 500 Mc to 7.5 Gc	J. Zorzy and R. F. Muehlberger	Microwave Journal	Nov., 1961
✓A-94	Precise Delay Measurement	H. T. McAleer	Electronics	Jan., 1961
A-95	An Accurate Substitution Method of Measuring the VSWR of Coaxial Connectors	A. E. Sanderson	Microwave Journal	Jan., 1962
A-96	The Use of Active Devices in Precision Bridges	H. P. Hall and R. G. Fulks	Electrical Engineering	May, 1962
A-97	Thyristor-Tunnel Diode Combination Generates Fast 10-ma Pulses	J. K. Skilling	Electronic Design	Feb., 1962
✓A-98	A Spectrum Analyzer from General Lab Instruments	R. W. Harley	Electronic Industries	Feb., 1962

Reprint No.	Title	Author	Publication	Date
✓A-99	The Measuring Devices of Electronics	D. B. Sinclair	Proceedings of IRE	May, 1962
A-100	Noise and Its Measurement	F. T. Van Veen	Electronics World	May, 1962
✓A-101	New Complementary Transistors Make Series Schmitt Circuits Practical	J. K. Skilling	Electronics	August, 1962
A-102	Dynamic Notch Filter	H. T. McAleer	Electronic Equipment Engineering	Nov., 1962
✓A-103	The Image-Parameter Design of the General Two-Section Elliptic-Function Filter	W. N. Tuttle	1962 IRE Convention Record	Nov., 1962
✓A-104	Magnetic Pickup Generates Frequency Markers	W. F. Byers	Electronics	Dec., 1962
✓A-105	Tunnel-Diode Delay-Line	H. T. McAleer	Electronic Equipment Engineering	Nov., 1962
✓A-106	Simple Method for Plotting Tunnel-Diode Switching Waveforms	J. K. Skilling	Electronics	March, 1963
✓A-107	Novel Feedback Loop Stabilizes Audio Oscillator	R. G. Fulks	Electronics	April, 1963
✓A-108	Design Chart for Constant-K Delay Lines	G. R. Partridge	Electronic Design	June, 1963
✓A-109				
A-110	Electronic Standards and Measurement	I. G. Easton	Electronic Industries	July, 1963
✓A-111	Direct-Reading Instruments	F. T. Van Veen	Electronics World	August, 1963
✓A-112				

Reprints of several articles that have appeared in the *Experimenter* can also be supplied:

Reprint No.	Title	Type No.	Experimenter Date
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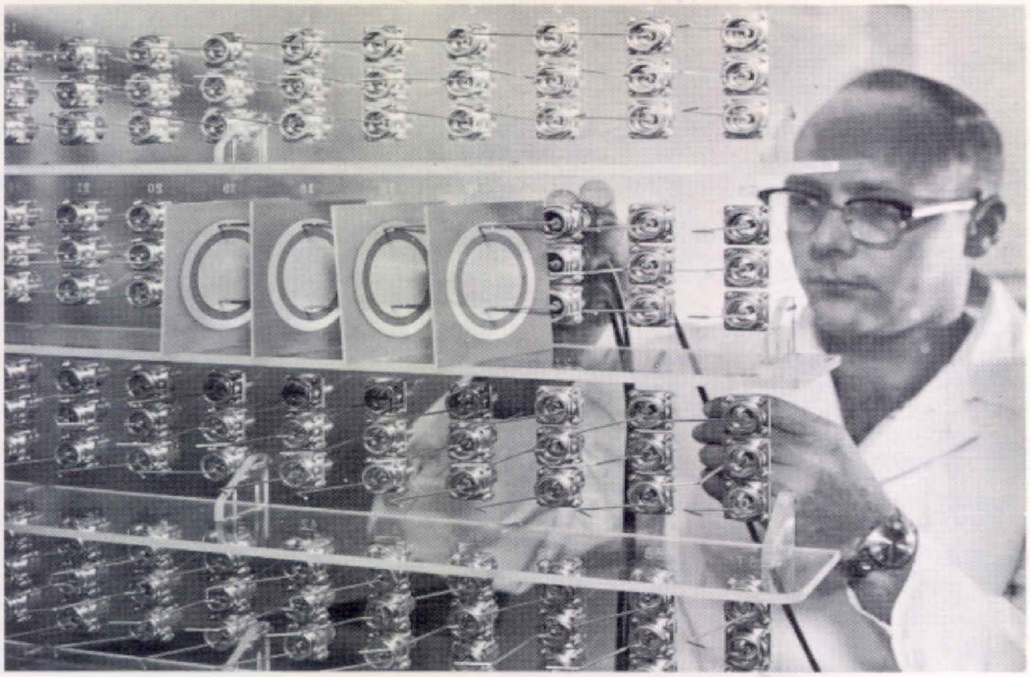
E-102	The Type 1603-A Z-Y Bridge	1603-A	July, 1955
E-103	A High-Precision Impedance Comparator	1605-A	April, 1956
E-104	The Measurement of Cable Characteristics		May-Aug., 1957
E-105	An Instrument Designed to Calibrate Capacitive Fuel-Gage Testers	P-582	Feb., 1958
E-106	A Graphic Level Recorder with High Sensitivity and Wide Ranges	1521-A	June, 1959
E-107	A Transfer-Function and Immittance Bridge for the 25–1500 Mc Range	1607-A	March, 1958 May, 1959
E-108	A New Universal Impedance Bridge	1650-A	March & April, 1959
✓E-109	Measurements of the Equivalent-Circuit Parameters of Tunnel Diodes	1607-A	July-Aug., 1960
E-110	A Generator of Random Electrical Noise	1390-B	Dec., 1951 Dec., 1959 Jan., 1960
E-111	New Eyes for Industry (Strobotac® electronic stroboscope)	1531-A	Sept., 1960
E-112	Rapid VSWR Measurements with Admittance Meter	1602-B	May, 1960
E-113	A Close Look at Connection Errors in Capacitance Measurements		July, 1959

Single copies free upon request.

✓E-114 Digits can lie

COAXIAL CONNECTORS AT DC



Courtesy Spaulding Fibre Company

DC TO MICROWAVE — That's the frequency range covered by TYPE 874 Coaxial Connectors. And for critical measurements at dc the positive contact, good shielding, and convenient plug-in features of the connector are just as important and useful as at microwave frequencies.

An excellent example of dc use is provided by the accompanying photograph which shows these connectors in a test chamber at Spaulding Fibre Company of Tonawanda, New York. In this photograph, samples of Spauldite laminates are being mounted on the inner door of the test chamber, whose temperature and relative humidity can be held precisely at a desired value or varied according to a predetermined time schedule.

The samples are 4″ x 4″ x thickness (usually 1/16″ to 1/8″) with sprayed conductive-silver-paint electrodes in the ASTM "Bullseye" pattern. They are being tested for volume resistivity and surface resistance, which is usually measured at the end of 96 hours' exposure to 90% relative humidity at 35C. Contact is made to the silver paint electrodes by means of spring brass wire fingers, gold plated to give low contact resistance and freedom from corrosion. The contact fingers are silver soldered to the center terminal of the General Radio TYPE 874-PB Coaxial Panel Connectors.

By means of shielded patch cords, each sample can be connected in turn to equipment capable of measuring resistances as great as 5 x 10^{15} ohms. At these values of resistance, shielding becomes very critical. Values obtained on a new glass fabric base epoxy laminate, used in critical military printed circuits, are on the order of 477,000,000 megohms/cm. volume resistivity and 5,700,000 megohms surface resistance.

General Radio Company

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