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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

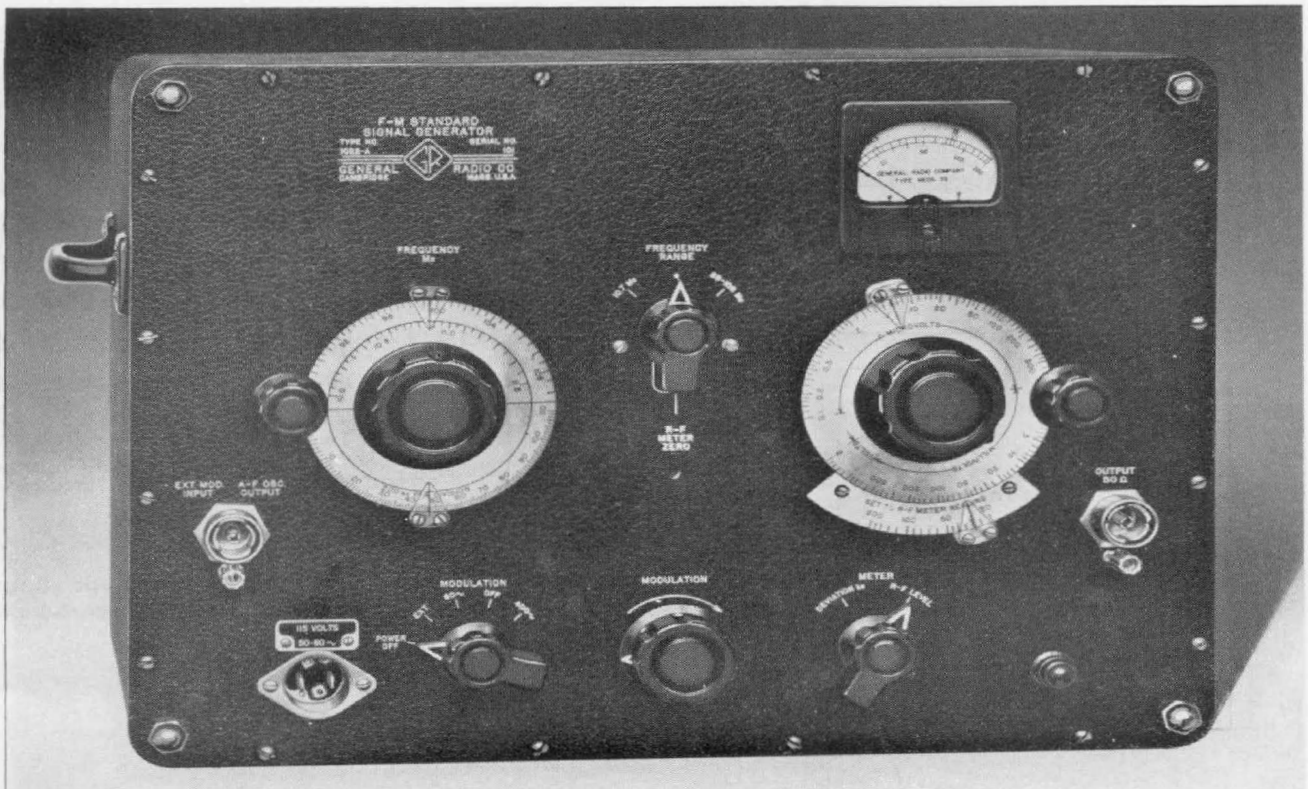
A SIMPLE STANDARD-SIGNAL GENERATOR FOR F-M BROADCAST USE

Also
IN THIS ISSUE

● **TO SUPPLEMENT** the TYPE 1001-A general-purpose a-m standard-signal generator announced in the September, 1949, *Experimenter*, an f-m standard-signal generator, specifically intended for measurements on f-m broadcast receivers, is now available.

The TYPE 1022-A F-M Standard-Signal Generator has been designed to provide first-class performance at a moderate price. Every effort has been made to use simple, direct methods in the design, and only those features necessary for measurements of f-m broadcast receivers have been included.

