

[54] **PRINTED-BOARD AND SIMILAR
TRANSMISSION-LINE STRUCTURE FOR
REDUCING INTERFERENCE**

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174/117 F, 117 FF, 68.5; 333/99 R, 81 A, 73
S

[56] **References Cited**
UNITED STATES PATENTS

2,754,484	7/1956	Adams	174/33 X
3,091,655	5/1963	Ruiter	174/32
3,033,970	5/1962	Eisler	174/117 FF X

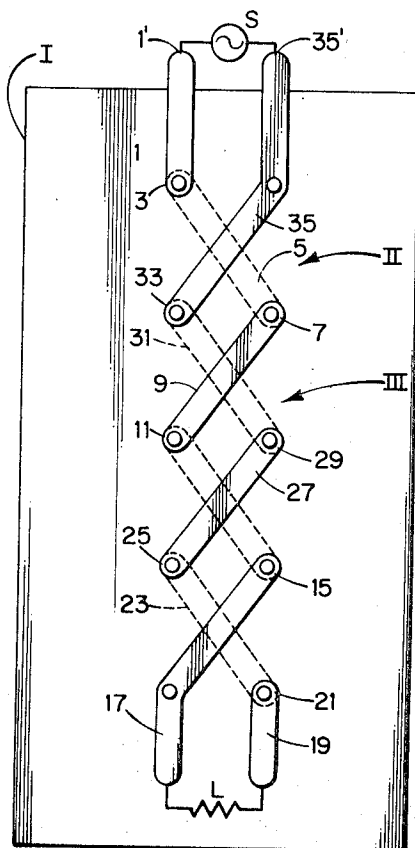
2,857,450	10/1958	Oliver	174/34
3,587,169	6/1971	Benke et al.	174/34 X
1,792,273	2/1931	Byk et al.	174/34

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[57] **ABSTRACT**

A novel transmission-line structure, particularly adapted for printed circuit sheets and the like, and embodying zig-zag line conductors formed of conductive strips successively disposed on opposite sides of the insulating sheet and interconnected transversely through the sheet, with the corresponding strips of each line conductor crossing those of the other line conductor, through on opposite sides of said sheet, effectively to provide a twist of the line conductors through at least a turn to effect magnetic field cancellation, self-shielding and interference suppression.

4 Claims, 5 Drawing Figures



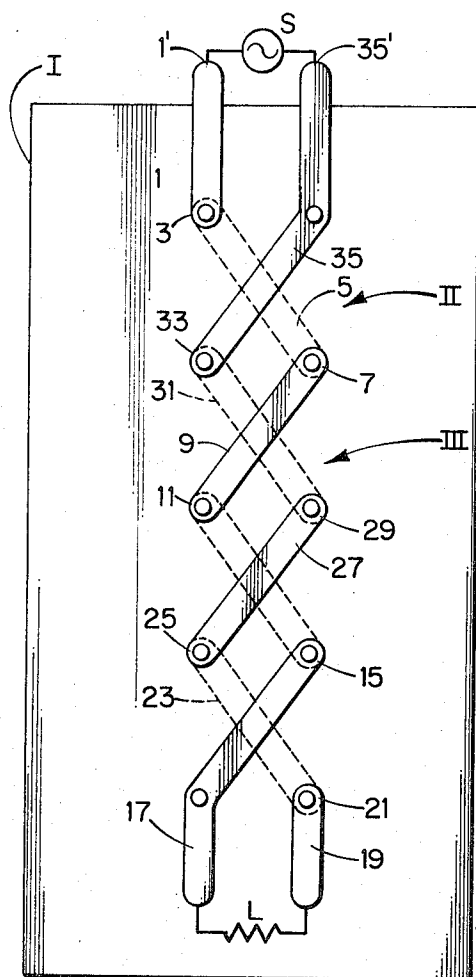


Fig. 1.

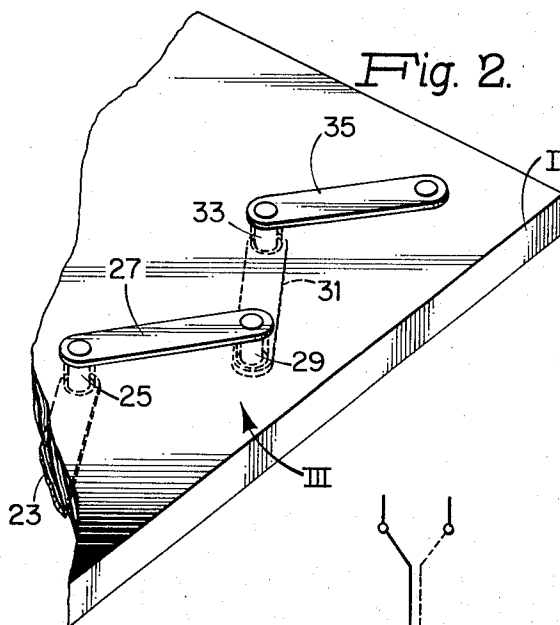


Fig. 2.

