

April 16, 1968

S. RASK

3,378,629

WOVEN CONDUCTOR AND METHOD OF FORMING THE SAME

Filed Aug. 9, 1965

3 Sheets-Sheet 1

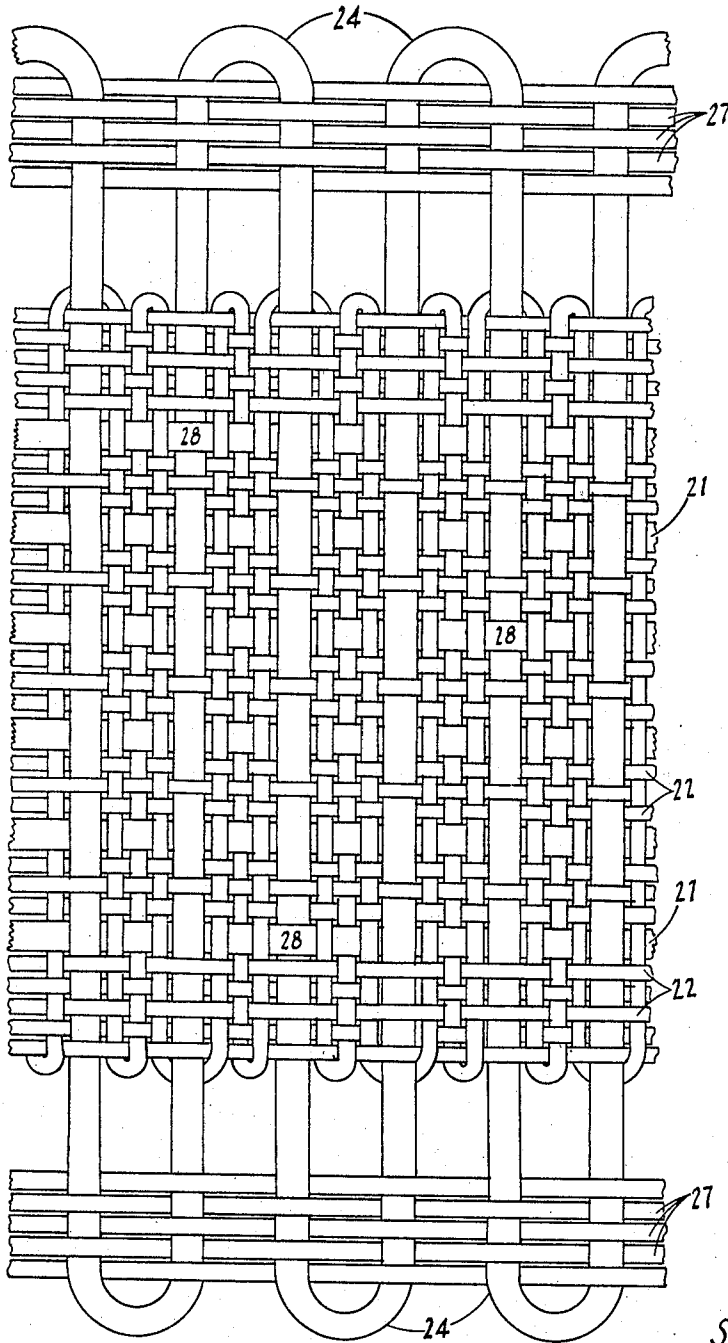


Fig. 1.

INVENTOR
Stanley Rask
BY
Arthur A. March
ATTORNEY

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3 Sheets-Sheet 2

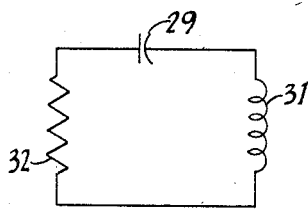


Fig. 2.

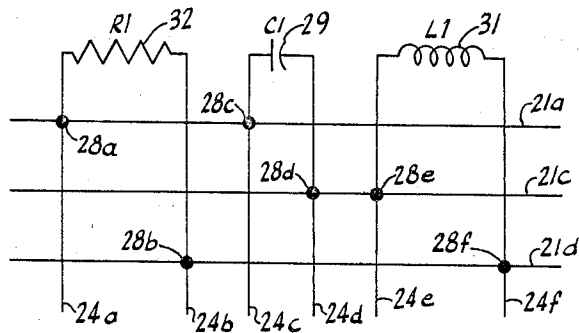


Fig. 3.