Figure 1. Panel view of the Type 1022-A F-M Standard-Signal Generator.



The instrument comprises an oscillator, covering the frequency ranges of 88-108 Mc and 10.7 Mc ±10%, and a reactance-tube modulator, providing deviations up to ±200 kc. The output voltage is obtained through a mutual-inductance-type attenuator and can be adjusted over a range from 0.1 μv to 1 volt on the 88-108 Mc range, and from 0.1 μv to 0.25 v on the 10.7-Mc range. The output impedance is 50 ohms resistive, constant over the tuning range.

The TYPE 1000-P5 Transformer described in an accompanying article can be plugged into the TYPE 874-P Output Jack to convert the 50-ohm unbalanced output system to 300 ohms balanced.

GENERAL FEATURES

The direct use of the r-f oscillator eliminates difficulties with spurious beats, or "birdies," that cause trouble in beat-type systems. The restricted tuning range opens up the tuning scale and facilitates precise frequency settings. For easy interpolation on the 88-108 Mc band, an auxiliary scale on the main tuning dial is marked in 200-kc intervals. On the 10.7 Mc range, this same scale provides intervals of approximately 20 kc.

The modulation system is flat from 20~ to 15 kc, and the instrument can therefore be modulated, from an external source, with any frequency that is of interest in designing f-m receivers. Fixed internal modulating frequencies of 60~ (line frequency) and 400~ are provided. When these are used, the modulation voltage appears at the external modulation binding posts to drive the horizontal plates of a cathode-ray oscillograph for sweep-generator applications. Deviation is indicated directly on a panel meter whose quasi-logarithmic scale spreads the readings at small deflections, so that good accuracy is obtained in reading small deviations as well as large.

Shielding is excellent. All the r-f circuits are contained within one casting, which is closed with a tight-fitting cover. All leads entering the casting are carefully filtered, and the amount of leakage from the assembly is so small that the extra attenuation provided by the panel and aluminum cabinet reduces the external leakage below the noise level. The testing specification on leakage, in fact, calls for no measurable signal to be detected on a high-sensitivity f-m receiver.

No provision for amplitude modulation is incorporated in the TYPE 1022-A itself. The TYPE 1023-A Amplitude Modulator, described in the accompanying article, was therefore designed to be used in conjunction with the signal generator for a-m tests.

Several of the circuits and design features, which contribute to the good performance and simplicity of the instrument, are unconventional and worthy of mention.

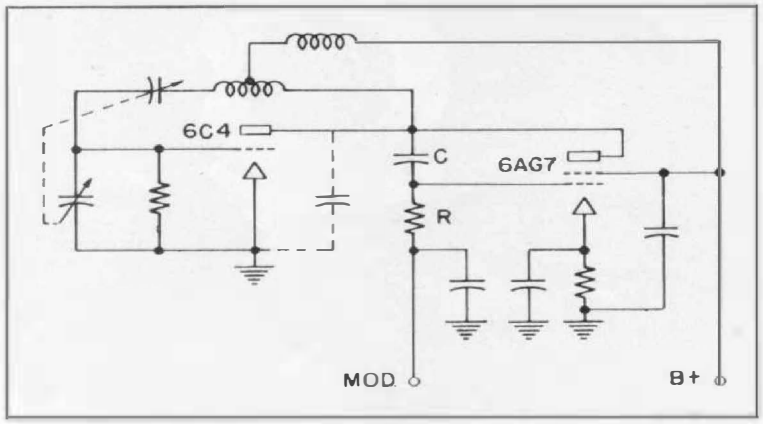


Figure 2. Elementary schematic diagram of the oscillator and reactance-tube circuits.