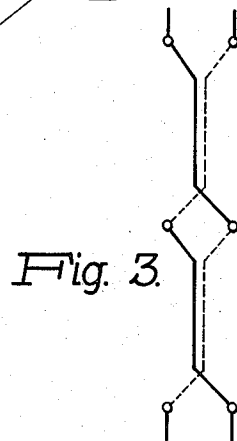


Fig. 3.

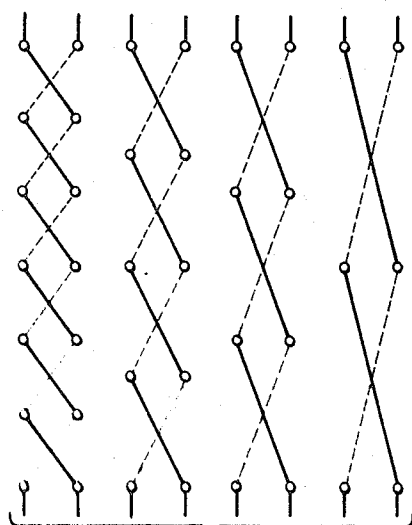


Fig. 4.

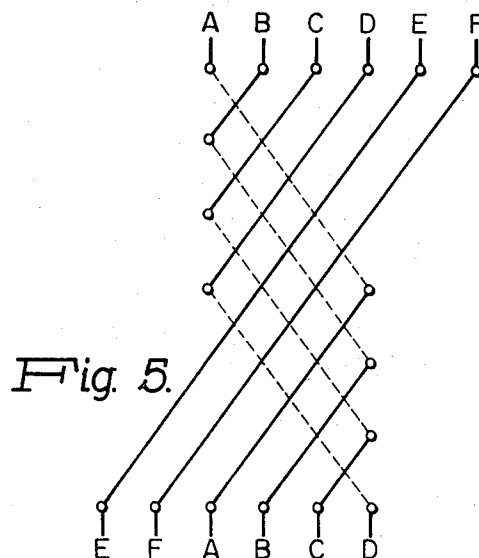


Fig. 5.

PRINTED-BOARD AND SIMILAR TRANSMISSION-LINE STRUCTURE FOR REDUCING INTERFERENCE

The present invention relates to transmission-line structures for printed boards and the like, being more particularly directed to structures designed for reducing electromagnetic interference in electronic and other equipment employing printed, etched or other wiring, secured upon insulating surfaces by automatic printing, etching, stamping or other methods.

In conventional hand-wired electronic equipments, shielding of critical transmission paths has conventionally been performed in a number of ways. If electromagnetic waveguides are employed, for example, containing electromagnetic energy within them, interference from outside sources entering the guides is completely prevented by the guide walls. Coaxial cables have also been used to conduct signal energy along a central conductor which is shielded from outside influences by an outer metallic sheath, constructed in a variety of ways, and which is also used as a return conductor. If a lesser degree of shielding from outside influences is tolerable, other transmission lines, including twisted pairs of wires, have been used; wherein magnetic fields impinging on such pairs of wires induce opposing voltages in different portions of the twisted pair. Since these portions are adjacent to one other and repeat at regular alternate intervals, fairly effective shielding against electromagnetic interference has been thus obtained.

Since all of the above transmission-line structures, however, have embodied the use of separate wires and cables connected between each of the sources and loads, their use to reduce interference effects in printed wiring circuits and the like has generally not been attempted for several reasons. First, the conductor pattern on a printed circuit board can only be applied to one or both of the two surfaces of the insulating board material, with the conductors applied as a single or few-layered surface deposit. Secondly, if two-sided printed circuits are used, the connections between the two sides have been deliberately restricted to as few as possible, the boards being typically soldered on the bottom surface only, using a dipping process or an automatic machine having a solder wave. Reliable connections to the top of the board, indeed, are achievable, in practice, only by additional manual soldering to the top (or component side) of the printed circuit board. Consequently, multi-conductor circuits having minimal radiation characteristics have not heretofore been considered as feasible in these types of constructions.

