United States Patent

[11] 3,609,208

[72] Inventor **Joseph L. Winpisinger**
Fairview Park, Ohio

[21] Appl. No. **73,961**
[22] Filed **Sept. 21, 1970**
[45] Patented **Sept. 28, 1971**
[73] Assignee **Lorain Products Corporation**

[54] **MAGNETICALLY COMPENSATED CONNECTOR FOR ELECTRICAL CIRCUITS**
8 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **174/32,** 174/117, 307/89, 317/260
[51] **Int. Cl.** **H01b 7/08**
[50] **Field of Search** ..... 174/32, 117 FF, 117 R; 317/261, 260; 307/89, 90, 91

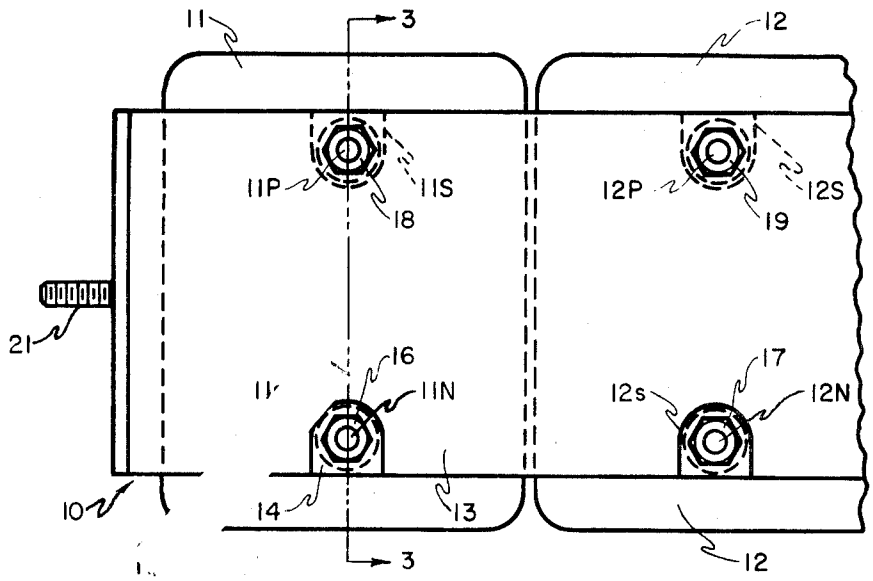
[56] **References Cited**

UNITED STATES PATENTS

3,300,695	1/1967	Cypra et al.	317/260
3,308,359	3/1967	Hayworth et al.	317/260

Primary Examiner—Lewis H. Myers
Assistant Examiner—A. T. Grimley
Attorney—John Howard Smith

ABSTRACT: A magnetically compensated conductor pair for connecting a plurality of circuit elements in parallel. A pair of conductors each having a thickness which is small in relation to the length and width thereof are insulated from one another by a sheet of a nonconductive material disposed therebetween. The terminals of each circuit component are connected only to predetermined respective conductors, the connections of each pair of component terminals being located so as to establish a symmetrical terminal distribution about the points where the conductors are connected to an external circuit. As current flows into one component terminal through one conductor and out of the other component terminal through the other conductor, the current distribution established in one conductor is equal and opposite to that established in the other conductor, on a point-by-point basis, along substantially the entire length and width of both conductors. This results in a mutual cancellation in the magnetic flux produced by current in the conductor pair and, thereby, in a reduction in the self-inductance thereof.