R-F OSCILLATOR

The oscillator circuit, shown in Figure 2, is based on the series-tuned circuit described by Clapp.[1] It was chosen both

[1] J. K. Clapp, "An Inductance-Capacitance Oscillator of Unusual Frequency Stability," *Proceedings of the I.R.E.*, March, 1948.

because it is inherently a stable circuit and because it gives a minimum change of deviation with the oscillator frequency.

Two tuning inductors, for the two frequency ranges provided, are mounted on a turret switch. For the particular frequency range selected, the appropriate inductor is moved to a position in which connections to the oscillator circuit are made and proper magnetic coupling to the mutual-inductance-type attenuator is established. The tuning capacitor has two sections, one connected in series with the inductor, between plate and grid, for tuning, and another connected from grid to ground to maintain proper feedback to provide constant output over the tuning range. The fixed capacitance between plate and ground, that completes the oscillator circuit, is provided by the capacitance component of the reactance-tube-modulator admittance and the plate-to-ground capacitance of the oscillator triode.

The circuit shown yields a deviation that ideally would vary inversely as the carrier frequency. This is not a very rapid variation, and could be compensated readily by a conventional ganged volume control in the modulation circuit. The departures from ideal behavior, however, have been put to good use in eliminating even this mechanical complication. It was found that the type of tube used for the reactance modulator tended to resonate in the 88-108 Mc range, with a consequent increase in effective input capacitance with frequency. Over this relatively narrow frequency range it was therefore found possible to maintain substantially constant deviation, without ganged controls, by proper choice of components, lead lengths, and mechanical layout.

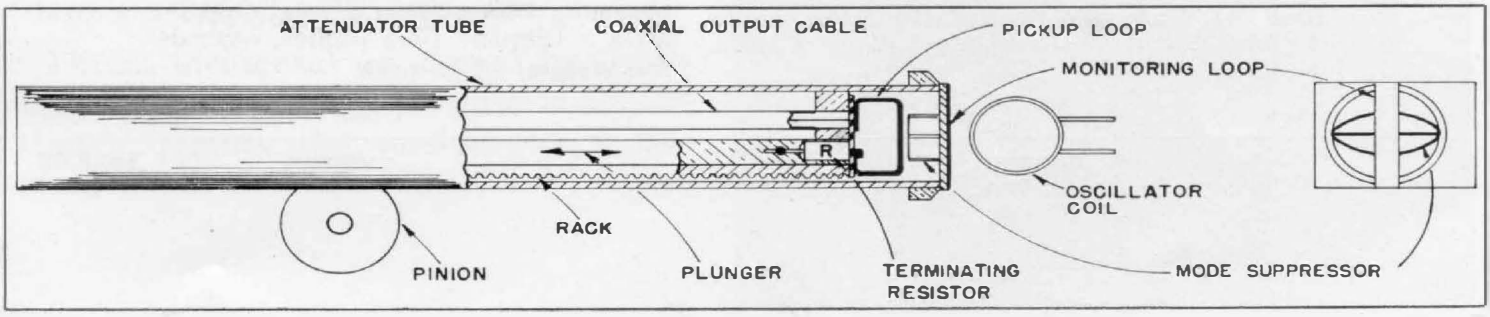
Over the 10.7 Mc band the deviation varies inversely as the carrier frequency but this variation is of less importance because the 10.7-Mc RMA standard intermediate frequency is in such wide use. The resistive element of the reactance-tube phase-splitting circuit is automatically switched with the tuning inductors to produce the same deviation at 10.7 as that maintained over the 88-108 Mc band.

OUTPUT SYSTEM

The mutual-inductance-type attenuator is magnetically coupled to the selected oscillator coil. A monitoring loop, placed directly across the attenuator mouth, samples the magnetic field at that point, and the induced voltage, rectified by a diode voltmeter circuit, actuates the panel meter. A mode suppressor, also located at this point, rejects unwanted components of the magnetic field and supports, in its vicinity, only the TE 1-1 mode that attenuates down a waveguide of circular cross section at the rate of 32 db/diameter.

