A Review of Coupling Methods

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While methods of coupling between vacuum tubes at audio frequencies may be broadly divided into but three classes; resistance, impedance, and transformer coupling, these methods contain many subdivisions which raise the total number of possible methods of coupling to a surprising figure.
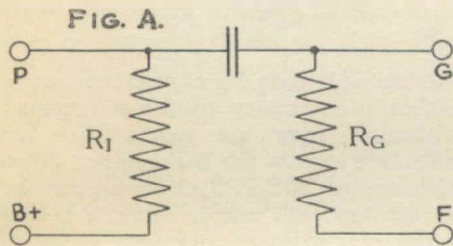
FIG. A.

Figure A is the usual resistance coupled amplifier. R, which determines the input resistance of the device should be several times the plate resistance of the tube out of which the coupling device is working. The size of the coupling condenser and of R_G may vary over a considerable range, depending upon the characteristic desired. For an efficient voltage transfer, R_G should be large compared with the input impedance of the tube. The capacity of the condenser will depend on the frequency range it is desired to cover, and on the value of R_G. It may be one-half to one microfarad where the frequency range extends well below one hundred cycles. A large condenser is sometimes viewed with disfavor on the ground that it causes "blocking" in the amplifier. Blocking will not occur, however, unless the grid of the amplifier tube is allowed to become positive. Proper biasing

will prevent this. The principal advantage of resistance coupling is well known. It is the method of coupling by means of which a good frequency characteristic may be obtained with least first cost. It has, however, the rather serious objection that the high input resistance causes a large drop in voltage between the source of plate power and the plate of the tube. Unless a rather high voltage is used at the source, the tube is not operated at the best part of its characteristic, and harmonics may be introduced. In all types of coupling devices where a condenser is used in the grid, care should be taken to keep the capacity of the condenser to ground at a low value.

FIG. B
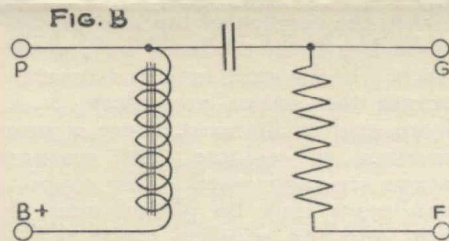
The arrangement shown in Figure B is derived from that of Figure A by substituting an impedance for a resistance as the input device. This has the advantage of a comparatively low voltage drop, and with proper design, can be made to cover any desired frequency range. The impedance of the choke should be several times the plate impedance of the preceding tube at the lowest frequency which it is to amplify.

The methods of Figure A and B can be modified as shown in Figure

FIG. C
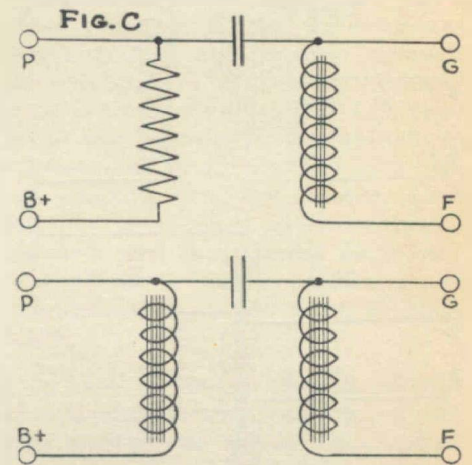
C. In these circuits, an impedance is used in place of a resistance in the output circuit. This arrangement is recommended where there is danger of grid current flowing momentarily, as on occasional loud signals, particularly in the last amplifier stage.

FIG. D
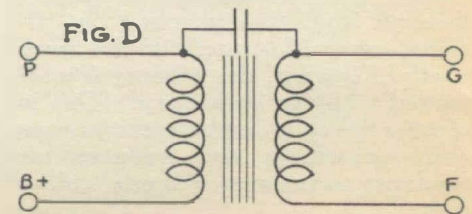
In the circuit of Figure C, the plate and grid coils are generally on different cores and are not magnetically coupled to each other. In Figure D, both coils have been put on the same core to form a 1:1 transformer, but the condenser has been retained and provides sufficient capacitative coupling at high frequencies to reduce

any tendency toward resonance at high frequency due to magnetic leakage.

