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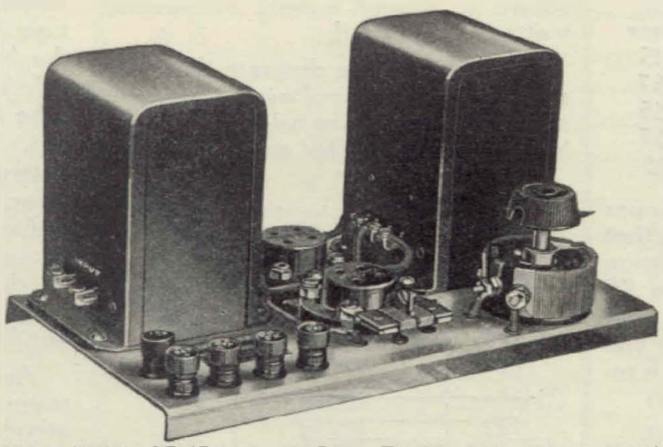
# *Power Amplification*

*By C. T. BURKE, Engineering Department*

Unlike the grid circuit of a vacuum tube, a loudspeaker consumes a considerable amount of power. The action of the last stage in the audio amplifier is therefore different from that of any preceding stage.

In order to understand clearly the difference in the action of the last amplifier stage, it is necessary to consider load impedances in the several stages and the current delivered to them. When amplification per stage is spoken of, voltage amplification is usually meant. It is customary to speak of the vacuum tube amplifier as a purely voltage device. This is not strictly true in any stage and is far from the truth in the power stage. While the grid of the tube operates on voltage alone, the plate must deliver power. The objection to the specification of voltage amplification alone is evident when an amplifier feeding a load of 100,000 ohms is compared with one feeding a load of 2,500 ohms. It is proper to refer to voltage amplification alone, only when the load impedances are equal; otherwise the load impedances should be specified or a correction applied. When an output transformer is used, the voltage across the primary of the transformer rather than across the speaker should be considered as the output voltage on considering voltage amplification.



THE NEW GENERAL RADIO TYPE 441 PUSH PULL AMPLIFIER. A VERY EFFICIENT AND CONVENIENT UNIT TO USE IN BUILDING POWER AMPLIFICATION.

The power consumed in the stages of the amplifier prior to the last is not generally appreciable. While the current delivered by the secondary is negligible, exciting current and transformer losses must be supplied by the plate circuit of the preceding tube.

The power requirements of the speaker, however, are large. Some of the power delivered is lost in the speaker windings, but most of it is transformed into sound waves and radiated. Current is required to actuate the speaker, and modern speakers are comparatively low impedance devices. This requires an impedance adjusting transformer in the plate circuit of the last tube, which involves a considerable step-down in voltage. The last stage of the amplifier must be capable of delivering an amount of power to the speaker commensurate with the volume of sound desired without overloading the tube if quality is to be preserved. In order to meet this requirement, a power stage should precede the speaker.

It is perhaps necessary to distinguish between a power amplifier and a powerful amplifier. A power amplifier cannot be applied successfully directly after the detector; one or more stages of voltage amplification must precede it. The greater the power rating of the amplifier, the more the voltage amplification required to precede it, as a general rule.

Receiving set power amplifier tubes range all the way from the –20 type with an undistorted output of about 100 milliwatts to the –10 type with an undistorted output of about 1500 milliwatts. As each of these tubes differs as to input requirements, the choice of the power amplifier will depend on the rest of the amplifier. If sufficient signal voltage is not available to operate the power amplifier satisfactorily, nothing is gained by adding it. It is, therefore, necessary to consider the first part of the amplifier in designing the power stage.

Too great voltage amplification in the audio amplifier should not be attempted, as undue noise and an unstable amplifier is likely to result. The audio amplifier should not be depended on for distant reception; that is the function of the radio frequency system.

For satisfactory amplification the detector output should be one-tenth to five-tenths volts (across the primary of the first coupling unit). Signal strengths of less than the lower value should be increased by radio frequency amplification, those greater than one-half volt should be cut down by means of a volume control, otherwise the detector is overloaded. Obviously, the only proper place for the volume control is in front of the detector. Volume controls across the

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audio transformer secondaries, or the speaker, are poorly placed.

