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A. CROSSLEY ET AL

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HIGH FREQUENCY INTERSTAGE COUPLING DEVICE

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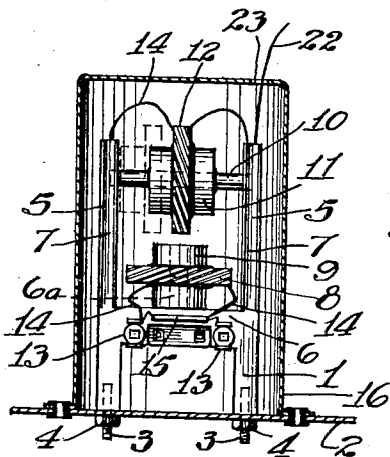


Fig. 1.

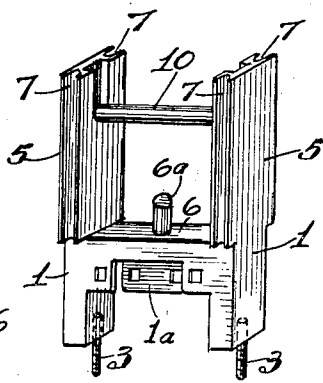


Fig. 3.

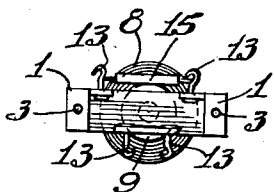


Fig. 2.

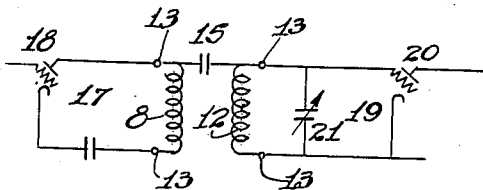
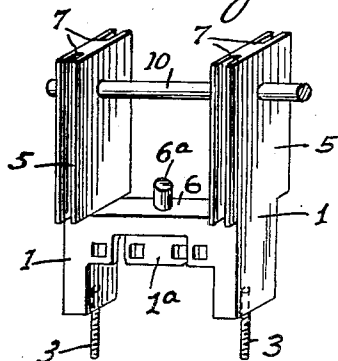


Fig. 4.

Fig. 5.



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HIGH-FREQUENCY INTERSTAGE COUPLING
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6 Claims. (Cl. 171-119)

This invention relates broadly to improve-
ments in high-frequency amplifying systems, and
more particularly to systems designed to be op-
erated at frequencies of about 150 kilocycles and
upwards, such for example as those in the high-
frequency amplifiers of radio receivers. Such
systems, in general, include in addition to the
amplifying thermionic relay, a resonant system
consisting of two inductance coils arranged in
magnetic relation to each other, one of the coils
being shunted by a variable condenser. The
condenser is normally of a type having very
low losses, and therefore the efficiency of the
complete design depends to a very large extent
upon the inductance coils.

A principal object of this invention is to pro-
vide a novel type of coupling means for use in
such an amplifying system, which, because of
its design, will greatly increase the efficiency of
the system. This object is attained in part by
using iron-cored inductances having new and
highly desirable attributes. The cores which
we use in these inductances are ferro-magnetic
and consist of finely-divided individually-insu-
lated iron particles compressed with a binding
material to make a core body. Cores of this type,
suitable for use at high frequencies, are dis-
closed in British Patents Nos. 366,475 and 403,368
and have recently been described in numerous
publications in the United States and abroad.
The combination of such a core with a suitable
winding is to be designed in accordance with
Patent No. 1,978,568, issued Oct. 30, 1934, for Im-
proved high-frequency inductance. The induc-
tance consists essentially of a tubular cylindrical
core of the type described, with a pancake uni-
versal winding at its center, the length of the
winding being usually from three-eighths to two-
thirds of the radial depth, the length of the core
being from $2\frac{1}{2}$ to 5 times the length of the wind-
ing.

Still a further object of the invention is at-
tained by so fashioning the insulating frame or
support on which the inductance coils and their
cores are mounted that it will constitute a single
and integral entity embodying all of the fea-
tures which are essential to admit of the mount-
ing of the cores and their coils thereon, as well
as to enable the frame or support to be itself
mounted on an adjacent part of the structure.
Furthermore, the frame may include elements for
accurately holding the leads in predetermined
relative positions in order that the spacing of
said leads will be definitely established.