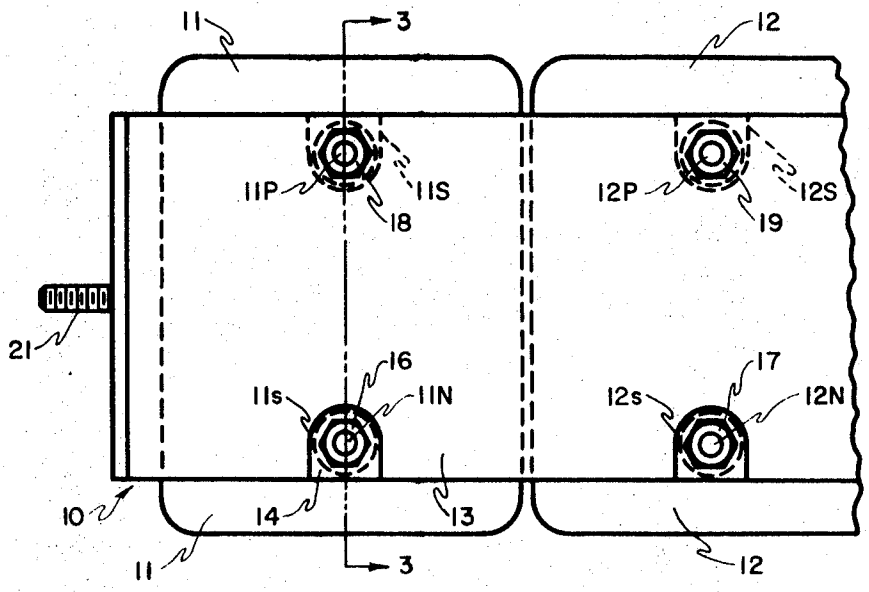


FIG. 1

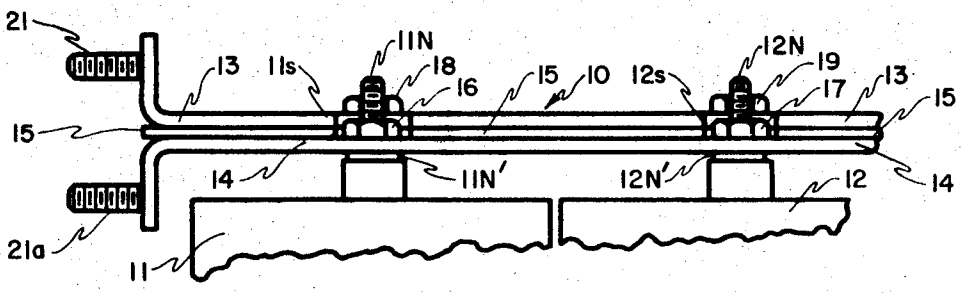


FIG. 2

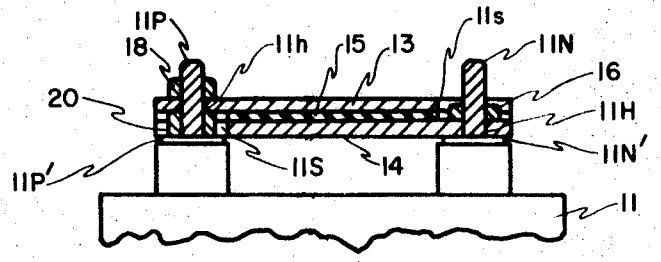


FIG. 3

INVENTOR.
JOSEPH L. WINPISINGER
BY John Howard Smith
ATT.

