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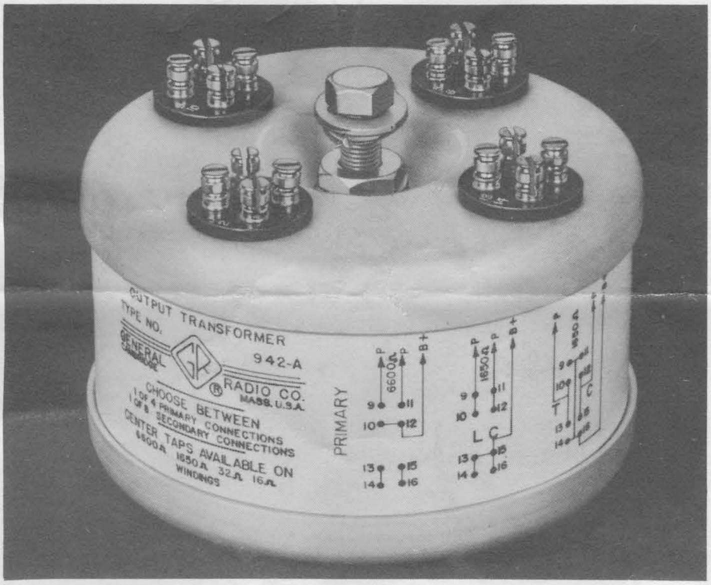
OPERATING INSTRUCTIONS
for
TYPE 942-A
OUTPUT TRANSFORMER



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OPERATING INSTRUCTIONS
for
TYPE 942-A
OUTPUT TRANSFORMER

The Type 942-A Transformer is designed primarily as a high-power output transformer for a push-pull amplifier, but is by no means limited to this specific use and may serve as a versatile 100-watt step-up or step-down transformer in a variety of applications.

The advantages of the toroidal core transformer[1] over one using a shell-type core are becoming more generally recognized. Chief among these are the high degree of astaticism and the extremely tight coupling that can be attained between windings extending around the complete circumference of the toroid.

The Type 942-A Output Transformer combines excellent frequency response, low distortion, high power-handling capacity, and flexibility of impedance ratios in a convenient, compact unit. Leakage reactance between primary sections is very small, to give minimum distortion from switching transients in conventional push-pull amplifier circuits. Connections to individual primaries are provided for use in the single-ended push-pull amplifier described in Section 7.

The Type 942-A Output Transformer uses the same high-quality toroidal core that is used in the Type V-5 Variacs, and can handle peak powers up to up to 100 watts with a minimum of harmonic distortion.

SECTION 1 INSTALLATION

By means of the single bolt and washers supplied, the transformer can be mounted above a chassis shelf or against a side wall. This requires a single hole (W-drill) in the chassis for the central mounting bolt. The transformer can also be mounted beneath a chassis shelf with the four terminal

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[1] Horatio W. Lamson, "Some Advantages of the Toroidal Transformer in Communication Engineering," Tele-Tech, May, 1950. Reprints available on request.

plates projecting through four additional holes 1-1/4 inches in diameter, spaced 90° apart, and on a radius of 1-3/4 inches from the central mounting bolt.

The central clamping stud in the transformer is insulated from the case on both ends. This stud should be grounded to the case at one end only; otherwise a resultant short-circuit turn around the core would affect the performance of the transformer. The nuts on the two ends of this central stud compress internal felt washers and seat against an internal cylindrical sleeve.

SECTION 2 TRANSFORMER WINDINGS

The toroidal core carries eight separate windings terminating individually in 16 terminals with no internal connections. The terminals are arranged to facilitate parallel or series connections. A 60 cycle, 2000 volt (r.m.s.) insulation test is made between each pair of these windings and between each winding and the case.

There are four identical duplex (semicircumferential) primary windings and two pairs of duplex secondary windings. The terminations, progressive sequence, and direction of these windings are as follows:

		TURNS MATCHED TO
"8-ohm" duplex secondaries	1 to 2 and 3 to 4	0.5%
"413-ohm" duplex primaries	9 to 15 and 13 to 11	0.06%
"413-ohm" duplex primaries	10 to 14 and 16 to 12	0.06%
" 4-ohm" duplex secondaries	5 to 6 and 7 to 8	0.6%

The secondaries are single-layer windings, while the primaries are progressive banked windings applied with a machine developed for this purpose. By a unique process, unbroken rubber sleeves are applied over the core and placed between each of the four "layers" of windings. Each pair of duplex windings is precisely balanced within one turn to eliminate circulating current losses when they are connected in parallel. The finished winding is wax-dipped prior to mounting.