Instead, other shielding approaches have been proposed, including multiple layer and conductor constructions for reducing interference in printed board circuits as described, for example, in U.S. Letters Patent No. 3,460,105; actual ground and interposed insulating strips and shields as described, for example, in U.S. Letters Patent No. 2,754,484; and multi-parallel-conductor laminates, as described, for example, in U.S. Letters Patent No. 3,118,016. Such proposals, however, disadvantageously all require extra or ancillary layers and/or conductors and are not thus adapted for ordinary single printed board use and the like.

In accordance with a discovery underlying the present invention, however, it has been found that a novel zig-zag, alternating opposite-side conduction strip transmission line can be provided upon even single in-

ulating boards and the like so as inherently to reduce radiation interference along the line.

An object of the present invention, accordingly, is to provide a novel conductor printed circuit transmission line structure that produces and is minimally sensitive to electromagnetic and electrostatic radiation.

A further object of the invention is to provide a novel printed circuit transmission line somewhat analogous to a twisted or braided conductor pattern in performance.

Still a further object is to provide a novel transmission line or more general utility, as well, and having minimal mutual interference characteristics.

Other and further objects are later described, being more fully pointed out in the appended claims. In summary, however, from one of its broad aspects, the invention contemplates a transmission line structure carried by an insulating sheet, having, in combination with the said sheet, a pair of zig-zag transmission line conductors each comprising a plurality of conductive strips successively disposed on opposite sides of said sheet and interconnected by conductive means extending transversely through said sheet; input and output terminal means correspondingly provided at the strips at opposite ends of the line conductors; and the line conductors being disposed such that the corresponding strips of each line conductor cross those of the other line conductor, though on opposite sides of said sheet, effectively to provide a twist of the transmission line conductors though at least a turn to effect magnetic field cancellation, self-shielding, and interference suppression.

The invention will now be described with reference to the accompanying drawings,

FIG. 1 of which is a top view of a two-conductor transmission line constructed in accordance with a preferred embodiment of the invention;

FIG. 2 is an isometric view, upon an enlarged scale of part of the line of FIG. 1; and

FIGS. 3, 4 and 5 are schematic views similar to FIG. 1 of modifications of the conductor patterns.

Referring to FIGS. 1 and 2, a source S of electric signals is shown at input terminals 1' and 35' connected, respectively to first conductor strips 1 and 35 disposed on the top surface of a supporting insulating sheet I. Each of the conductor strips 1 and 35 is the first of a plurality of strips (5-9-13-17 and 31-27-23-19) respectively comprising substantially equal-length segments of such a pair of transmission lines. The current passing through each conductor strip (such as the strip 1) is fed transversely through the sheet I to the next successive strip (5) by through-connectors (3). Such through-connectors as 3, 7, 11, etc., may take various forms, such as a metallic insert of rolled or seamless eyelet form, wire, or a plated connection, such as a plated-through hole. Successive strips 1-5-9-13-17 (and 35-31-27-23-19) are disposed on opposite sides of the insulating sheet I and arranged in zig-zag fashion such that corresponding strips of each line (5 and 35, 9 and 31, 13 and 27, and 17 and 23) cross one another, but insulatingly, on opposite sides of the sheet I. Connections transversely between opposite sides of the printed circuit board, as at 3, can be reliably accomplished by plating conductive material (such as copper) on the inside wall of holes drilled or punched through the printed circuit board, as at 3, can be reliably accomplished by plating conductive material (such as copper) on the inside wall of holes drilled or punched

through the printed circuit board, permitting a multitude of reliable connections to be made from one side of the printed circuit board to the other and thereby obviating the need for soldering manually all connections to the top of the printed circuit board. Such through-connections can thus be used as a useful interconnecting of circuit elements, rather than as an undesirable and to-be-avoided connection, as in the prior art.

Tracing the current from the source S, after passing through transverse through-connector 3, the current from the left-hand terminal of source S is next passed along bottom surface conductor 5. The current is then conducted via through-connector 7 to top surface conductor 9; then by through-connector 11, to bottom surface conductor 13; by through-connector 15, to top surface conductor 17, etc.; and ultimately to the left-hand terminal of load resistance L, which may be any desired utilization means.

Current from the right-hand terminal of load resistance L is returned to the right-hand terminal of source S via top surface conductor 19, through-connector 21 bottom surface conductor 23, through-connector 25, top surface conductor 27, through-connector 29, bottom surface conductor 31, through-connector 33, and top surface conductor 35, FIG. 2.

In essence, the energy from source S is thus conducted to load L via a pair of conductors which have experienced a right-hand zig-zag twist of two complete turns, although the actual conductor portions are located on the flat surfaces of insulating medium I and in transverse electric connections passing through the board medium I.