Inductances of the class here contemplated

normally occur in pairs, one coil being connected
in the output circuit of a first thermionic relay,
and the other coil being connected in the input
circuit of a second thermionic relay. In order to
transfer energy from the first circuit to the sec-
ond, the coils may be coupled magnetically and
thus form a transformer, or they may be coupled
capacitively by means of a small condenser
connecting their high-potential ends, or a com-
bination of magnetic and capacitive coupling
may be used in order to obtain more uniform
gain over the desired band of frequencies. The
coil in the output circuit of the first thermionic
relay is usually called the primary, and the coil
in the input circuit of the second thermionic
relay is usually called the secondary. In some
instances, however, these designations may be
reversed, and either of the thermionic relays
may in certain types of apparatus be arranged so
that it does not operate strictly as an amplifier.
These variations, however, are not material with
respect to the application and scope of the pres-
ent invention. The variable tuning condenser is
usually shunted across the coil here designated
as the secondary coil.

In present-day designs, coupling devices of the
class here under consideration normally employ
two magnetically-coupled air-core inductances.
By suitably designing the primary and secondary
windings and by adjustment of the tuning con-
denser, the system may be tuned to be resonant
at the desired frequency. In order to effect a
maximum transfer of energy between the primary
and the secondary, it is essential that the mag-
netic coupling between the two windings shall be
closely of the optimum value. In the present de-
signs, it is normal to establish the degree of
coupling in the design of the transformer, so that
when the coils are assembled the proper coupling
will exist.

Because of the losses which normally exist in
air-core coils of the type now commonly used,
it is not essential to provide means for adjust-
ing the coupling between the primary and second-
ary coils after the unit is assembled. It is
usually sufficient to determine experimentally
what physical relation between the two coils will
give approximately the correct coupling and then
to mechanically design the transformer so as to
produce this relation.

In the designs herein described, the losses in
the coils themselves are greatly decreased, and
it therefore becomes desirable to provide means
for accurately adjusting each coupling device to
the desired coupling between primary and

secondary. The present invention, therefore, includes designs employing coils having greatly increased efficiency, and arrangements whereby two such coils may be magnetically related in a coupling device with means for producing an accurate adjustment of the magnetic coupling between the windings. It is also possible to provide an adjustment, as hereinafter explained, whereby the magnetic coupling adds to the capacitive coupling.

Additionally, it is possible to so adjust the transformers of the present invention that there is substantially no magnetic coupling between the primary and secondary, that is, the magnetic coupling is zero and the coupling between the circuits is entirely capacitive. Heretofore, in circuits where it was desired to have no magnetic coupling between two inductances which would otherwise constitute the primary and the secondary of a magnetically-coupled transformer, it has been necessary to surround each of the windings by a separate electro-magnetic shield.

Because of the higher efficiency of iron-core coils, it is possible to obtain greater energy transfer with less coupling than is permissible with air-core coils. This results in an increase in the electrical efficiency of the coupling device. For example, one embodiment of the invention uses about 8% magnetic coupling between the coils and a coupling condenser of 15 micromicrofarads. An alternate form uses zero magnetic coupling and a coupling condenser of 25 micromicrofarads. Either of these coupling devices will give substantially twice the amplification while maintaining the selectivity the same as it would be with air-core coils.

The invention will be better understood by reference to the accompanying drawing, which is illustrative of one possible mechanical embodiment of the invention and in which—

Fig. 1 is an elevation of a high-frequency coupling device employing ferro-magnetic core bodies;

Fig. 2 is a bottom view of the coupling device shown in Fig. 1;

Fig. 3 is a view in perspective of the supporting frame for the coupling device elements;

Fig. 4 presents a simplified schematic wiring diagram which illustrates a method of employing the coupling device of this invention in the circuits of a high-frequency amplifier, and

Fig. 5 shows a slight modification of the frame disclosed in Fig. 3.