Assuming a signal of 0.2 volt, and a voltage amplification of 20 (one stage low-ratio transformer and tube) there is available for operating the power stage 4 volts. Assuming a 2 to 1 step-up for the input transformer to the power tube, 8 volts is available at the grid of the power tube. Tube data tables show the output under these conditions with various tubes to be as follows. Power is in milliwatts in each case. As the plate voltage available is generally limited, the plate voltage required is also given. If lower plate voltages are used the input must be reduced to avoid over-loading, and, as will be observed, this is an important factor in choosing the amplifier tube. This data is calculated from vacuum tube data tables and represents approximate average values.

Signal Voltage 8

| Tube | Power Output | Plate Voltage |
|---|---|---|
| 201A | 50 | 135 |
| 120 | 15 | 67 |
| 112 | 120 | 135 |
| 171 | 28 | 67 |
| 210 | 65 | 135 |

Obviously the 112 is the proper tube to use. Suppose, however, that the input voltage and amplification ratio had been such as to give 25 volts at the power tube grid. As neither the 201A nor 112 tube can be used on this voltage the choice reduces to:

Signal Voltage 25

| Tube | Power Output | Plate Voltage |
|---|---|---|
| 120 | 110 | 135 |
| 171 | 350 | 135 |
| 210 | 950 | 350 |

In comparing the 171 and 210 tubes it should be noted that under these conditions the 210 requires a plate voltage of 350 as compared to 135 for the 171. In order to operate with 135 volts on the plate of the 210, the input voltage would have to be cut to 9 volts with the volume contol, when the output would become but 65 milliwatts.

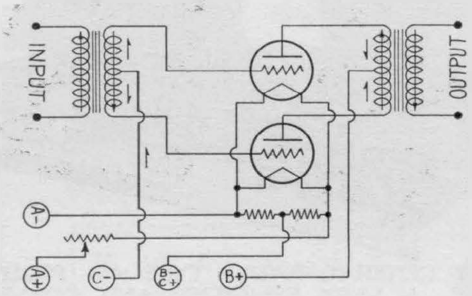
Increasing the input still further to 35 volts, only the 171 and 210 tubes may be used, the 171 giving 530 milliwatts output with 170 volts plate, and the 210 giving 1500 milliwatts with 425 volts plate. Again comparing the outputs for equal plate voltage, we find that the output of the 210 is only 140 milliwatts at 170 volts plate.

The 171 tube will take a maximum input of 40 volts with 180 volts plate, giving a 700 milliwatt output.

So far, only single power tubes have been considered. Where considerable power output is required, the push-pull connection, using two tubes in a single stage, offers many advantages even where the output desired is no greater than could be obtained with a single tube.

In the "push-pull" stage, two tubes are so connected that their power outputs add. Any type of tube may be used, the choice of tube depending on the same consideration outlined as applying to the single tube type. Thus the push-pull connection might be used with –12 type tubes when the input voltage is too low for operating a tube of the –71 type satisfactorily, but when greater power is required than is obtained from a single –12 type, –71 tubes might be used in order to obtain a greater power output than is possible with a single 210 without the high plate voltage needed for that type of tube, or 210 tubes might be used where a power output of several watts was required.

Referring to the diagram the large arrows show how voltages impressed across the input are added in phase in the output. The smaller arrows




show the course of voltages which are in phase in the grid circuits. These voltages cancel out and do not appear in the output. This fact is of great importance in the operation of the amplifier as it permits a greatly increased power output. Tube overloading, so long as grid current does not flow, is due to the amplifier working over a curved portion of its characteristics, introducing harmonics of the original frequency. As these harmonics are in phase, they cancel out and do not appear in the output. The working range of a tube is not limited to the straight portion of the characteristic when used in a push-pull amplifier. So greatly is the power output increased by this fact, that the maximum undistorted output from the push-pull amplifier is not twice but five to seven times that of a single tube. This feature is of particular importance when working into the low impedance load presented by most of the modern high quality loudspeakers, since the effect of a low impedance in the plate circuit is to increase the curvature of the tube characteristic, and lessen its capacity for undistorted power output.