An electric current passed from source S to load L would normally generate a magnetic field perpendicular to the plane of insulator board I, this field being proportional to the product of the current and the area II formed by the portions of, for example, conductors 5, 9, 31, and 35 enclosing it. If the structure described above were constructed symmetrically, a magnetic field of the same magnitude, but opposite polarity, would be created by the same current in area III formed by the portions of conductors 9, 13, 27, and 31 enclosing it. These two opposing magnetic fields would cancel each other at a distance large compared to the dimension of a full twist, and show a substantial reduction in field strength (compared to the field of a single area) at closer distances. In essence, the effective twisting of the conductors has shielded the transmission line.

The same analysis can be made and the same result can be achieved for fields in the left-right direction. Here, the product of length of the conductor portions and the thickness of the insulating medium I form the relative areas.

By reciprocity, the strength of the induced voltage due to an external alternating magnetic field is proportional to the magnetic field generated by the conducted current. Consequently, such a transmission line shows little susceptibility to interference from external fields.

Heretofore, transmission lines of printed circuit construction have been restricted to those configurations which did not involve crossing of conductors via connections through the insulating medium and were practically restricted to parallel conductor construction. In such cases, interference reduction could only be accomplished by having the conductors as narrow as possible and the insulating medium as thin as possible. It

can readily be appreciated that this prior-art construction is severely limited in both physical strength and the transmission lines power-handling capability, while demanding high precision in its construction.

The present invention, aside from being quite non-critical as to thickness or strength of insulating medium or conductor thickness, is also very tolerant of any misalignment between the top-surface and the bottom-surface conductors. This may be seen by imagining the bottom-surface conductors all being displaced to one side. The size of the areas II and III would not be changed, though the through-connections would no longer fall on the center of the bottom conductors.

The conductor construction of FIGS. 1 and 2 is illustrated for a transmission line of relatively low capacitance. If a lower impedance is desired, this can be achieved by having a higher proportion of the conductors located on top of each other. This is schematically represented in FIG. 3 where the solid lines indicate top-surface conductors, dashed lines indicate bottom-surface conductors, and dots represent the through-connections. The conductor segments here have straight intermediate sections between oppositely extending crossing portions, forming somewhat Z-shape conductor segments.

In applications where a multitude of transmission lines must operate in close proximity, each carrying different signals and being susceptible to interference from signals in the other transmission lines, a construction may be effected in accordance with the invention in which each transmission line is twisted or transposed at a different pitch compared to its neighbors. This is shown schematically in FIG. 4, with the same symbol notations as FIG. 3. Here, four transmission lines are schematically shown, with the first or left-hand transmission line experiencing three complete turns; the second, two complete turns; the third, one and one-half turns; and the fourth, one turn in the length shown. This type of zig-zag construction may be made to any desired length and with any number of conductors, limited only by the fabrication facilities.

In certain applications, moreover, it is sometimes desired to have transmission lines of more than two conductors. The present invention readily allows twisting of any multiple number of conductors, as schematically shown in FIG. 5 for the case of a four-conductor transmission line cable. Conductors A, B, C, and D are twisted about each other for one full turn, while auxiliary conductors E and F, carrying non-critical currents, have been allowed to pass between the top spaces between the conductors. The lengths of the conductor segments in this embodiment may thus be different for the successive segments.

The technique described above is not, however, restricted to twisted multiple conductors, but may with equal ease be applied to conductor configurations of a braided or woven shape, now possible only with individual wire conductors. Similarly, the invention is not restricted to rigid printed circuit applications, but may be used with flexible, thin insulating films as well. The invention, furthermore, is not restricted to conductors and through-connectors made by conventional etching and plating methods, but is usable with constructions made by other suitable processes, including those involving diffusion processes or vacuum deposition processes. Further modifications will also occur to those skilled in the art, and all such are considered to fall

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within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A transmission line structure carried by an insulating sheet, having in combination with the said sheet, a pair of zig-zag transmission line conductors each comprising a plurality of conductive strips successively disposed on opposite sides of said sheet and interconnected by conductive means extending transversely through said sheet; input and output terminal means correspondingly provided at the strips at opposite ends of the line conductors; and the line conductors being disposed such that the corresponding strips of each line conductor cross those of the other line conductor, though on opposite sides of said sheet, effectively to

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provide a twist of the transmission line conductors through at least a turn to effect magnetic field cancellation, self-shielding, and interference suppression.

2. A transmission-line structure as claimed in claim 1 and in which said zig-zag configuration comprises a plurality of substantially equal-length successive conductive strips.

3. A transmission-line structure as claimed in claim 1 and in which said zig-zag configuration comprises conductive strips each of substantially Z-shape.

4. A transmission-line structure as claimed in claim 1 and in which said zig-zag configuration comprises conductive strips of a plurality of different lengths.

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