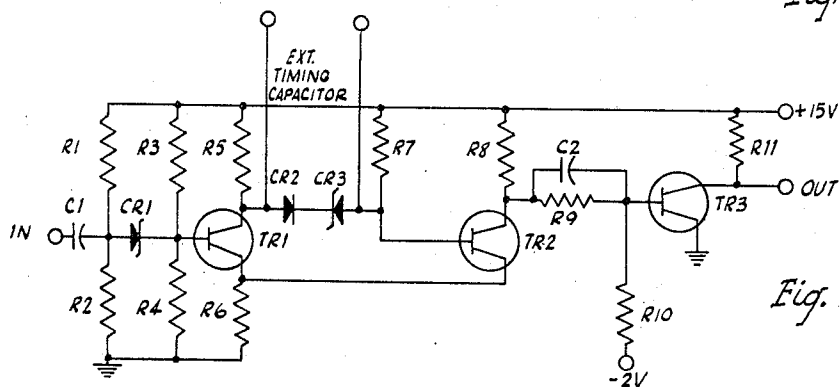


Fig. 4.

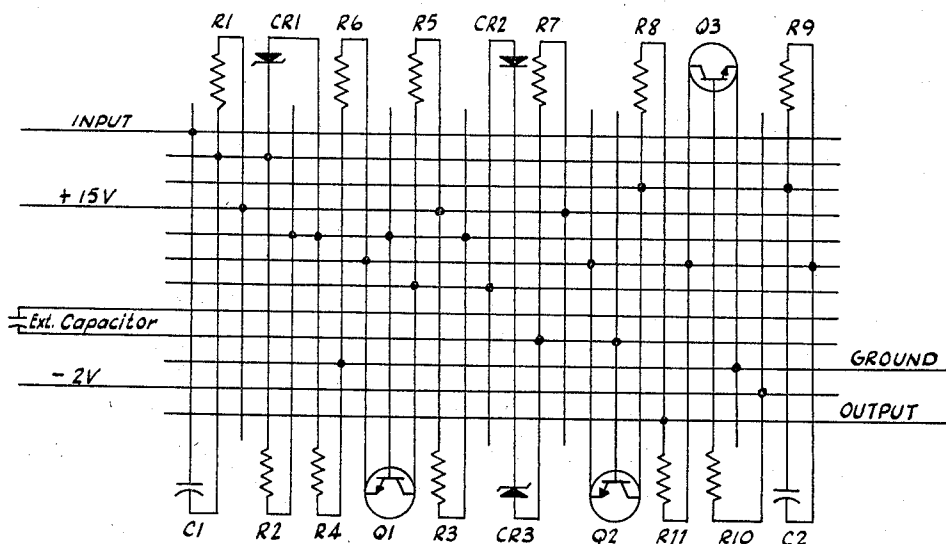


Fig. 5.

INVENTOR.

Stanley Rask

BY

Arthur A. March
ATTORNEY

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3 Sheets-Sheet 3

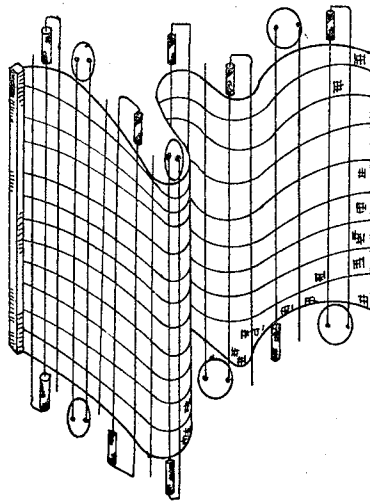


Fig. 6.

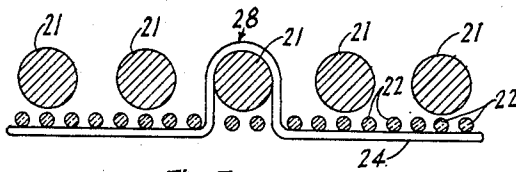


Fig. 7.

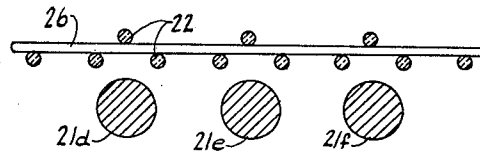


Fig. 8.