If alternating current filament supply is used a further advantage of the push-pull connection appears, because hum voltages in the two tubes are in phase and therefore their fundamentals and odd harmonics cancel in the output. The result is a much quieter amplifier than is possible using a single tube.

For use with the Type 441 Push-Pull Amplifier, illustrated, the General Radio Company recommends the type –26 tubes. The maximum undistorted power output of the amplifier with these tubes is greater than a single type –71 tube, and the unit possesses the further advantage of quiet operation on alternating current supply, and a greater gain than is possible with a –71. Due to the latter fact the unit requires considerably less signal voltage on the tube grids to obtain maximum output. This in turn requires less gain between the detector and the power stage. If, however, the voltage amplifier has sufficient gain to deliver fifteen to twenty volts at the primary of the input transformer –71 type tubes can be used in the push-pull amplifier with excellent results.

As is usual when using a power stage, the gain in voltage is comparatively small, about 6 from the primary of the input transformer to the speaker terminals. The gain from the primary of the input transformer to the primary of the output transformer is about 20. It should be remembered, however, that very little power is delivered to the input transformer, while several hundred milliwatts are delivered to the speaker.

The input impedance of the type 441 unit is 30 henries. The turns ratio of the primary of the input transformer to the entire secondary is 1 to 4.5. There is a step down of about 3.5 to one in voltage in the output transformer to adapt the tubes to the speaker impedance. This gives the proper impedance ratio for –26 type tubes. When using the –71 type better results will be obtained if the speaker is connected between one plate terminal and the center of the primary of the output transformer. The resistance of the output transformer primary is so low that little direct current flows in the speaker under these conditions, and no stopping condenser is required.

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# Definition of the Transmission Unit

*By Horatio W. Lamson, Engineering Department*

The use of the Transmission Unit (TU) as the proverbial " yardstick" for measuring the gain or degree of amplification in amplifiers, the loss in any type of transmission circuit, or for comparing the strength of two signals, is becoming so universal that we believe a definition of this unit will be of interest to our readers.

Let us consider, for the sake of a concrete example, the case of the push-pull amplifier illustrated by the diagram in Mr. Burke's article in this issue. In order for this instrument to function, a certain amount of alternating current power, P1, measured, if you will, in milliwatts, must be supplied to the input terminals of the amplifier. There will be, in this case, a greater amount of power P2, likewise measured in milliwatts, delivered to the loudspeaker from the output terminals of the amplifier.

The quantity $\frac{P_2}{P_1}$ is called the "Power Ratio" of the amplifier. To express this power ratio in transmission units we make use of the relation:

$$\frac{P_2}{P_1} = 10^{\frac{n}{10}} \text{ or } N = 10 \log \frac{P_2}{P_1}$$

That is, the number of transmission units, N, is equal to ten times the logarithm (to the base 10) of the power ratio.

A conversion table is printed below giving the relation between transmission units and the power ratio gain or loss. From this we see, for example, that an amplifier has a gain of 7.0 TU when its power ratio is 5.01, or that there is a loss of 2.6 TU in a telephone line when the power ratio of the same is 0.550, etc.

For power ratios greater than 10 or less than 0.1, we may use the same table by following the proper one of the four procedures described below:

1—Divide the power ratio gain by ten and add ten to the corresponding number of TU.

2—Multiply the power ratio loss by ten and add ten to the corresponding number of TU.

3—Subtract ten from the number of TU gain and multiply the corresponding power ratio gain by ten.

4—Subtract ten from the number of TU loss and divide the power ratio loss by ten.