FIG. E
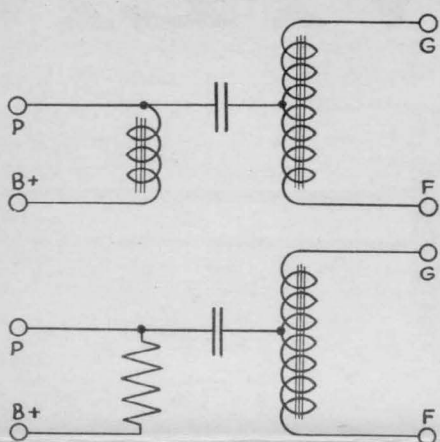
In the circuit of Figure E, advantage is taken of the step-up in voltage obtained by the auto-transformer connection. This feature increases the volume per stage, and may be combined with any of the systems of Figures A to D.
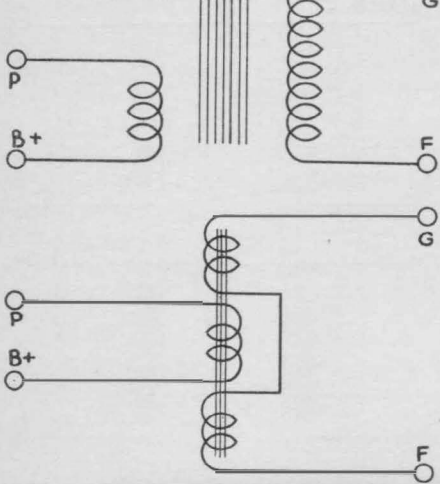
FIG. F

Figure F is the usual form of transformer. Proper design calls for an input impedance which is high in comparison with the source out of which it is working. The great advantage of this type of coupling is, its superior efficiency in consequence of the gain in voltage in passing through the transformer. In the transformer illustrated in the lower part of Figure F, the primary is interleaved with the secondary. This increases the coupling between primary and secondary, and reduces any tendency to resonance due to leakage flux.

Figure G, represents an adaptation of the principle of Figure D to a transformer of other than unity ratio. The condenser is connected to the secondary at the point where the secondary induced voltage is equal to the primary impressed voltage. The presence of the condenser reduces

FIG. G
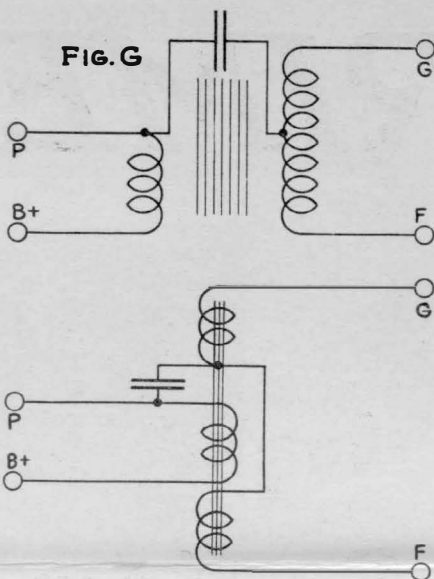
any tendency toward a resonant peak at the higher frequencies. This connection may, of course, also be used in conjunction with an interleaved primary.

FIG. H
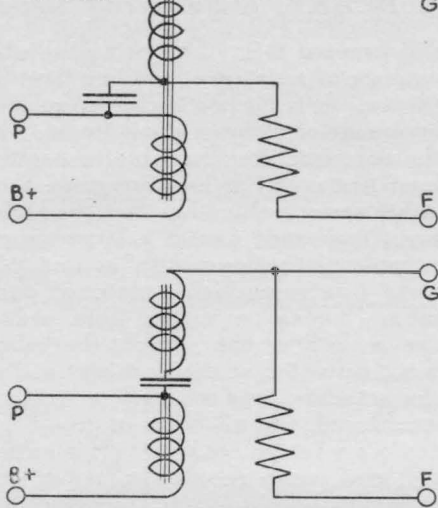
In the circuit of Figure H, the portion of the transformer secondary between the condenser tap and the filament has been replaced by a resistance. If the grid leak is connected across the entire secondary, i. e., from grid to filament, there is some sacrifice of volume, but resonant peaks are suppressed. The coupling condenser may be placed near the grid and the winding made with a tap, instead of in two sections. There