The field that excites the monitoring loop is therefore of the same character as that which excites the attenuator pickup loop, and a true measure of output voltage, under all conditions, is given by the meter reading and the posi-

Figure 3. Cutaway view of the attenuator and termination.



tion of the attenuator plunger. The plunger slides within the attenuator tube and incorporates a well, in which a 50-ohm terminating resistor is mounted. This resistor is connected to an output cable of 50 ohms characteristic impedance by the pickup loop, which is carefully proportioned to act as a π-type artificial-line section of the same characteristic impedance.

A completely smooth termination system ideally results from this combination and, since the system was originally designed for operation at frequencies up to 500 Mc, the departure from perfection at lower frequencies is principally the $\pm 2\%$ tolerance of the terminating resistor itself.

For standardizing the attenuator dial in terms of the meter reading, use is made of the adjustable index and auxiliary scale illustrated in Figure 1. When the adjustable index is set on this scale to agree with the meter reading, the dial index moves with it to assume the proper position for the indicated level of magnetic field at the attenuator mouth, and the dial then reads directly in open-circuit output voltage. The quasi-logarithmic meter scale indicates both the 0.25 volt level at 10.7 Mc and the 1-volt level over the 88-108 Mc band well upscale to make possible precise settings on both frequency bands. Changes of output over each band are quite small and minor readjustment of the index as the frequency is varied is generally found necessary only when measurements of the highest accuracy are required.

—D. B. SINCLAIR

SPECIFICATIONS

Carrier Frequency Range: 10-11.5 megacycles and 88-108 megacycles in two ranges.

Frequency Calibration: The dial is adjusted to better than $\pm$ 0.25% at all points.

Frequency Stability: *Instantaneous Stability* (F-M Noise Level) — more than 50 db below 75 kc deviation. *Slow Drift* — less than 0.005% after first 20 minutes of operation.

Open-Circuit Output Voltage: 88 to 108 Mc range — less than 0.1 microvolt to more than 1 volt; 10.7 Mc — less than 0.1 microvolt to approximately 0.25 volt.

Output Impedance: 50 ohms nominal; actual $(50 + j0) \pm (3 + j2)$.

Maximum Output Voltmeter Error: $\pm 10\%$ when zero is correctly set.

Maximum Attenuator Error: $\pm 2\%$ at minimum attenuation, increasing linearly to $\pm 5\%$ at maximum attenuation.

Leakage: Cannot be detected on high-sensitivity, commercial f-m receivers.

Frequency Modulation: 0-200 kc deviation.

Internal Modulation Frequencies: Line frequency and 400 cycles.

External Modulation: 20 c to 15 kc; approximately 7 volts at 0.5 megohm are required.

Distortion: At 400-cycle modulation, less than 3% at 75 kc deviation; less than 10% at 200 kc deviation.

Incidental Amplitude Modulation: Less than 5%.

Accuracy of Indication:

Variation of Deviation Carrier Frequency: 88- to 108-megacycle range, $\pm 5\%$; 10.7-megacycle range, approximately inversely proportional to carrier frequency.

Variation with Modulation Frequency: $\pm 2\%$ 20 c to 2 kc; $\pm 10\%$, 2 kc to 15 kc.

Meter Error: ± 2 kc, maximum.

Power Supply: 110-130 or 220-260 volts, 50-60 cycles.

Power Input: Approximately 50 watts.

Tubes:

1—6C4	1—6AG7	1—6SL7	1—6AL5
1—2050	1—6AQ6	1—6H6	1—991

Accessories Supplied:

1—874-R20 50-Ω Output Cable
1—Power Cord
1—874-C Cable Connector

Other Accessories Available: TYPE 1000-P5 Transformer (50 Ω unbalanced to 300 Ω balanced), TYPE 1000-P1 Termination Unit (50 Ω).

Terminals: Output and external modulation terminals are TYPE 874 Coaxial Connectors.

Mounting Dimensions: (Height) 13⅝ x (width) 20¼ x (depth) 10⅝ inches, overall.