The nominal impedance values specified in the connection diagrams printed on the transformer case are based on a generator impedance of 6600 ohms for all four primary windings in series. This is the customary value used for a pair of 6L6 tubes operating push-pull class AB. If these primary windings are connected in series-parallel or all in parallel the corresponding generator impedances should be 1650 and 413 ohms respectively.

The four secondary windings are so proportioned that matching loads will have the following impedance values:

TABLE I

A. Outside Windings in Parallel	4 ohms
B. Inside Windings in Parallel	8 ohms
C. Outside Windings in Series	16 ohms
D. Inside Windings in Series	32 ohms
E. Series Combination of A and B	23 ohms (23.31)
F. Series Combination of B and C	47 ohms (46.63)
G. Series Combination of A and D	59 ohms (58.63)
H. Series Combination of C and D	93 ohms (93.26)

The composite secondaries, E, F, G, H involve all of the secondary windings, thereby giving a maximum of copper efficiency.

SECTION 3 AVAILABLE IMPEDANCE RATIOS

Matching generator and load impedances are not limited to the values specified above, provided that they have the corresponding ratios. The eighteen different primary-to-secondary turns and impedance ratios that are obtainable are listed in Table II, together with the corresponding nominal impedance values. Internal losses disregarded, turns ratios are also voltage or current ratios.

TABLE II

To Obtain		Connection to be Used			
		One Choice		Alternate	
Turns Ratio	Impedance Ratio	Pri	Sec	Pri	Sec
40.6	1650	6600	4		
28.7	825	6600	8		
20.31	413	6600	16	1650	4
16.83	283.2	6600	23		
14.36	206.2	6600	32	1650	8
11.90	141.6	6600	47		
10.61	112.6	6600	59		
10.16	103.2	1650	16	413	4
8.41	70.8	6600	93	1650	23
7.18	51.6	1650	32	413	8
5.95	35.4	1650	47		
5.31	28.16	1650	59		
5.08	25.78	413	16		
4.21	17.70	1650	93	413	23
3.59	12.89	413	32		
2.974	8.85	413	47		
2.653	7.04	413	59		
2.103	4.42	413	93		

For six of these ratios there is a choice of either of two connections, depending upon whether one is more concerned with extending the extreme low range of the frequency characteristic (using the high-impedance windings) or the extreme high-frequency range (using the low-impedance windings).

It will be noted that center taps (B+) are provided on 6600- and 1650-ohm primary windings, permitting conventional push-pull excitation. Center taps are also available on the 32- and 16-ohm secondary windings.

SECTION 4 COUPLING COEFFICIENTS

Two different terminal connections designated respectively as TC and LC are indicated for obtaining the 1650-ohm primary. With the TC (tight-coupled) arrangement, each half of the primary winding covers the complete circumference of the toroid, giving thereby an extremely tight coupling between the two halves of the primary. Switching transients occurring with class AB operation in conventional push-pull systems are thereby minimized, and this TC arrangement is recommended when conventional push-pull circuits are used.

With the LC (loose-coupled) connections, each half of the primary windings is on a separate semicircumference of the toroid. Such an arrangement gives more leakage reactance between the two halves of the primary, but, on the other hand, produces a lower capacitance and a more extended high-frequency range than the TC connections. Choice depends upon the more important criterion. The 6600-ohm primary and all of the secondaries are tight-coupled.

The degree of coupling attained is indicated by the following data:

Windings	Leakage Inductance	$(1 - \tau^2)$ *
Half Primary to Half Primary		
Tight-Coupled	2.8 mh	0.00047
Loose-Coupled	58.0 mh	0.0097
Full Primary to		
4- or 16-ohm Secondaries	18.0 mh	0.00075
Full Primary to		
8- or 32-ohm Secondaries	14.2 mh	0.00059
Full Primary to		
Composite Secondaries	6.4 mh	0.00027

* The coupling coefficient, τ, varies with the permeability of the core and increases with the operating level. The listed values are at initial permeability. Note that leakage inductance is referred to the primary.