FIG. 4a

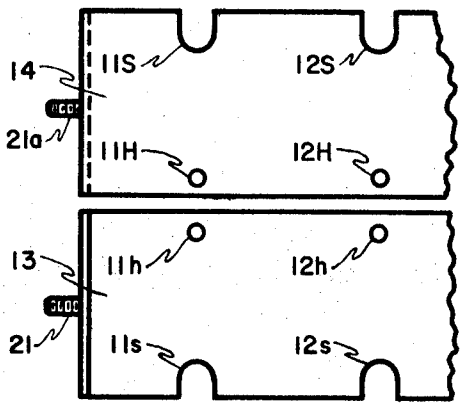


FIG. 4b

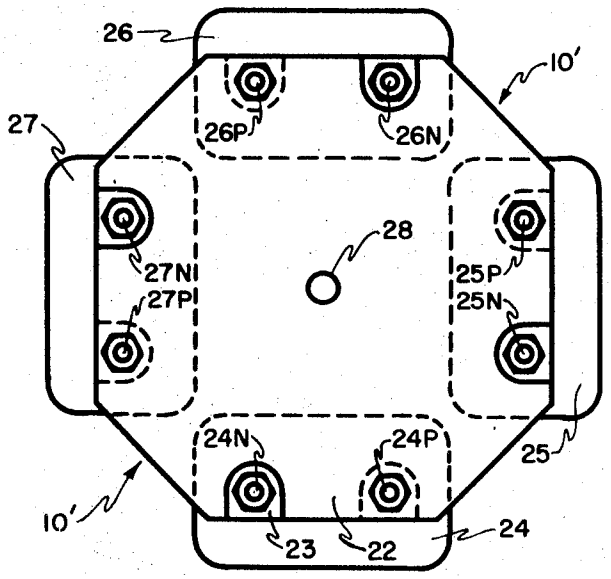


FIG. 5

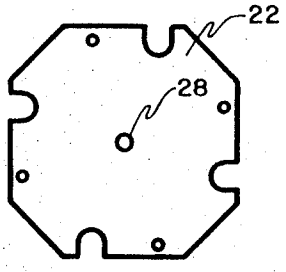


FIG. 7a

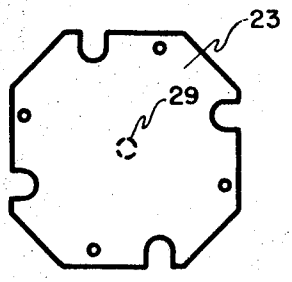


FIG. 7b

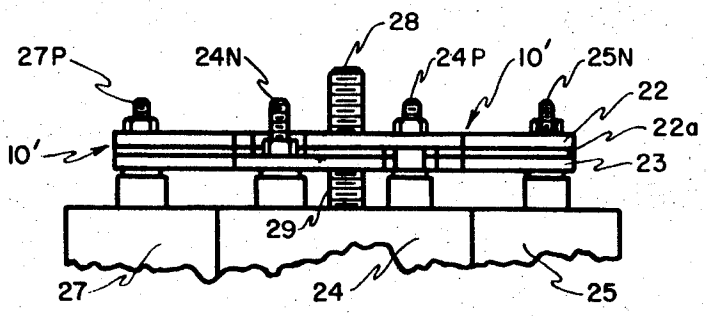


FIG. 6

INVENTOR.
JOSEPH L. WINPISINGER
BY John H. Smith
ATT.

MAGNETICALLY COMPENSATED CONNECTOR FOR ELECTRICAL CIRCUITS

BACKGROUND OF THE INVENTION

The present invention relates to magnetically compensated circuit connectors and is directed more particularly to circuit connectors for connecting two or more circuit elements in parallel.

As is well known, the self-inductance of a conductor is a measure of the magnetic flux which a current in the conductor produces in the region of space surrounding the conductor. Because of the undesirable effect the self-inductance of circuit connectors can have on the dynamic response and other important characteristics of an electrical circuit, it has been the practice to utilize magnetically compensated conductor pairs in making critically important circuit connections. In such conductor pairs equal but oppositely directed currents are made to flow in closely disposed conductors so that the flux produced by the current flowing in one direction in one conductor approximately cancels the flux produced by the current flowing in the opposite direction in the other conductor. This effect is, of course, produced only in those sections of the conductor pair where the conductors are located close to one another. Thus, the lengths of straight conductor necessary to connect the conductors of a magnetically compensated conductor pair to different respective terminals in a circuit are uncompensated.

In circuitry wherein parallel connected components are used this uncompensated end length of conductor, though negligible in other circuitry, may be highly detrimental to circuit operation. Prior to the present invention, it was difficult to achieve a high degree of magnetic compensation where the plurality of circuit elements were to be connected in parallel. One reason was that the distance between different terminals of the same component represented the minimum length of uncompensated conductors which could be utilized in the circuit. In the case of a bank of parallel connected capacitors, for example, the shortest length of magnetically uncompensated conductor able to connect a twisted pair to both terminals of a capacitor is equal to the distance between the capacitor terminals. This length of uncompensated conductor must, of course, be multiplied by the number of capacitors to be connected in parallel to determine the total effective length of uncompensated conductor which is present in the parallel connection.