FIG. J
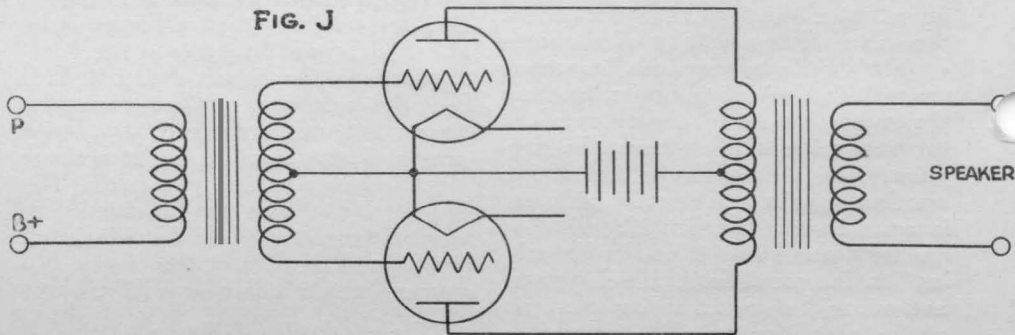
is some advantage in placing the coupling condenser as shown in Figure H, as capacity to ground from the large (physically) coupling condenser is reduced.
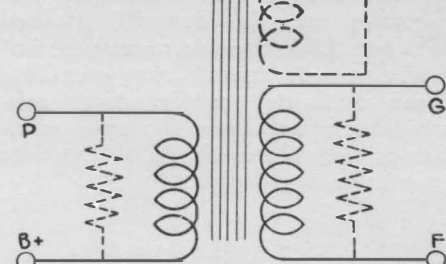
FIG. I
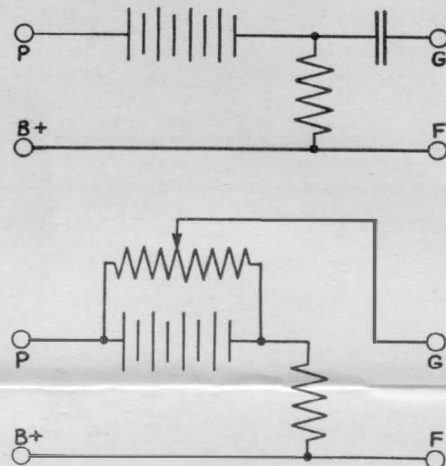
The circuits of Figure I are conventional for amplifying direct voltages.

Resonant peaks may be suppressed by means of any of the methods illustrated in Figure K.

FIG. K

Resistances may be connected across either the primary or the secondary, although they are generally more effective across the secondary. A resistance of 200,000 ohms across the secondary will make even a rather poor transformer perform satisfactorily. Amplification will, of course, be greatly reduced. Resonant peaks will also be reduced by the short-circuited third winding.

For some purposes, it is not desirable to pass a wide band of frequencies. In such cases, tuned coupling devices as shown in Figure L should be used. The push-pull amplifier shown in Figure J has several advantages. One is greater un-

FIG.L

The Type 411
Synchronous Motor
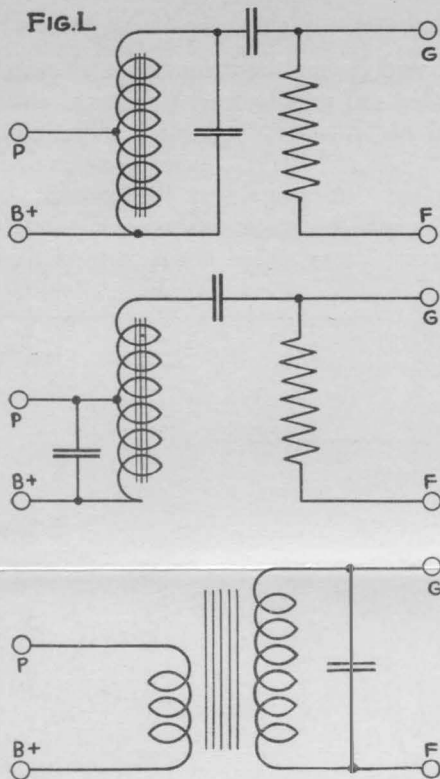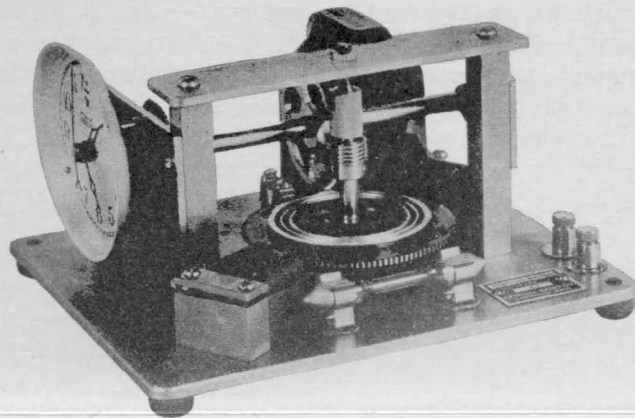
distorted output than is possible with two tubes in parallel or a single tube. Even harmonics are eliminated. As most of the harmonics introduced by tube overloading are even, this permits operation of the tubes at heavier loads than is possible with the usual system. Another advantage is the elimination of D. C. magnetization of the output transformer core, as the direct current flows in opposite directions from the two tubes. Auto-transformers may, of course, be used in the push-pull amplifier.