The tight coupling achieved between the primary and secondary windings permits feedback to be taken from the secondary circuit with a minimum of phase shift at high frequencies.

The 6600-ohm primary has an inductance of about 24 henries at initial permeability. This value increases substantially as the operating level is raised. The inductance of all windings, at a given level, is directly proportional to their nominal impedance values. See Figure 2.

SECTION 5 COPPER EFFICIENCY - POWER RATING

The copper efficiency is indicated by the following ratios of d-c resistance to nominal source or load impedance Z.

Winding	$R_{d\text{-}c}/Z$
Primary	0.046
4- or 16-ohm Secondary	0.062
8- or 32-ohm Secondary	0.066
Composite Secondaries	0.034

During operation at constant level, the power rating of an output transformer is determined by: (1) temperature rise due to internal losses, (2) the level of distortion introduced by the transformer at low frequencies and (3), ultimately, the voltage rating of the insulation. In speech or music high levels occur intermittently, so that the heating effect is not usually important, and the rating is determined chiefly by the distortion introduced by the nonlinear magnetic characteristic of the core.

The level at which serious distortion occurs depends both upon the core material used and the peak flux density, which varies inversely with the with the frequency. At a specific frequency, an arbitrary value of permissible distortion may be chosen to specify the rated level.

Since transformer distortion rises abruptly above a certain voltage level, only a small change in rating occurs for a considerable range of permissible values of distortion. Likewise, the impedance of the source driving the transformer does not change the rating appreciably. Reduction of the source impedance reduces the distortion value but makes little change in the level at which the abrupt rise in distortion occurs.

As anticipated, the low-frequency power rating varies, to a first approximation, inversely with the resistance load applied to the secondary. At the nominal impedance, the transformer can be expected to handle over 40 watts at 20 cps with a distortion less than 1%. This level increases as the square of the frequency to 160 watts at 40 cps. When supplying a load one-half the nominal impedance, the transformer can handle 80 watts at 20 cps. However, the efficiency at higher audio frequencies is reduced when less than the rated load is used.

At higher frequencies, (above 50 cps), the power limit for continuous operation is set by copper loss, since eddy current losses in this transformer are generally negligible, and reduced flux density minimizes hysteresis losses.

The maximum allowable temperature is 65°C, which permits 8 watts internal dissipation with an ambient temperature of 35°C. Since the over-all copper efficiency is of the order of 92%, the continuous rating is specified as 90 watts at this ambient temperature. The rating will then be proportional to the difference between 65°C and the actual ambient temperature. When an appreciable direct current is in the windings, the d-c power dissipated must also be included in determining the continuous rating for a given application.

A check of this transformer by the standard RTMA test[2] for speaker-matching transformers indicated a rating appreciably in excess of 100 watts.

Adequate secondary windings make this output transformer suitable for for supplying constant-voltage audio distribution systems.[3] For example. the standard 70-volt operating level may be obtained from the 93-ohm secondary for 50 watts or from the 47-ohm secondary for 100 watts.

The lower voltage systems or higher power levels, or both, are provided for by the lower impedance windings.

SECTION 6 FREQUENCY CHARACTERISTIC

The frequency characteristic of an audio transformer depends, in part, upon the source and load impedances and the turns ratio. The leakage reac-between primary and secondary, and the winding capacitances, determines the high-frequency cut-off, while the low frequency characteristic is determined by the primary reactance, which, in turn, is a function of both frequency and operating level.

Typical high-frequency characteristics for the Type 942-A, with matching turns ratios and tight-coupled primaries, are shown in Figure 1. A comparison of Curves A and B shows the effect of changing the nominal impedance level of a transformer that is coupling a given source and load, while a comparison of curves B and C demonstrates the effect of changing the impedances of both source and load coupled by a given transformer.

Figure 2 gives the over-all frequency characteristics with a 1650-ohm source and a 93-ohm load. The effect of the lower capacitance of the LC primaries on the upper range is indicated, and the low-frequency range is de-

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[2] RTMA Standard SE-106, Sound Systems, July, 1949, Engineering Department, Radio-Television Manufacturers Association, Section V.

[3] RTMA Standard SE-101, Amplifiers, December, 1947, Engineering Department, Radio-Television Manufacturers Association, Section III. Also, RTMA Standard SE-106, Sound Systems, July, 1949, Engineering Department, Radio-Television Manufacturers Association, Section II.