Another difficulty is achieving a high degree of magnetic compensation, with previously available conductor pairs, was that the conductors making up such pairs could not be located as close together as in the present invention for the fluxes produced by the equal and opposite currents in the conductors of the conductor pair to as efficiently cancel each other for each point in space. With a twisted pair, the closest effective distance between the conductors is equal to the sum of the radii of the two conductors including the insulation. In this and other types of magnetically compensated pairs in which the separation between the centers of the conductors is greater than with the present invention, in relation to the cross-sectional areas of the conductors, the fluxes produced by the conductors do not as efficiently cancel one another within the region of space immediately surrounding the conductor pair. Such prior arrangements are satisfactory in many applications but the present invention is particularly advantageous when used with parallel connected electrical components.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide an improved, magnetically compensated conductor pair for connecting a plurality of circuit elements in parallel.

Another object of the invention is to provide a magnetically compensated conductor pair having conductors located so close to one another that the mutual cancellation of magnetic flux is substantially complete.

It is another object of the invention to provide a magnetically compensated conductor pair so arranged that the effective separation between the centers of the conductors making up the pair is small in relation to the cross-sectional area of either conductor.

Yet another object of the invention is to provide a magnetically compensated conductor pair which requires no magnetically uncompensated lengths to conductor to connect the conductors making up the pair to the different terminals of a circuit component.

Still another object of the invention is to provide a magnetically compensated conductor pair for connecting, in parallel, the terminals of two or more circuit elements, the conductor pair including parallel disposed conductor sheets separated by an insulating sheet, each terminal pair on each component being connected to the conductor sheets so that the current distribution in each sheet is substantially equal and opposite to the current distribution of the adjacent sheet.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of one exemplary bank of capacitors in which the capacitors are connected in parallel in accordance with the invention,

FIG. **2** is a front elevation of the capacitor bank of FIG. **1**.

FIG. **3** is a cross-sectional view taken along the line **3—3** of FIG. **1**,

FIGS. **4***a* and **4***b* are top plan views of conductor plates suitable for use in the connector assembly of FIGS. **1**, **2** and **3**.

FIG. **5** is a plan view of another exemplary bank of capacitors in which the capacitors are connected in parallel in accordance with the invention,

FIG. **6** is a front elevation of the capacitor bank of FIG. **5** and,

FIGS. **7***a* and **7***b* are top plan views of conductor plates suitable for use in the connector assembly of FIG. **5**.

DESCRIPTION OF THE INVENTION

Generally speaking, the present invention relates to an improved inductively compensated conductor pair for paralleling a plurality of circuit elements such as capacitors. The utilization of this conductor pair substantially improves the dynamic voltage and current characteristics of the parallel connected circuit elements by effectively reducing the series inductance which is associated with each conductor with the conductor pair. As will be described more fully presently, this is accomplished by so arranging and constructing the conductors that the magnetic flux produced by current in one conductor is cancelled in an improved manner by the magnetic flux produced by current in the other conductor and by so connecting the terminals of the circuit elements to the conductor pair that the above mutual magnetic field cancellation occurs over substantially the entire length and width of the both conductors.

Referring to FIGS. **1** and **2**, there is shown a connector assembly **10** suitable for connecting capacitors **11** and **12** in parallel. As is best seen in FIG. **2**, connector assembly **10** includes upper and lower conductor plates **13** and **14**, respectively, which are separated by a sheet **15** of a suitable insulating material.