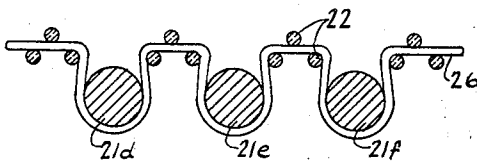


Fig. 9.

Fig. 10.

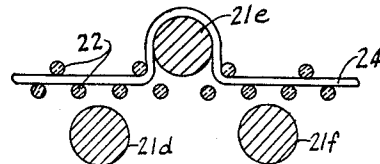
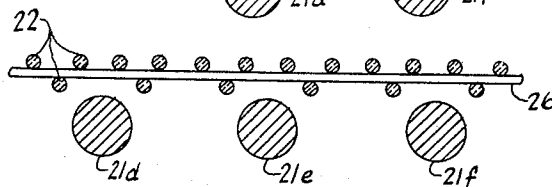


Fig. 11.

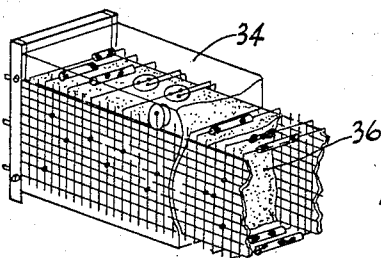


Fig. 12.

INVENTOR.

Stanley Rask

BY

Arthur A. March

ATTORNEY

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3,378,629

WOVEN CONDUCTOR AND METHOD OF FORMING THE SAME

Stanley Rask, New York, N.Y., assignor to Continental Copper & Steel Industries, Inc., New York, N.Y., a corporation of Delaware

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5 Claims. (Cl. 174—117)

This invention relates to a woven matrix comprising both conducting and insulating warp members and conducting and insulating fill members in which the conductive fill members are woven into direct contact with each other at nodal points spaced apart at predetermined locations on the fabric.

The concept of a matrix system of interweaving wires and dielectric fibers, or yarns, has been employed heretofore in providing a basic strip of fabric to which electrical components can be connected and in which certain of the wires running in one direction can be joined to wires running in a perpendicular direction to form interconnections between the electrical components. In such woven circuits one of the important points is to make the inter-connections between wires as simple as possible, and in accordance with that requirement, the present invention provides for weaving the wire conductors and dielectric yarns in a predetermined pattern such that, at nodal points where the wires are to be interconnected, those running in one direction are deliberately brought up through the dielectric yarns and crossed over those running in the perpendicular direction. It is equally important that, at other points of near inter-section between perpendicular wires, there must be a layer of dielectric yarn between the wires to insulate them from each other, and the present invention provides for this insulating layer. The dielectric yarn is of material capable of withstanding soldering temperatures so that all that is necessary to create the inter-connections is to run the woven fabric through a hot solder bath or a wave or jet soldering device in which the nodal points will be automatically joined together by the solder. Thereafter the fabric may be treated with a suitable material to retain the separation between other points of the wire conductors, and then electric terminals or components or connectors may be attached to selected wires to form a finished circuit or cable.

The invention will be described in greater detail in connection with the drawings in which:

FIG. 1 shows a section of a strip of woven circuit fabric as it comes from the loom;

FIG. 2 is a simple electrical circuit;

FIG. 3 shows the components of the circuit of FIG. 2 arranged for connection by means of a wire matrix;

FIG. 4 shows a more complex electrical circuit diagram;

FIG. 5 is a schematic representation of a matrix circuit equivalent of the circuit in FIG. 4;

FIG. 6 is a pictorial representation of the circuit of FIGS. 4 and 5;

FIG. 7 is a simplified schematic representation of a cross-section of the cloth of FIG. 1;

FIGS. 8-11 are simplified schematic representations of cross sections of the fabric of FIG. 1 at successive steps in the weaving thereof; and

FIG. 12 is a perspective, phantom view of a section of an electronic device incorporating woven circuits.

FIG. 1 shows an embodiment of the woven circuit fabric of this invention prepared as an elongated, rather narrow strip, somewhat similar in appearance to a seat belt. However, there is no limit in theory as to the width of the fabric and it could be made as wide as available looms are capable of producing.

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In textile weaving, the yarn running the length of the fabric is called the warp. The yarn inserted by a shuttle across and at right angles to the warp is known as the weft, or fill. Automatic looms are well-known in the weaving industry which provide for holding the warp strands in separate headles independently of each other and shifting them so that the warp yarns are raised and lowered selectively to permit shuttles to be inserted selectively to produce any desired pattern at high speed.