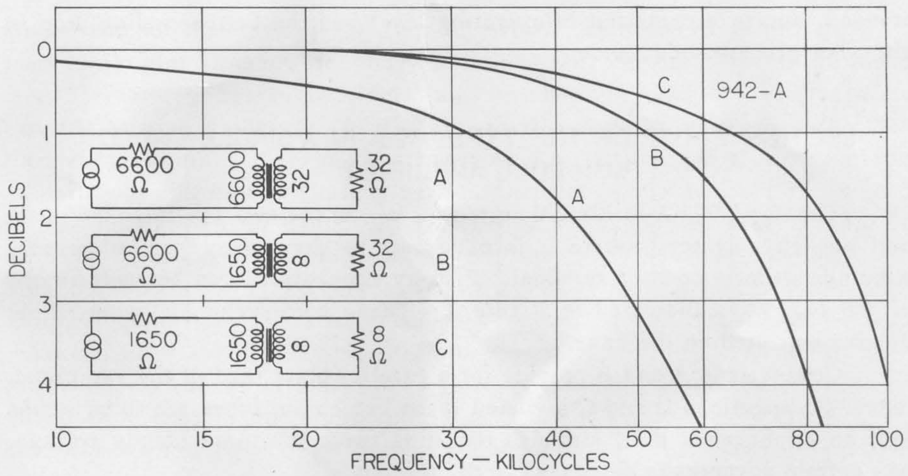
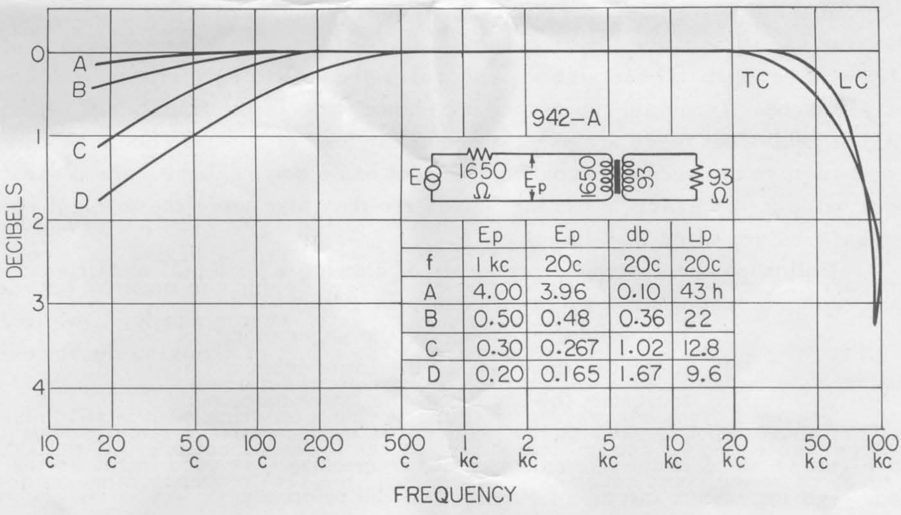


Figure 1.

High-Frequency Characteristics of the Type 942-A Output Transformer.



	Ep	Ep	db	Lp
f	1 kc	20c	20c	20c
A	4.00	3.96	0.10	43 h
B	0.50	0.48	0.36	22
C	0.30	0.267	1.02	12.8
D	0.20	0.165	1.67	9.6

Figure 2.

Over-All Frequency Characteristics of the Transformer.

pressed, due to a reduction in operating level and the corresponding drop in effective primary inductance.

SECTION 7 USE OF THE TYPE 942-A IN A SINGLE-ENDED PUSH-PULL AMPLIFIER

The Type 942-A is ideally suited for use in the new single-ended push-pull amplifier system[4] where it is necessary to have two separated primary windings with no common terminal. Primary connections can be made in any of the four ways indicated in Figure 3. These correspond in layout to the diagrams printed on the case.

Connections A and B provide for a parallel plate feed of the two output tubes. Connections D and C are used if the two output tubes are to be series fed, an arrangement that, although requiring twice the plate supply voltage, has certain advantages discussed in the reference.[4]

Either A or C gives the best low-frequency characteristic. The nominal impedance of each primary is 1650 ohms so that, when 6L6 or equivalent tubes are used, a secondary load of Z ohms should be applied across whichever of the eight secondary combinations has a nominal impedance closest to the Z value. Exact "matching" loads are thus the nominal impedance values cited in Table 1.