Net Weight: 35 pounds.

Type		*Code Word*	*Price*
1022-A	**F-M Standard Signal Generator***	ABIDE	**$625.00**

*U. S. Patent No. 2,125,816.

A VERSATILE AMPLITUDE MODULATOR FOR V-H-F STANDARD-SIGNAL GENERATORS

Although designed particularly for use with the TYPE 1022-A F-M Standard-Signal Generator, the TYPE 1023-A Amplitude Modulator may be used generally with standard-signal generators at frequencies between 5 Mc and 220 Mc, to produce an amplitude-modulated signal with no significant incidental fm.

GENERAL CHARACTERISTICS

The amplitude modulator consists simply of a grid-modulated aperiodic amplifier that is connected between the output of the standard-signal generator and the device under test. It is designed specifically to work out of a 50-ohm source impedance and to have a gain of 0.1, substantially flat from 10 Mc to 150 Mc and reasonably flat from 5 Mc to 220 Mc.

Modulation up to 80% is provided, either internally at the power-line frequency or from an external source from 20 to 15,000 cycles. Envelope distortion is less than 5% at 80% modulation. The gain and modulation percentage are substantially independent of r-f input voltage from 1 microvolt to 1.5 volts; at higher input voltages the gain decreases and envelope distortion increases.

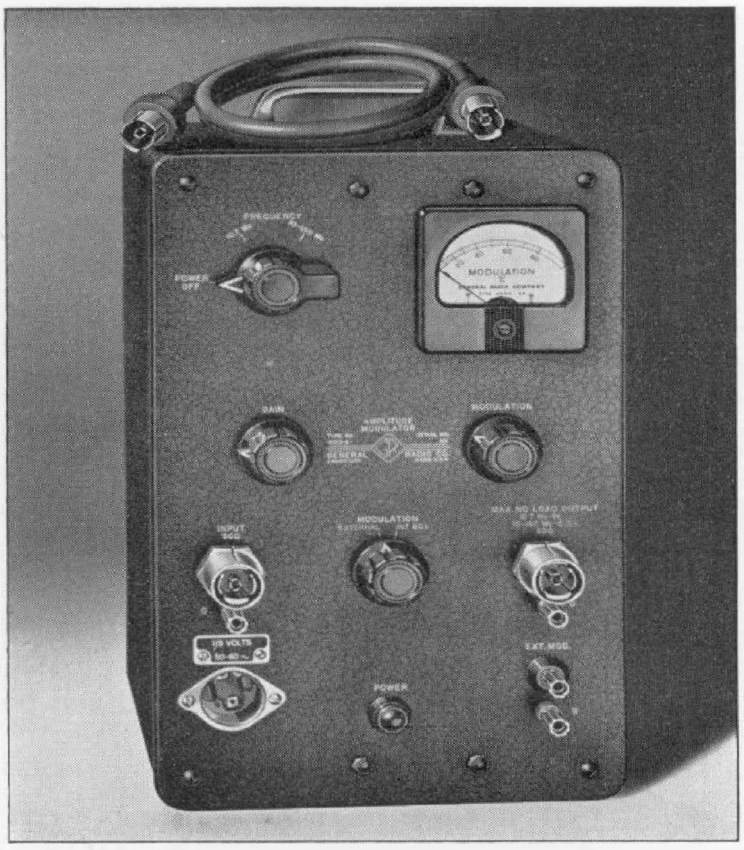
The output impedance, nominally 50 ohms resistive, is $(50 + j0) \pm (5 + j4)$ from 10 Mc to 150 Mc, and the resultant voltage standing-wave ratio is less than 1.15. At higher frequencies the VSWR increases, reaching a value of about 2.0 at 220 Mc.

INCIDENTAL FM

Direct incidental fm caused by "pulling" of the oscillator frequency is almost absent because the modulation is accomplished on the output side of the standard-signal-generator attenuator. On direct comparison, a standard-signal generator, even one having a modulated amplifier following the oscillator, when modulated with the TYPE 1023-A Amplitude Modulator shows spectacularly better performance than when it is modulated with its own internal modulation system.