In adapting this automatic weaving technique to the production of electrical circuits, wires, indicated by the heavier strands 21 are interspersed with insulating fibers 22 to form the warp, and another wire 24 is woven back and forth, together with insulating yarns 26 as the weft, or fill. For purposes to be described hereinafter, it is desired that the fill wires extend outwardly beyond the edges of the main part of the fabric and therefore additional warp yarns 27 are provided at each side of the fabric spaced from the main warp yarns 22 to provide supports for the conductive fill wire 24. Nodal points 28 are shown spaced at various places across the surface of the fabric at locations determined by the pattern automatically woven into the cloth in accordance with the circuit with which the cloth is to be used.

A simple form of circuit is shown in FIG. 2 in which a capacitor 29, a coil 31, and a resistor 32 are connected in a closed series loop. In ordinary circuit construction, each of the three electrical components would have terminals that would be connected directly to terminals of the other two components, or they might be connected by additional lengths of wire if they were too far apart physically to be connected directly together. In the case of printed circuits, the three components 29, 31 and 32 would be electrically and mechanically attached by soldering to spaced eyelets on the surface of a flat printed circuit board and would be interconnected by conductive strips running along the surface of the board.

The components shown in FIG. 2 can be connected by means of a matrix of wires as provided by the fabric of FIG. 1 in a simple manner as shown in FIG. 3. In this case the warp wires are indicated by reference numerals 21a-21c, and the fill wires are indicated by reference numerals 24a-24f, one for each of the terminals of each of the components. Where the conductive fill wires 24a-24b, are to be connected to the conductive warp wires 21a-21c, the nodal points are indicated by reference characters 28a-28f, but at other crossings between the conductive warp and the conductive fill, no connection is desired. By tracing out the circuit going from the nodal point 28a through the resistor 32 to the nodal point 28b and thence along the conductive warp 21c to the nodal point 28f, and so on, it will be seen that matrix circuit in FIG. 3 is electrically identical with the circuit of FIG. 2.

FIG. 4 shows a more complex circuit, which in this case is a conventional schematic diagram of a monostable multivibrator, the operation of which will not be analyzed since the circuit is purely illustrative and does not form a part of this invention. The circuit of FIG. 4 is transformed into a matrix schematic diagram in FIG. 5 similar to the matrix circuit of FIG. 3 except that it is more complex. The individual components are shown connected along both edges of the strip rather than along one edge, which permits a significant reduction in the number of conductive fill wires required to form the circuit. For example if it is desired to connect the components only by means of the matrix circuit and not by direct connection from the terminal of one component to the terminal of an adjacent component, placing the components along only one edge of the woven strip would require one conductive fill wire for each terminal and a conductive warp wire for each interconnection between electrically adjacent terminals. Connecting the components along both edges of

the strip can make it possible, in theory, to use as little as half the number of conductive fill wires and one conductive warp wire for each series loop. Of course, in actual practice, the reduction in the number of conductive warp and conductive fill wires will not normally reach this level but there will still be a significant saving.

It is not necessary to keep the woven circuit of FIG. 5 arranged in a flat configuration. The woven fabric may be folded or pleated as may be required to fit the circuit into a limited space and as is shown in FIG. 6. While this can be done with the normal point to point connections to some extent in classical electrical circuits, it is not as simple to do so, and it is impossible to do so in ordinary printed circuits using rigid boards.

FIG. 7 is a simplified diagram of the conductive fabric of this invention. The large circles represent the warp wires 21 in section, and the small circles represent the warp yarns 22, also in section. A conductive fill wire 24 is shown woven up and over the center warp wire to make a nodal point 29. The insulating fill yarn that is woven with the warp yarns 22 to make up the insulating portion of the fabric is not shown in this figure, but the location of the warp yarns 22 between the warp wires 21 and the fill wire 24 does indicate the fact that the warp and fill wires 21 and 24 are basically on opposite surfaces of the insulating fabric.

FIGS. 8-11 show the cloth from the same point of view as does FIG. 7 except that each of the FIGS. 8-11 is spaced one shot, pick, apart moving successfully down the length of the fabric to illustrate the way that the warp and fill materials are interwoven. FIG. 8 shows one length of insulating fill 26 going across the width of the cloth with alternate ones of the insulating warp yarns 22 on opposite sides of the insulating fill 26, as is common in forming a simple piece of woven cloth. The conductive warp 21 is shown below the surface of the cloth formed by the insulating fill and warp, which is basically the preferred location for the conductive warp so that it will be insulated as well as possible from the conductive fill.