For a more complete discussion of these methods of coupling, the reader is referred to the following:

Telephone Systems and Audio Frequency Apparatus. Cohen, Aldridge and West. Proc. Wireless Sec.—Inst. of E. E. Sept., 1926.

The Performance and Properties of Telephone Frequency Intervalve Transformers. D. W. Dye—Experimental Wireless. Vol. 1, Page 691. 1924.

Vacuum Tube Amplification. S. E. Anderson. Proc. Radio Club of America. December, 1922.

Transformer Coupled Audio Amplifiers—A. W. Saunders, Proc. Radio Club of America. Sept., 1926.

Telephone Transformers—W. L. Casper—Proc. A. I. E. E. Page 196, Vol. 43. 1924.

Low Frequency Intervalve Transformers—P. W. Williams, Proc. of Wireless Section, Inst. of E. E. September, 1926.

In checking a source of constant frequency current, great accuracy may be attained by using the source to drive a synchronous motor, and counting the motor revolutions over a long period. Synchronous motors may be built which will operate properly at audio frequencies. Higher frequencies may be checked by means of stepping down the frequency by means of a series of oscillators, with harmonics of the lower frequency oscillators adjusted to synchronism with the fundamentals of those of higher frequencies.

The Type 411 Synchronous Motor is designed for use in calibrating frequency standards by this method. The motor drives a clock movement and when supplied with two-tenths of a volt-ampere at 1000 cycles will keep correct time. The motor will run from any source of 500 to 1800 cycles providing two-tenths of a volt-ampere.

The motor is not self-starting, but must be brought up to correct speed gradually. This is easily done by spinning the corrugated portion of the shaft with the finger. The motor will not synchronize if it is run too fast and then is permitted to slow down by its own friction, as the pole pieces do not have a sufficiently strong magnetic effect to overcome the drag thus produced. A Neon tube, operated through a transformer from the source, is placed beneath the periphery of the rotor. Looking through the rotor teeth at the Neon tube, the teeth will appear to be stationary when the motor is in synchronism. The two grooves in the rotor should be about half filled with mercury to prevent hunting which is otherwise likely to occur with this type of motor.

The poles are not magnetized and it is therefore necessary to have about ten or fifteen milliamperes direct current also flowing through the winding. A satisfactory arrangement is to modulate a UX 171 tube from the source it is desired to measure and to connect the tube output directly to the motor (not through a speaker filter or transformer) and the normal plate current of about twelve milliamperes magnetizes the poles very satisfactorily.

In case the motor should get out of adjustment the location of the four pole-pieces should be checked to see that they are all opposite their respective rotor projections. The upper and lower bearings are of sapphire in which the steel pivots run, and should be given a drop of clock oil about once in six months. The worm gears and other bearings should also be oiled at the same time. The rotor should run quite freely but without appreciable play in the bearings. This adjustment may be changed readily by loosening the lock-nut at the top and turning the screw in or out. The jewels are mounted in small plungers backed by a spring to prevent damage.

Specifications of the Type 411 Synchronous motor are as follows: Dimensions 8"x7"x5", weight 7 pounds. Price $130. Code Word: "SEDOY".

Correlated Acoustic Chart

This chart represents the relation between the musical scale and piano key-board, giving the frequencies of each note in terms of complete vibrations per second according to the two principal scales and pitches used in musical and scientific work, viz: The INTERNATIONAL equally tempered scale based on A=435 complete vibrations per second, which is generally used by musicians — the SCIENTIFIC or PHOLOSOPHICAL scale — generally used by physicists — based on MIDDLE C=256 complete vibrations per second. It also shows the correlated range of the various instruments within the orchestral range and the different voices which constitute the vocal range. The shaded keys are not included on a standard piano key board. The extreme organ range not shown on the chart is from 16 cycles to 16, 384 cycles, PHYSICAL pitch.
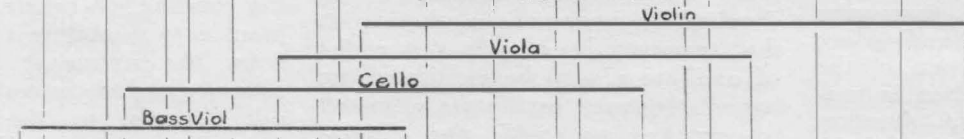