For the most refined measurements, however, it should be pointed out that a further source of equivalent fm arises from the phase modulation produced by changes in the input impedance of the tube over the modulation cycle. When the TYPE 1023-A Amplitude Modulator is operated from a 50-ohm source at 100 Mc, this equivalent fm only amounts to 10 cycles for 80% modulation at a 60-cycle modulating frequency. However, fm arising from phase modulation increases linearly with the modulating

Figure 1. Panel view of the Type 1023-A Amplitude Modulator.



frequency, and this equivalent fm will increase to 2500 cycles when the modulating frequency is raised to 15,000 cycles.

I-F BAND

A feature of the instrument, particularly important when it is used with the TYPE 1022-A F-M Standard-Signal Generator, is a second operating range that can be selected by a switch. This second range provides a gain of 10 at the 10.7 Mc, RMA standard fm-receiver intermediate frequency, with a band-width to the half-power points of ±0.6 Mc. On this range the gain and modulation percentage are substantially independent of input voltage at levels up to 0.1 volt. Output voltages up to 3 volts, however, can be obtained without serious increase in envelope distortion if some change in gain can be tolerated. The output impedance is $(50 - j2) \pm (2.5 \pm j1)$ at 10.7 Mc (a VSWR less than 1.15), and varies over the entire band within $(50 - j4) \pm (5 \pm j15)$ to produce a VSWR of less than 1.4.

GAIN STANDARDIZATION

Since the grid-modulation process involves varying the effective trans-conductance of the amplifier tube with modulating voltage, it is not feasible to stabilize the amplifier by means of negative feedback. As a consequence, some change in gain may be expected over periods of extended operation. A gain control, mounted on the panel, provides adjustment over a sufficient range to compensate for these changes and to correct for changes in gain as a result of changes in frequency or of switching ranges. When the instrument is used with a standard-signal generator having a 50-ohm output impedance, the gain can be quickly and accurately standardized by, first, connecting the receiver under test to the standard-signal-generator output directly and setting to a reference voltage; then, second, reconnecting the receiver to the output of the TYPE 1023-A Amplitude Modulator, resetting the standard-signal-generator attenuator to a reading 10:1 greater or 10:1 less than the original reading (for the 10-150 Mc or 10.7 Mc range, respectively) and adjusting the gain until the same receiver output is obtained.

EXAMPLES OF USE

A simple method of checking ratio-detector performance, for instance, is to use the combination of a TYPE 1022-A F-M Standard-Signal Generator, modulated at 400 cycles, and a TYPE 1023-A Amplitude Modulator, modulated at 60 cycles. With the 400-cycle modulation voltage used as horizontal deflection, and the output of the ratio detector used as vertical deflection on a cathode-ray oscilloscope, the discriminator characteristic will be displayed on the oscilloscope screen. For small amplitude-modulation percentages, no departure from the conventional pattern will be noticeable, but, as the amplitude modulation is increased, multiple patterns will begin to appear. These multiple patterns will pass through a common central point, since no significant incidental fm is introduced by the TYPE 1023-A Amplitude Modulator, and the fanning out at the ends will give a measure of the a-m response of the detector at the modulation percentage indicated by the panel meter. Figure 2 is a typical pattern.

For simple tests of performance of limiters or ratio detectors, the instrument gives almost ideal performance when used as described. It should be emphasized, however, that the generator is entirely satisfactory for even more

refined tests where separation of f-m and a-m response is obtained by the use of sharply tuned filters, because the equivalent fm introduced by 80% modulation at 1000 cycles is only about 150 cycles, or 54 db below ±75 kc deviation.