If the ultimate in copper efficiency (power rating) is of prime importance, at some sacrifice of the low-frequency characteristic, either connections B or D should be used. These give the nominal impedance of each primary a value of 413 ohms. To obtain the proper impedance ratio in the transformer, when 6L6 or equivalent tubes are used, a secondary load of Z ohms should be connected across the secondary combination that has a nominal impedance closest to a value Z/4. Exact "matching" loads are thus four times the nominal impedance values cited in Table 1.

Following the customary procedure of drawing a push-pull amplifier circuit with an "upper" and a "lower" tube, in Figure 3,

K_u indicates the cathode of the upper tube,

P_ℓ indicates the plate of the lower tube,

S_ℓ indicates the screen of the lower tube, etc.

Connection A is used for the parallel-fed, high impedance circuits shown in Figures 6 and 8 in the reference[4], while connection C is used in the series-fed, high impedance circuit of Figure 2 in the reference.

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4 "A New Push-Pull Amplifier Circuit," A.P.G. Peterson, General Radio Experimenter, October, 1951.

TYPE 942-A OUTPUT TRANSFORMER

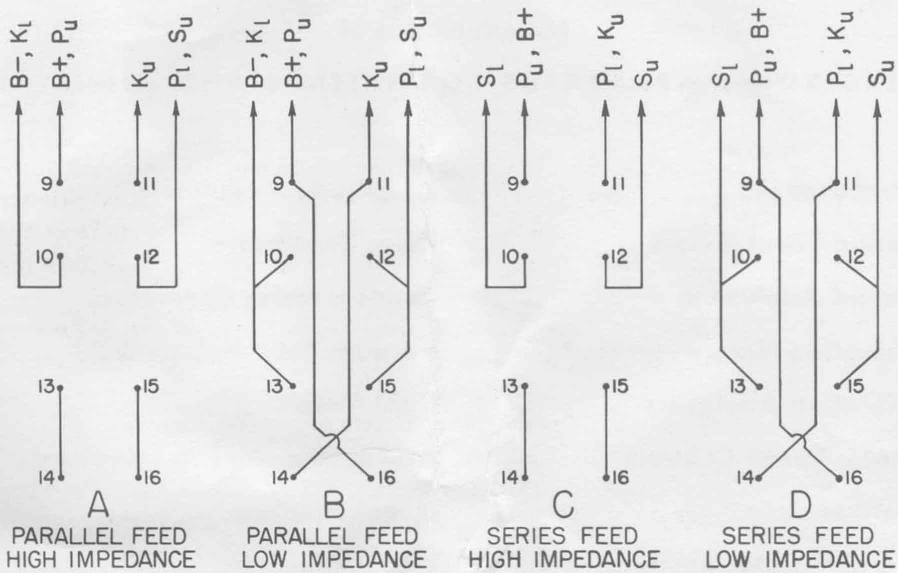

Figure 3.

Transformer Connections for Push-Pull Amplifier Circuits.

GENERAL RADIO COMPANY

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- Stroboscopes
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- Pulse Generators
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- Audio-Frequency Meters
- Modulation Meters
- Distortion Meters
- Audio Transformers
- Knobs and Dials
- Plugs and Jacks
- Binding Posts
- Potentiometers

Form 774-C
October, 1956

Printed in U.S.A.

#1: TWO semi-circles of 113 turns each of #22 magnet wire for the two 8-Ohm secondaries
Rubber sleeve over first secondary
#2: TWO semi-circles of 800 turns each of #32 magnet wire for the two inner 412.5-Ohm primaries
Rubber sleeve over first primary
#3: TWO semi-circles of 800 turns each of #32 magnet wire for the two outer 412.5-Ohm primaries
rubber sleeve over outer primary
#4: TWO semi-circles of 80 turns each of #20 magnet wire for the two 4-Ohm secondaries
Polycrystalline wax applied to completed windings and encased in an aluminum collar plus two aluminum end covers and bolted together.
Core cross sectional area=0.9X2 inches or 1.8 square inches.

FLUX density @ 30 volt-amperes = 13.23 kilogauss @ 20 cycles per second.
FLUX density @ 50-volt-amperes = 17.1 kilogauss @ 20 C/S which is in the knee of the curve and subject to high distortion.