Referring to Fig. 1, the coupling device here illustrated consists of an insulating frame 1, preferably of a phenolic compound such as bakelite molded in one piece, in order to avoid the cost of assembling operations which would be necessary if it included, as it might, a plurality of elements. The frame 1 is designed to be conveniently secured to the receiver chassis 2 by means of the threaded mounting studs 3, which are preferably molded into the frame 1, and nuts 4.

The frame 1 comprises parallel side bars 5, united by a cross bar 6, and provided with grooves 7 in certain of which the leads 14 from the coils may be secured by any suitable cementitious substance. It is desirable that they be held in fixed relation to the frame so that their relative positions are maintained. One of the grooves 7 may carry a lead 22 from the high-potential terminal 13 of the secondary coil upward, to be more conveniently attached to the grid cap terminal on an associated thermionic relay.

The cross bar 6 sustains the coil 8, and may be provided with an integral fixed stud 6a, extending into and cemented to the hollow cylindrical core 9 of the coil 8.

The frame 1 carries a wood or molded guide rod 10, freely extending through the hollow cylindrical core 11 of the coil 12, to thereby permit the core 11 and the coil 12 to be moved relatively to the center of the magnetic system. This adjustment of the core 11 and the coil 12 might, however, be attained if said guide rod 10 were longitudinally movable and said core and said coil were fixed thereto as shown in Fig. 5.

The coils 8 and 12 constitute the primary and secondary, respectively, of the coupling device. The coils are preferably of the type produced on a universal winding machine and are designed to have a desirable relation of length to depth of winding. For use in the band of frequencies between 550 and 1500 kilocycles, the primary coil 8 may have an inductance of about 3.2 millihenries, and be resonant at a frequency below the desired band of frequencies, thereby producing the minimum effect on the gain within the desired band of frequencies. It may be wound with number 36 solid single silk covered enameled wire. The secondary coil 12 may be wound with Litzendraht wire consisting of ten strands of number 41 enameled wire, and may have an inductance of about 250 microhenries so as to cover the desired band of frequencies when tuned by a variable condenser having a maximum capacity of about 365 micromicrofarads. The coils 8 and 12 are secured to the cores 9 and 11, respectively, by means of any suitable cement.

In the embodiment here shown, it will be noted that the core 9 of the primary coil 8 is smaller than the core 11 of the secondary coil 12. Since the secondary coil is a component of a tuned circuit, it is desirable to keep its losses as low as possible. Hence a relatively small coil on a relatively large core is used. The primary coil, however, is untuned, and its losses may be higher without serious effect. Hence for the sake of economy a relatively large coil on a relatively small core is used. This choice may be found advantageous in those cases where cost is an important consideration.

Referring to Figs. 1 and 2, terminals 13 extend outward from the frame 1, being preferably eyeletted through square holes in the frame 1. Leads 14 from the coils 8 and 12 extend to the terminals 13, either directly from the coils or secured in the grooves 7 in the frame 1. The leads 14 may be soldered or attached by other suitable means to the terminals 13. Coupling condenser 15 is mounted as shown relative to the frame 1 by soldering it to the two terminals 13 which connect to the high-potential ends of the coils 8 and 12. For operation in the frequency band between 550 and 1500 kilocycles, this condenser may have a capacity of 25 micromicrofarads, in which case zero magnetic coupling may be used; or it may have a capacity of 15 micromicrofarads in conjunction with about 8% magnetic coupling. In general, different values of capacitive or magnetic coupling, or combinations of both, can be used to adapt the design to the individual requirements of a particular piece of receiving apparatus.

Referring again to Fig. 1, the assembly may include a metal shield 16 which is usually desirable in order to prevent electro-magnetic and electrostatic coupling between adjacent coupling devices. The shield 16 may be arranged to be eye-

letted to the chassis 2 as shown, or otherwise suitably fixed in place. It should be provided with a hole 23 to receive the control-grid lead 22 from a thermionic relay. The metal chassis 2 of the receiver completes the shielding of the coupling device.

Fig. 3 serves to make clear a preferred construction of the molded insulating frame 1. The small extensions 1a for the terminals 13 are arranged to readily permit eyeletting of the terminals in place. The extensions adjacent the sides of the frame receive the high-potential terminals of the primary and secondary respectively, and the centrally located extensions on the opposite side of the frame receive the low-potential terminals.