Owing to its very low incidental fm, the TYPE 1023-A Amplitude Modulator is also useful with the TYPE 1001-A and the TYPE 805-C Standard-Signal Generators. Incidental fm in these instruments, as in most a-m signal generators, is characteristically a function of the carrier frequency as well as of percentage modulation, amounting to as much as 20 kc at 50 Mc and 80% to 100% modulation, which is greater than the bandwidth of ordinary communication channels. When the TYPE 1023-A Amplitude Modulator is used, however, the improvement is of the order of 1000:1, and incidental fm is practically eliminated as a source of error in receiver measurements.

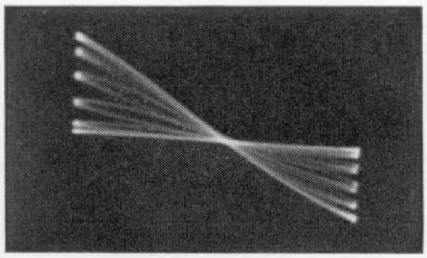


Figure 2. Typical response of a ratio detector to combined fm and am.

— D. B. SINCLAIR

SPECIFICATIONS

*Pass Band**	*Input Voltage Range** *(From 50-ohm source)*	*Output Impedance* *Nominal*	*VSWR*	*Output Volts*	*Gain*
10 to 150 Mc	0-1.5 v at 50 ohms	50 ohms	1.15	1/10 Input V	0.1
10.1 to 11.3 Mc	0-0.1 v at 50 ohms	50 ohms	1.4 (1.13 at 10.7 Mc)	10 Input V	10

*Instrument can be used over the range of 5 to 220 Mc, but gain will vary somewhat with frequency, and output impedance will not stay within above limits. Input voltages can be increased beyond above figures at some increase in envelope distortion and decrease in gain.

Amplitude Modulation: 0 to above 80% continuously adjustable, accurate to (5% of meter reading + 1% modulation).

Internal Modulation: At power line frequency.

External Modulation: Flat within ± 1 db from 20 c to 15 kc; approx. 5 volts into 10,000 ohms will produce 80% modulation.

Envelope Distortion: Less than 5% at 80% modulation. Decreases with the modulation percentage.

Frequency Modulation: Direct incidental fm from reaction on a low-impedance standard-signal generator is negligible. Equivalent fm from variable phase shift is of the order of 10 cycles for 80% modulation at 60 cycles and is proportional to modulating frequency and modulation percentage.

Carrier Noise Level: Better than 45 db below 80% modulation.

Leakage: At least 45 db below output signal on 10 to 150 Mc range; at least 60 db on 10.7 Mc range.

Terminals: Input and output terminals are TYPE 874 Coaxial Connectors.

Power Supply: 105 to 125 (or 210 to 250) volts; 50 to 60 cycles. Demand is 15 watts.

Tubes: One 6AC7 and one 6X5GT; both are supplied.

Accessories Supplied: One TYPE 874-R20 Patch Cord.

Other Accessories Available: TYPE 1000-P5 Transformer (50 ohms unbalanced to 300 ohms balanced; TYPE 1000-P1 Termination Unit, 50 ohms; TYPE 874-Q1 Adaptor (for Type N Connectors).