| No. of T.U. | Power Ratio | | No. of T.U. | Power Ratio | | No. of T.U. | Power Ratio | |
|---|---|---|---|---|---|---|---|---|
| | Gain | Loss | | Gain | Loss | | Gain | Loss |
| 0.1 | 1.023 | .977 | 3.6 | 2.29 | .437 | 7.1 | 5.13 | .195 |
| 0.2 | 1.047 | .955 | 3.7 | 2.34 | .427 | 7.2 | 5.25 | .191 |
| 0.3 | 1.072 | .933 | 3.8 | 2.40 | .417 | 7.3 | 5.37 | .186 |
| 0.4 | 1.096 | .912 | 3.9 | 2.45 | .407 | 7.4 | 5.50 | .182 |
| 0.5 | 1.122 | .891 | 4.0 | 2.51 | .398 | 7.5 | 5.62 | .178 |
| 0.6 | 1.148 | .871 | 4.1 | 2.57 | .389 | 7.6 | 5.75 | .174 |
| 0.7 | 1.175 | .851 | 4.2 | 2.63 | .380 | 7.7 | 5.89 | .170 |
| 0.8 | 1.202 | .832 | 4.3 | 2.69 | .372 | 7.8 | 6.03 | .166 |
| 0.9 | 1.230 | .813 | 4.4 | 2.75 | .363 | 7.9 | 6.17 | .162 |
| 1.0 | 1.259 | .794 | 4.5 | 2.82 | .355 | 8.0 | 6.31 | .158 |
| 1.1 | 1.288 | .776 | 4.6 | 2.88 | .347 | 8.1 | 6.45 | .155 |
| 1.2 | 1.318 | .759 | 4.7 | 2.95 | .339 | 8.2 | 6.61 | .151 |
| 1.3 | 1.349 | .741 | 4.8 | 3.02 | .331 | 8.3 | 6.76 | .148 |
| 1.4 | 1.380 | .724 | 4.9 | 3.09 | .324 | 8.4 | 6.92 | .144 |
| 1.5 | 1.413 | .708 | 5.0 | 3.16 | .316 | 8.5 | 7.08 | .141 |
| 1.6 | 1.445 | .692 | 5.1 | 3.24 | .309 | 8.6 | 7.24 | .138 |
| 1.7 | 1.479 | .676 | 5.2 | 3.31 | .302 | 8.7 | 7.41 | .135 |
| 1.8 | 1.514 | .661 | 5.3 | 3.39 | .295 | 8.8 | 7.59 | .132 |
| 1.9 | 1.549 | .645 | 5.4 | 3.47 | .288 | 8.9 | 7.76 | .129 |
| 2.0 | 1.585 | .631 | 5.5 | 3.55 | .282 | 9.0 | 7.94 | .126 |
| 2.1 | 1.622 | .617 | 5.6 | 3.63 | .275 | 9.1 | 8.13 | .123 |
| 2.2 | 1.660 | .603 | 5.7 | 3.72 | .269 | 9.2 | 8.32 | .120 |
| 2.3 | 1.698 | .589 | 5.8 | 3.80 | .263 | 9.3 | 8.51 | .118 |
| 2.4 | 1.738 | .575 | 5.9 | 3.89 | .257 | 9.4 | 8.71 | .115 |
| 2.5 | 1.778 | .562 | 6.0 | 3.98 | .251 | 9.5 | 8.91 | .112 |
| 2.6 | 1.820 | .550 | 6.1 | 4.07 | .245 | 9.6 | 9.12 | .110 |
| 2.7 | 1.862 | .537 | 6.2 | 4.17 | .240 | 9.7 | 9.33 | .107 |
| 2.8 | 1.906 | .525 | 6.3 | 4.27 | .234 | 9.8 | 9.55 | .105 |
| 2.9 | 1.950 | .513 | 6.4 | 4.37 | .229 | 9.9 | 9.77 | .102 |
| 3.0 | 1.995 | .501 | 6.5 | 4.47 | .224 | 10.0 | 10.00 | .100 |
| 3.1 | 2.04 | .490 | 6.6 | 4.57 | .219 | 20.0 | 100 | .01 |
| 3.2 | 2.09 | .479 | 6.7 | 4.68 | .214 | 30.0 | 1,000 | .001 |
| 3.3 | 2.14 | .468 | 6.8 | 4.79 | .209 | 40.0 | 10,000 | .0001 |
| 3.4 | 2.19 | .457 | 6.9 | 4.90 | .204 | 50.0 | 100,000 | .00001 |
| 3.5 | 2.24 | .447 | 7.0 | 5.01 | .200 | 60.0 | 1,000,000 | .000001 |

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# *VITAL FACTORS*
## *in attaining*
# *High Quality Reproduction*


Type 285

High quality reproduction depends upon three things; correctly designed coupling units, proper use of amplifier tubes, and an efficient reproducing device.