To the end that lower conductor plate **14** may be connected to negative capacitor terminals **11N** and **12N** without being connected to positive capacitor terminal **11P** and **12P**, plate **14** is provided with holes **11H** and **12H** and slots **11S** and **12S**. In the present embodiment these holes and slots are located at respective edges of conductor plate **14** as shown in FIG. **4***a*. As plate **14** is being positioned with respect to capacitors **11** and **12**, capacitor terminals **11N** and **12N** pass upward through holes **11H** and **12H**, respectively, until plate **14** comes to rest against the respective conductive shoulder sections **11N'** and **12N'** of these terminals. Once in contact with these shoulders, conductor **14** may be held in place by suitable fastening means here shown as nuts **16** and **17**. When terminals **11N** and **12N**

are passed upward through holes 11H and 12H, capacitor terminals 11P and 12P pass upward through slots 11S and 12S, respectively. The latter slots are sufficiently large that no electrical contact exists between plate 14 and capacitor terminals 11P and 12P when plate 14 comes to rest on shoulders 11N' and 12N'. Thus, plate 14 is connected to the negative terminal of each capacitor but is not connected to the positive terminal of any capacitor.

A sheet 15 of a suitable insulating material is then laid on top of lower conductor 14 to prevent electrical contact between the latter and upper conductor 13 which will be applied later. The thickness of insulating sheet 15 should be as small as the voltage between conductors 14 and 13 will allow. This is because the thinner sheet 15 is made, the lower will be self-inductance of connector assembly 10. It will be understood that sheet 15 must be provided with openings of sizes and locations which will permit a good electrical contact between the capacitor terminals and the conductor plates.

In order that upper plate 13 may be connected to capacitor terminals 11P and 12P without being connected to capacitor terminals 11N or 12N, plate 13 is provided with holes 11*h* and 12*h* and slots 11*s* and 12*s*. These holes and slots are located at opposite respective edges of conductor 13 as shown in FIG. 4*b*. As plate 13 is being positioned with respect to capacitors 11 and 12 (after the positioning of plate 14 and insulating sheet 15) capacitor terminals 11P and 12P pass upward through holes 11*h* and 12*h* respectively, until plate 13 comes to rest against conductive spacers such a conductive spacer 20 in FIG. 3. This spacer occupies the open space created by slot 11S in underlying plate 14 to bridge the gap between conductive shoulder 11P' and conductor plate 13 and thereby assure a mechanically rigid electrical contact therebetween. Thereafter, plate 13 may be fastened to terminals 11P and 12P by suitable nuts 18 and 19. When terminals 11P and 12P are passed upward through holes 11*h* and 12*h*, capacitor terminals 11N and 12N pass upward through slots 11*s* and 12*s*, respectively. These slots are sufficiently large to assure that no electrical contact exists between plate 13 and capacitor terminals 11N and 12N when plate 13 comes to rest upon conductive spacers such as spacer 20. Thus, plate 13 is connected to the positive terminals of each capacitor but is not connected to the negative terminal of any capacitor.

Because conductors 13 and 14 and the insulation 15 therebetween have thicknesses which are small in relation to the respective lengths and widths thereof, the centers of these conductors may be located closer together than would be possible if conductors of equal cross-sectional areas but different cross-sectional shapes were utilized. As a result, magnetic flux cancellation provided by a conductor pair shaped in accordance with the invention is substantially more effective in reducing self-inductance than the magnetic flux cancellation provided by conductor pairs having conventional cross-sectional shapes such as, for example, the twisted pair having conductors of circular cross section and thus is more adaptable to parallel-connected components.

It will be understood that additional circuit elements may be connected in parallel with capacitors 11 and 12 by connecting these additional elements to plates 13 and 14 in the same manner as capacitors 11 and 12. If additional elements are so added, the additional holes and slots in the conductor plate should have a spacing corresponding to the terminal spacing of the additional elements, the holes and slots of one plate being located opposite the slots and holes, respectively, of the other plate. This will assure the desired electrical isolation between the conductor plates.