ACOUSTIC CHART

WIND INSTRUMENTS
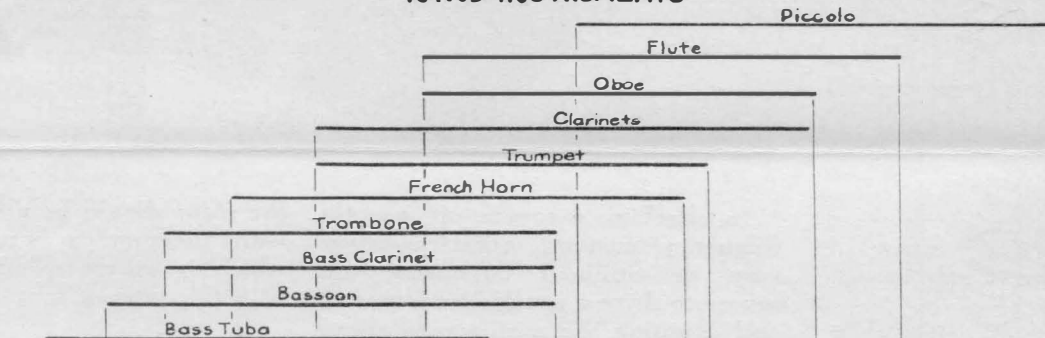
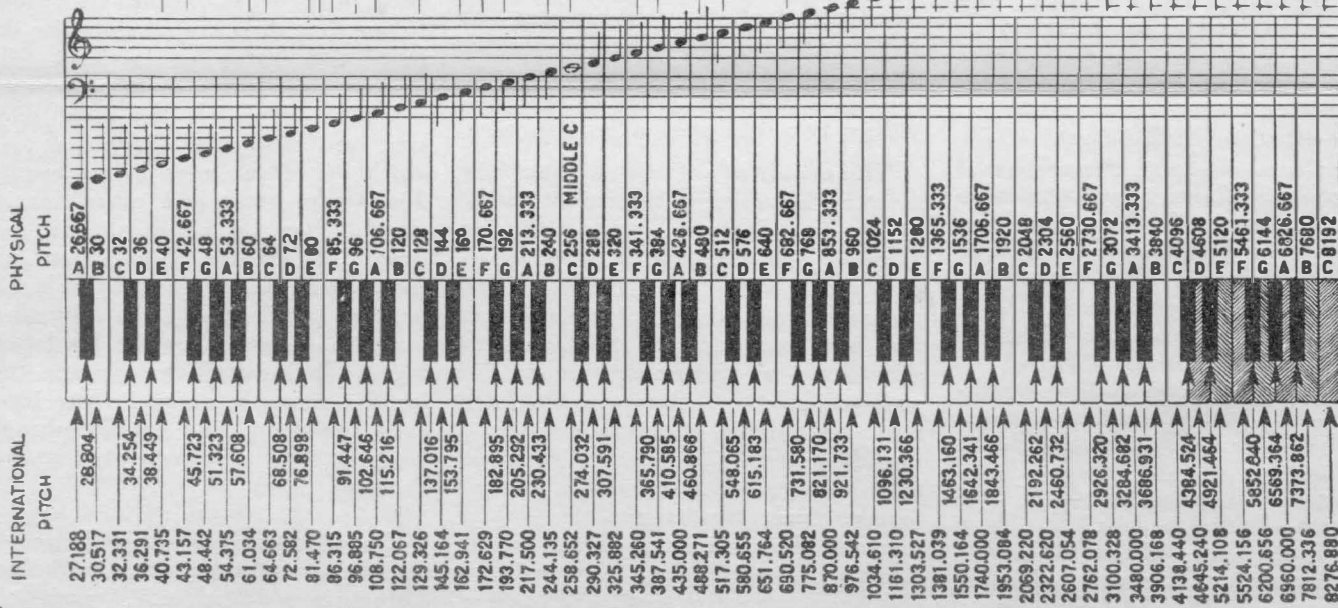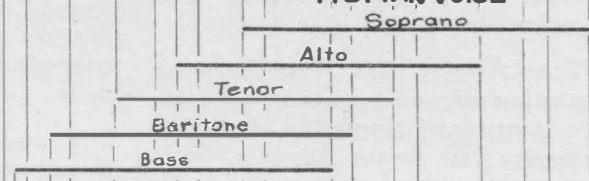PERCUSSION INSTRUMENTS

STRING INSTRUMENTS

HUMAN VOICE

For those who are keeping a continuous file of the various issues of the "Experimenter" and would like a copy of the Acoustic Chart to mount on a piece of stiff cardboard for handy references, we have extra copies which we will be glad to send on request.

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