For over a decade the subject of audio frequency amplification has been extensively studied in the laboratories of the General Radio Company with particular attention given to the design of coupling units.

As a result of this exhaustive research the General Radio Company has been, and is, the pioneer manufacturer of high quality Audio Transformers, Impedance Couplers, and Speaker Filters.

If the amplifier of your receiver is not bringing out the rich bass notes and the mellow high tones as well as those in the middle register why not rebuild your amplifier for ***Quality Reproduction*** with ***General Radio*** coupling units.

Type 373

### TYPE 285 AUDIO TRANSFORMERS

These transformers give high and even amplification of all tones common to speech, instrumental, and vocal music. Available in two ratios.

Type 285-H Audio Transformer 1 to 6--Price $6.00

Type 285-D Audio Transformer 1 to 3--Price $6.00

### TYPE 367 OUTPUT TRANSFORMER

This unit adapts the impedance of an audio amplifier to the input of any cone type speaker, thus promoting better tone quality and protecting the speaker windings against possible damage from A. C. voltages. Similar in appearance to the Type 285.

Type 367 Output Transformer----------Price $5.00

### TYPE 373 DOUBLE IMPEDANCE COUPLER

Many prefer the impedance coupling method of amplification to resistance coupling as lower plate voltages may be used and greater amplification may be obtained. The Type 373 is contained in a metal shell and connected in a circuit in precisely the same manner as a transformer.

Type 373 Double Impedance Coupler---Price $6.50

### TYPE 387-A SPEAKER FILTER

The Type 387-A consists of an inductance choke with condenser. It offers a high impedance to audio frequency current and forces these currents to pass through a condenser into the speaker, thereby improving tone quality and protecting the speaker windings.

Type 387-A Speaker Filter-------------Price $6.00

Type 445

*Write for Series A of amplification booklets describing various amplifier units*

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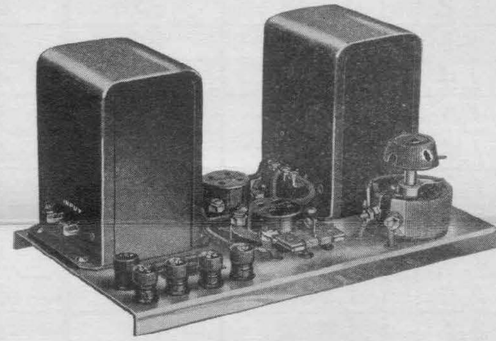
**General Radio Co.**

*Cambridge, Mass.*



Type 441

### TYPE 445 PLATE SUPPLY AND BIASING UNIT

The Type 445 meets the demand for a thoroughly dependable light socket plate supply and grid biasing unit that is readily adaptable to the tube requirements of any standard type receiver. Any combination of four voltages from 0 to 180 may be taken from the adjustable "B" voltage taps. A variable grid bias voltage from 0 to 50 is also available. The unit is designed for use on 105 to 125 volt (50 to 60 cycle) A. C. lines and uses the UX-280 or CX-380 rectifier tube.

Licensed by R. C. A. and through terms of the license may be sold with tube only.

Type 445 Plate Supply and Grid Biasing Unit ------------------------------Price $55.00

Type UX-280 or CX-380 Rectifier Tube Price $ 5.00

### TYPE 441 PUSH-PULL AMPLIFIER

The Type 441 is completely wired and consists of two high quality push-pull transformers, with necessary sockets and resistances mounted on a nickel finished metal base board. It may be used with any power or semi-power tube to increase the undistorted output of the amplifier with the result that better quality is reproduced from the loudspeaker with more volume than is obtained from other methods of coupling.

Licensed by the R. C. A. and through terms of the license may be sold with tubes only.

Type 441 Push-Pull Amplifier---------Price $20.00

Type UX-226 or CX-326 Amplifier Tube, Price 3.00

Type UX-171 or CX-371 Amplifier Tube, Price 4.50

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*PARTS and ACCESSORIES*

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