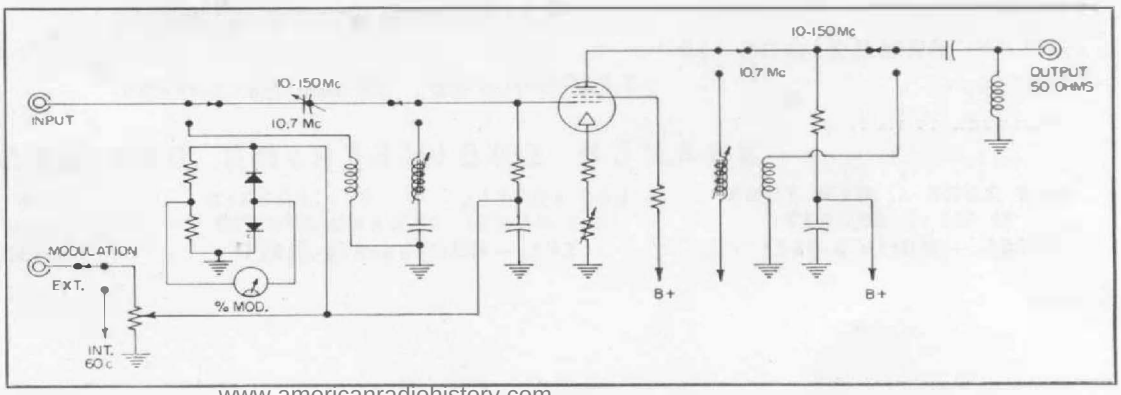


Figure 3. Elementary schematic diagram of the Amplitude Modulator.

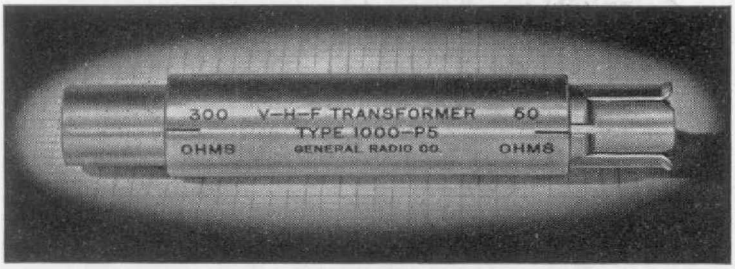
Mounting: Aluminum panel with black crackle finish; aluminum cabinet with black wrinkle finish.

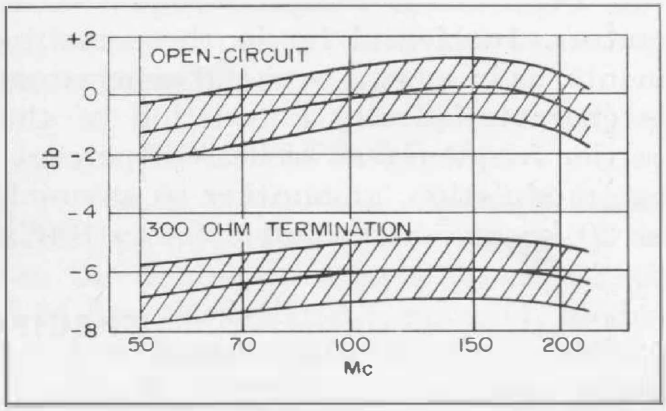
Dimensions: (Height) 14⅝ x (width) 9⅛ x (depth) 8¼ inches overall.

Net Weight: 14½ pounds.

Type		*Code Word*	*Price*
1023-A	**Amplitude Modulator**	EXULT	**$250.00**

A TRANSFORMER FOR 300-OHM BALANCED OUTPUT FROM STANDARD-SIGNAL GENERATORS





Frequency characteristic of the Type 1000-P5 V-H-F Transformer. Shaded areas show tolerances.

The TYPE 1000-P5 V-H-F Transformer is designed to plug into a standard-signal generator having a 50-ohm unbalanced output and produce an equal balanced open-circuit voltage behind a 300-ohm balanced impedance for r-f measurements of fm and tv receivers.

The transformer is mounted in a cylindrical container terminated at one end in a TYPE 874 Coaxial Connector and at the other in a socket designed to receive the Alden Type HA902P Connector for standard 300-ohm open parallel-wire line.

SPECIFICATIONS

Frequency Range: 50 Mc to 250 Mc.

Frequency Characteristic: See plot.

Accuracy: See plot.

Input Impedance: Approximately 300 ohms. Designed to work out of 50-ohm source.

Terminals: Input — General Radio TYPE 874 Coaxial Connector.
Output — Fits Alden Type HA902P Connector.

Dimensions: (Length) 4⅜ x (diameter) ⅞ inches.

Net Weight: 3½ ounces.

Type		*Code Word*	*Price*
1000-P5	**V-H-F Transformer**	ARSON	**$27.50**

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