Fig. 4 shows a coupling device of the type herein contemplated connected between the output circuit 17 of the thermionic relay 18 and the input circuit 19 of the thermionic relay 20. The primary coil 8 is connected in series with the anode and cathode of the thermionic relay 18.

It will be observed that the coils 8 and 12 are mutually at right angles and that the cores 9 and 11 are also mutually at right angles. It will be clear that by positioning the coil 12 and the core 11 at what may be designated as the magnetic center of the magnetic system comprising the cores 9, 11, and the coils 8, 12, there will be no magnetic coupling whatever between the coils 8 and 12, or at least only a very small degree of coupling. However, by shifting the coil 12 and the core 11 longitudinally along its guide rod 10, a degree of coupling of a substantial order and adequate for the purpose of the design can be secured. The advantage of the arrangement lies in the fact that it is possible to quickly obtain in production any desirable degree of coupling with only a small movement of the coil 12 and the core 11. A possible adjusted position of the coil 12 and the core 11 is indicated by the dotted outline in Figure 1. After the coil 12 and the core 11 have been adjusted to the position producing the desired degree of coupling, they are securely cemented in place.

Capacitive coupling or a combination of capacitive and magnetic coupling is often desirable in coupling devices designed for use over a band of frequencies, since it is often possible to materially improve the uniformity of gain and selectivity which is obtained over the band of frequencies by a proper choice of the coupling means. Capacitive coupling between the primary and secondary circuits is obtained by means of the condenser 15. The desired degree of magnetic coupling, within a range from zero to a substantial order, is readily obtained by adjustment of the position of the coil 12 and the core 11. If desired, the magnetic coupling can be made to aid the capacitive coupling by moving the coil 12 and the core 11 in the opposite direction from the zero coupling position.

Certain specific design data and constants have been given to complete the description of the present invention. It should be understood, however, that these constants are mentioned merely by way of example in describing certain specific embodiments which in practice have proved satisfactory, and are not intended to sug-

gest any specific limitations as to the scope of this invention.

Having thus described our invention, what we claim is:

1. A high-frequency coupling device including a concentrated primary and a concentrated secondary winding, ferro-magnetic cores for each of said windings, said windings being mounted upon said cores, said cores being relatively adjustable and mounted mutually at right angles, whereby the electromagnetic coupling between said primary and secondary windings may be adjusted to have any desired low degree of coupling, said primary winding having a natural frequency lower than any frequency to which said secondary winding is intended to be tuned.

2. A high-frequency coupling device including a frame, two compressed comminuted tubular ferro-magnetic cores mounted mutually at right angles upon said frame, a concentrated primary winding wound on one of said cores, a concentrated secondary winding wound upon the other of said cores, said primary winding having a natural frequency lower than any frequency to which said secondary winding is intended to be tuned.

3. A high-frequency coupling device comprising primary and secondary structures mounted mutually at right angles upon an insulating frame, said primary and secondary structures each consisting of a concentrated winding wound upon a compressed comminuted tubular ferro-magnetic core, means whereby the electro-magnetic coupling between said windings may be adjusted to any desired small value, said primary having a natural frequency lower than any frequency to which said secondary winding is intended to be tuned.

4. A frame for a high-frequency transformer, said frame having upstanding elements, a cross bar uniting said upstanding elements and having means for sustaining a magnetic core, widely-spaced means for supporting a pair of high-potential terminals, and adjacent means for supporting a pair of low-potential terminals.

5. An insulating frame for supporting the ferro-magnetic cores, the leads to the windings, and the terminals for the leads of a high-frequency transformer, said frame having two upstanding elements united by a cross bar, an upwardly extending post upon said cross bar for supporting one of said cores, perforated flanges extending downwardly from said cross bar adjacent said upstanding elements for supporting the high-potential terminals of said transformer, perforated flanges extending downwardly centrally of said cross bar for supporting the low-potential terminals of said transformer, and grooves in said upstanding elements for supporting the leads from the terminals to the windings of said transformer.

6. A moulded insulating frame for a high-frequency transformer, said frame having upstanding elements which serve as spacing means for the leads of said transformer, and a cross bar for fixedly uniting said upstanding elements, said cross bar carrying perforated flanges for supporting terminals for said leads.

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