FIG. 9 shows a successive shot in which the shuttle guiding the insulating fill 26 has moved back from the other side and each of the insulating warp yarns 22 have been moved to the opposite position that it occupied in FIG. 8. That is, if a particular warp yarn 22 were above the insulating fill 26 in FIG. 8, it is moved down by its headle so that it is below the insulating fill 26 in FIG. 9. The conductive warp wires 21 remain below the level of the insulating warp and fill yarns 22 and 26, just as in FIG. 8.

FIG. 10 shows the tie down of the conductive warp, which must take place at intervals so that the conductive warp will not become separated from the cloth layer. In this figure, the headles controlling the individual conductive warp wires 21 have been moved up so that as the insulating fill 26 is carried across by the shuttle it will, in effect, follow the path indicated to bring it below the conductive warp wires and thus tie them to the fabric. This need not take place at every shot but may take place every few shots.

FIG. 11 illustrates a shot in which the conductive fill wire 24 has been brought across from one edge of the cloth to the other and in such a way as to make a nodal point. For this purpose the headle controlling the second conductive warp wire from the left, indicated by reference character 21e, has been moved up out of line with the other conductive warp wires to permit the conductive fill wire 24 to pass beneath it. Thereafter on a successive shot, the conductive warp wire 21e will be brought back into line with its other conductive warp wires and the position of FIG. 8 will be repeated. It is not necessary that a nodal point be made each time the conductive fill 24 is passed across the cloth; there may be occasions, as illustrated in FIG. 1 where a conductive fill will not have any nodal points but will simply connect a component on one edge of the cloth with another component on the other edge.

In order to provide a reliable connection at each of the nodal points 29 in FIG. 1, the crossed warp and fill conductors 21 and 24, which have already been partially crimped in the weaving process just described, are soldered in a continuous batch process. While various forms of soldering arrangements may be used, a typical one involves first cleaning the cloth chemically to remove oil, grease, dirt, and starch. The latter is usually included in yarn manufacturing to serve as a binder for the individual filaments of the yarn and as a lubricant in the loom. The fabric is then fluxed, heated, and passed through a solder bath. A thin film of molten solder adheres to the entire length of the wires or, if the wires are stranded, the solder wicks into the wire without clinging anywhere to the insulating yarn or bridging across the yarn from one wire to another. At the nodal points 28, in particular, the solder forms a well filleted joint. After the soldering, the cloth is washed to remove the flux and is dried and put back on reels.

In addition to soldering the wires at the nodal points, it is also possible to weld the wires since they are directly in contact with each other.

The next step in the handling of the cloth normally is to apply a plastic material to keep the insulating yarns from spreading apart under flexure and allowing the conductive warp wires 21 and the conductive fill wires 24 to come into contact with each other at points where such contact is not desired. Only the yarns and wires in the central portion of the tape as shown in FIG. 1 are normally impregnated. The fill wires 24 extending beyond the edge of the cloth tape are not coated, and the coating therefore does not complicate the process of applying terminals or components to these wires.

The impregnations used vary according to the properties desired. The electrical properties, such as insulation resistance and dielectric strength, and the environmental performance characteristics, such as resistance to moisture and humidity, vibration and temperature capabilities, flexural strength, and modulus of elasticity, will depend on this impregnation to a large extent.

Thereafter it is common to sever the conductive fill wires 24 at a point near the insulating yarns 27 so that the single conductive fill wire 24 shown in FIG. 1 will be divided into a large number of conductive fill wires, each insulated from the others, except where nodal points may join them together through the medium of one or more of the conductive warp wires 21. In view of the fact that the weaving process is quite accurate, the spacing between adjacent conductive fill wires may be very accurately determined and, any further accuracy that may be required in positioning these wires may be obtained by combing them to obtain exact spacings. Certain spacings have been agreed upon as standards in the electronic industry for producing printed circuits, and these same spacings can be maintained in the woven material of the present invention. Moreover the woven material has the advantage that, if there is a slight digression in the formation of the cloth, such slight digression may be eliminated by combing whereas in printed wiring boards, nothing can be done to modify the layout, once the boards have been printed. A further factor in favor of the woven circuit of the present invention is that all that is necessary to change the circuit to include or to remove components is to notify the weaver to change the automatic arrangement of the loom so that nodal points will be made at different locations. In printed circuits, on the other hand, the entire printed wiring board may have to be completely re-done in order to add an extra component. As a further factor in favor of the woven material of the present invention, it is possible by means of computer to go directly from the circuit layout to the loom control to cause nodal points to be formed at the desired locations for the best inter-connection of components. Moreover the basic material used in weaving the fabric of the present invention is quite inexpensive. For