To the end that conductors 13 and 14 may be magnetically compensated at substantially every point along both the length and width thereof, these conductors are arranges to be connected to the external circuitry at circuit terminals 21 and 21*a* which here take the form of threaded terminal posts, these terminal posts being located at the midpoints of the ends of the respective conductors. This locates the P terminal of each capacitor at substantially the same distance from circuit terminal 21 along conductor 13 as the N terminal of each capacitor is located from circuit terminal 21*a* along conductor 14. This results in a symmetrical component terminal distribution.

Since the currents between the P and N terminals of each capacitor and the ends of the respective conductors distribute themselves substantially evenly over the widths of the respective conductors, and since the P and N terminals of each capacitor are equidistant from the circuit terminals of the respective conductors, it will be seen that, on a point-by-point basis, the current in one conductor plate is substantially equal in magnitude and opposite in direction to the current in the other, adjacently disposed conductor plate. As a result, the flux produced by current in one conductor, such as 13, is substantially cancelled by the flux produced by the current in the other, such as 14, leaving the conductor pair free of self-inductance all the way from the circuit terminals to the individual component terminals. Thus, there are eliminated the magnetically uncompensated lengths of conductor formerly thought necessary to connect a pair of component terminals to a magnetically compensated conductor pair.

The advantageous properties of the above-described point-by-point cancellation are available to any additional components which are connected to connector assembly 10 in the manner shown in FIGS. 1, 2 and 3. This is because the current distribution which is established in one conductor plate by current into one terminal of any additional component is balanced by the current distribution which is established in the other conductor plate by current out of the other terminal of that additional component. Consequently, while the magnitude of current flow in the vicinity of previously connected components is affected by the addition of components in parallel, the balance between the currents flowing in conductors 13 and 14 is not so affected.

FIGS. 5, 6 and 7*a* and 7*b* show another arrangement whereby a plurality of circuit elements may be connected in parallel in accordance with the invention. Therein, a connector assembly 10' including upper and lower conductor plates 22 and 23, respectively, and an insulating sheet 22*a* connects capacitors 24, 25, 26 and 27, in parallel between an upper plate circuit terminal post 28 and a corresponding lower plate circuit terminal post 29. This is accomplished by connecting the positive capacitor terminals 24P, 25P, 26P and 27P to upper plate 22 and by connecting the negative capacitor terminals 24N, 25N, 26N and 27N to lower plate 23, these connections being made in the manner previously described with reference to FIG. 1, 2 and 3.

While the distribution of current in plates 22 and 23 of FIG. 5 differs from the distribution of currents in conductors 13 and 14 of FIGS. 1 and 2, the same flux-cancelling effect is produced by both arrangements. This is not only because of the close physical proximity of conductor plates 22 and 23 but also because of the substantially equidistant symmetrical relationship which each pair of capacitor terminals bears to circuit terminals 28 and 29. This relationship causes the current distributions established in adjacently disposed portions of the upper and lower conductor plates to be approximately equal and opposite. In addition, since the foregoing results are achieved at substantially every point along the length and width of both plates, there is eliminated the uncompensated lengths of conductor which were previously necessary to connect a magnetically compensated conductor pair to different terminals of the same component.

In view of the foregoing, it will be seen that a connector assembly constructed in accordance with the invention is adapted to greatly reduce the self-inductance of a conductor pair by so shaping and locating the conductors thereof that the flux produced by the current in one conductor cancels the flux produced by the equal and opposite current in the other conductor, on a point-by-point basis, over substantially the entire length and width of the each conductor.

It will be understood that the embodiments shown herein are for explanatory purposes only and may be changed or modified without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a magnetically compensated connector assembly for connecting a plurality of circuit elements in parallel, in combination, first and second conductor plates each having a length and width substantially greater than the thickness thereof, insulating means, said insulating means being disposed between said conductor plates to electrically isolate each conductor plate from the other along the length and width thereof, means for connecting said first conductor plate to predetermined terminals of a plurality of circuit elements and second means for connecting said second conductor plate to predetermined other terminals of said plurality of circuit elements.

2. A magnetically compensated connector assembly as set forth in claim 1 wherein said first and second conductor plates are provided with respective circuit terminal means whereby said plates may be connected to respective external circuitry, the terminals of each component being substantially equidistant from the circuit terminal means of the conductor plates to which they are respectively connected.