one thing a common form of conductive warp and fill material is copper wire, usually tinned, but not necessarily so, and a usual form of insulating yarn is fiber glass. Fiber glass has the ability to stand up under the heat of the soldering bath better than many other materials, although if lower temperatures are used, other insulating yarns may provide other factors that have especially desirable characteristics. And as for the conductive wires, both those for the warp and those for the fill, they may, as has already been indicated, be either solid or stranded and they may be made of different materials. To take just one example, which is not to be considered as limiting, the conductive materials may be made of nickel iron so as to be able to make connection directly to nickel iron relay terminals without producing a contact voltage. This can be very important in circuits operating at low voltages of the order found in solid state circuits.

FIG. 12 is an illustration of another application of the woven circuit materials of the present invention. In this figure two woven circuit panels have been combined with components in an arrangement which has come to be called a cordwood type of construction. Electrical components too bulky to be supported easily from the edges of the woven cloth may be supported from a satisfactory framework, indicated here by reference character 34. If desired the space between the woven circuit panels may be filled with a foamed-in-place plastic material 36.

While this invention has been described in terms of specific embodiments it will be recognized by those skilled in the art that the true scope of the invention is determined only by the following claims.

What is claimed is:

1. A woven matrix comprising: a plurality of conductive warp members; a plurality of insulating warp members substantially parallel to each other and forming a first band having a pre-determined width and two narrower bands, one on each side of said first band and spaced therefrom; a conductive fill member; and a plurality of insulating fill members woven with those of said insulating warp members in said first band to form an insulating fabric and woven with said conductive warp members to bind them to said fabric, said conductive fill member being woven back and forth across all of said insulating warp members to be bound by those of said insulating warp members in said first band to said fabric, said conductive fill member being spaced from said conductive warp members by said insulating fabric except at nodal points, said conductive fill member being woven into direct contact with said conductive warp members at selected intersections to define said nodal points.

2. A woven matrix comprising: a plurality of conductive warp members; a plurality of insulating warp members substantially parallel to each other and forming a first band having a pre-determined width and two narrower bands, one on each side of said first bands and spaced therefrom; a conductive fill member; and an insulating fill member woven back and forth across only those of said insulating warp members in said first band to form

an insulating fabric and woven with said conductive warp members to bind them to said fabrics, said conductive fill member being woven back and forth across all of said insulating warp members to be bound to said fabric by insulating warp members in said first band, said conductive fill member being spaced from said conductive warp members by said insulating fabric except at nodal points, said conductive fill member being woven into direct contact with said conductive warp members at selected intersections to define said nodal points.

3. The method of forming the woven matrix comprising: placing insulating and conductive warp members in a loom; moving said conductive warp members and selected ones of said insulating warp members in one direction relative to the remainder of said insulating warp members to separate said conductive and said selected ones of said insulating warp members from said remainder; directing the insulating fill member between the separated warp members; moving said remainder of said warp members and said selected ones of said warp members in opposite directions and directing the insulating fill member therebetween; moving at least one of said conductive warp members relative to the remainder of said conductive warp members; directing the conductive fill member between said one of said conductive warp members and the remainder of said conductive warp members to form a nodal point at the intersection of said conductive fill member and said one of said conductive warp members; returning said one of said conductive warp members to alignment with the remainder of said warp members; directing an insulating fill member adjacent to said conductive warp members to anchor the same in place; repeating the steps of directing said insulating fill member and said conductive fill member in a pre-determined pattern to form a woven cloth forming a first band with said conductive fill member woven back and forth and extending outwardly beyond the edges of said first band; providing additional warp yarns supporting said portions of said fill member extending outwardly beyond the edges of said first band to form two narrower bands, one on each side of said first band and spaced therefrom; removing said cloth from said loom; and anchoring said nodal points.

4. The method of claim 3 in which said nodal points are anchored by passing said cloth into contact with a source of molten solder.

5. The method of claim 3 in which said nodal points are anchored by welding the respective conductive warp and conductive fill members at said nodal points.

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L. E. ASKIN, L. H. MYERS, *Examiners*.

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