3. A magnetically compensated connector assembly as set forth in claim 1 in which said first and second connecting means are disposed opposite one another across the width of said conductor plates.

4. In a magnetically compensated connector assembly for connecting a plurality of circuit elements in parallel between circuit terminal means of the connector assembly, in combination, first and second conductor plates each having a length and width substantially greater than the thickness thereof, insulating means, said insulating means being disposed between said conductor plates to electrically isolate each conductor plate from the other and maintain relative proximity therebetween, means for electrically connecting said first conductor plate to predetermined terminals of a plurality of two terminal-circuit elements, means for electrically connecting said second conductor plate to predetermined other terminals of a plurality of two terminal-circuit elements, said connecting means being located symmetrically with respect to said circuit terminal means, said symmetrically located connecting means directing the distribution of current along the length and width of said first conductor plate to be substantially equal and opposite, on a point-by-point basis, to the distribution of current along the length and width of the approximately disposed second conductor plate.

5. In a magnetically compensated connector assembly for connecting a plurality of circuit elements in parallel, in combination, a sheet of an electrical insulating material, a first conductor overlying said insulating sheet, a second conductor underlying said insulating sheet, said conductors each having a thickness which is small in relation to the width thereof and each having a width at least as great as the distance between the terminals of the circuit elements which are to be connected in parallel, means for securing said underlying conductor to predetermined terminals of a plurality of two terminal-circuit elements, a plurality of openings in said overlying conductor whereby said securing means associated with said underlying conductor may avoid electrical contact with said overlying conductor, means for securing said overlying conductor to predetermined other terminals of said plurality of two terminal-circuit elements, a plurality of openings in said underlying conductor whereby said securing means associated with said overlying conductor may avoid electrical contact with said underlying conductor, the magnetic flux produced by the current in one direction in the overlying conductor being substantially cancelled by the magnetic flux produced by the current flowing in the opposite direction in the underlying conductor to reduce the self-inductance of said conductors.

6. A magnetically compensated connector assembly as set forth in claim 5 in which said conductors are provided with respective circuit terminals means, the distance between one component terminal of each circuit element and the circuit terminal means of the conductor to which said one terminal is connected being substantially equal to the distance between the other component terminal of each circuit element and the circuit terminal means of the conductor to which said other terminal is connected.

7. In a magnetically compensated connector assembly for connecting a plurality of circuit elements in parallel between circuit terminal means of the connector assembly, in combination, first and second conductors said conductors each having a thickness which is small in relation to the width thereof and each having a width approximately equal to the distance between the terminals of the circuit elements which are to be connected in parallel, electrical insulating means, said insulating means being disposed between said conductors to electrically isolate each conductor from the other, means for securing one terminal of each circuit element to said first conductor at one edge thereof, means for securing the other terminal of each circuit element to said second conductor at the opposite edge thereof said securing means associated with the terminals of each component being located symmetrically with respect to the circuit terminal means, currents flowing in said conductors through each component distributing themselves substantially evenly throughout the conductive region bounded by the terminals of such component and the circuit terminal means of the connector assembly.

8. In a magnetically compensated connector assembly for connecting a plurality of circuit elements in parallel, in combination, first and second sheetlike conductor plates, insulating means, said insulating means being disposed between said plates to electrically isolate each plate from the other, a plurality of first connecting means for connecting one terminal of each circuit element to said first conductor plate, a plurality of second connecting means for connecting the other terminal of each circuit element to said second conductor plate, said first and second connecting means being disposed symmetrically around the periphery of said connector assembly, first and second circuit terminal means, means for connecting said circuit terminal means to respective ones of said first and second conductors at the centers of the faces thereof, the current flowing between the circuit terminal means of said first conductor and one terminal of each circuit element being substantially balanced, on a point-by-point basis, by the current flowing between the circuit terminal means of said second conductor and other circuit element terminals.