July 15, 1958 M. W. SLATE 2,843,829

ELECTRICAL INDUCTANCE

Filed Dec. 30, 1952 2 Sheets-Sheet 1

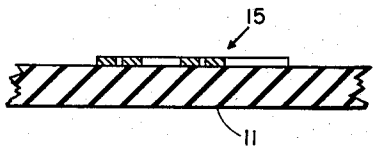

Fig. 3

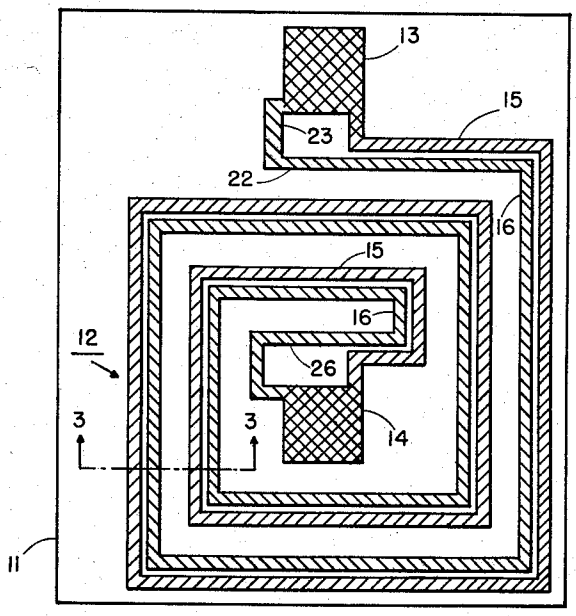

Fig. 2

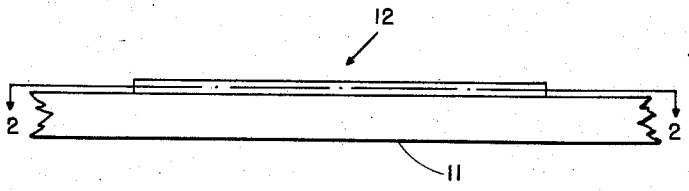

Fig. 1

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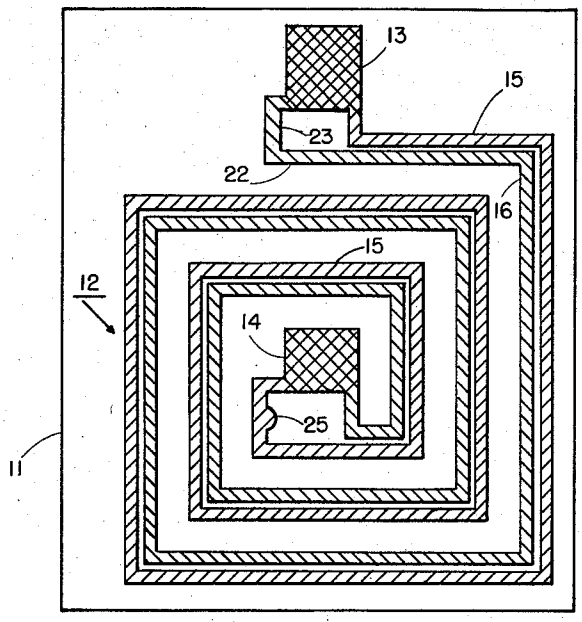

Fig. 5

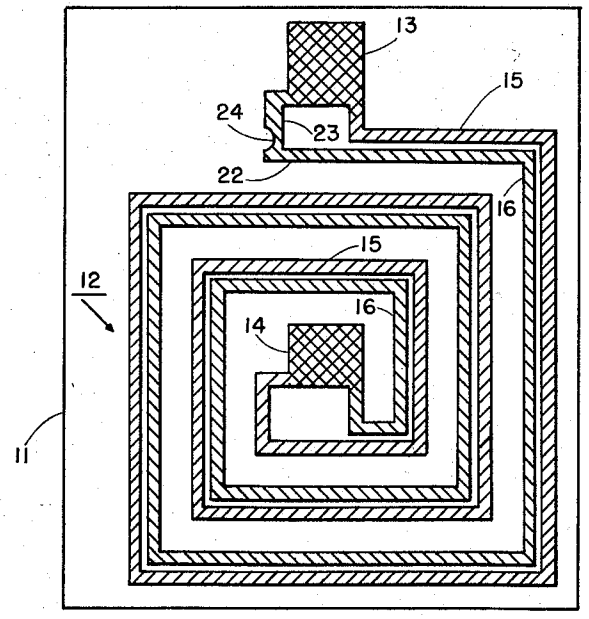

Fig. 4

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ELECTRICAL INDUCTANCE

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Application December 30, 1952, Serial No. 328,587

6 Claims. (Cl. 336—200)

This invention relates to electrical inductance coils and particularly to a physical form of such coils in printed-circuits.

Electrical inductance coils in printed-circuits generally are in the form of a planar spiral and the inductive conductor is preferably made as thin with respect to its width as is physically possible and consistent with electrical effectiveness. The radio frequency currents with which the printed-circuits are used tend to concentrate near the sharp outer edges thereof due to the skin effect and proximity effect. This phenomenon reduces the cross sectional area of the conductor by reducing the effective conducting width and thereby lowers the electrical efficiency or "Q" of the inductance coil. Accordingly it is a fundamental object of the instant invention to provide an electrical inductance coil having an improved electrical efficiency, a high L-R ratio and a high electrical "Q." Other objects and advantages of the invention will in part be obvious and in part appear hereinafter.

The invention accordingly is embodied in a planar electrical inductance coil formed as a spiral carrying a plurality of parallel planar conductors spaced from each other, the overall width of said plurality of said planar conductors being about the width of a conductor in a coil of single conductor construction, whereby the number of edges near which the currents are concentrated is increased, effectively increasing the cross sectional area of the conductor and thereby improving the electrical efficiency and "Q" of the coil. The invention accordingly is embodied in a planar inductance coil having features of construction, combinations of elements, and arrangements of parts hereinafter to be set forth in greater detail.

In the drawings:

Figure 1 is an edge view of a coil somewhat enlarged showing it in relation to a fixed base on which it would be carried.

Figure 2 is a plan view of the planar coil in one embodiment formed in accordance with the instant invention. With respect to Figure 2, it is to be understood that the coil could take any geometrical form; that is, its outline could be circular or elliptical as well as the rectilinear form shown.

Figure 3 is a section taken at line 3—3 of Figure 2.

Figure 4 representing one embodiment of my invention, shows how the impedance of one of the conductors is increased by the removal of material.

Figure 5 depicts a still further embodiment of my invention wherein the impedance of one of the conductors is decreased by the addition of material to the conductor.

Referring to Figure 1, **11** is an insulating supporting base on which the printed inductance coil **12** is carried. As seen in Figure 2, the terminals of the coil are **13** and **14** respectively, which may be buttons or contact points in the base. The conductor **15**, commencing at the terminal **13**, is divided into a plurality of electrical paths which follow the planar spiral path of the coil to the other terminal **14**. This construction is so arranged that the effective impedances of the several paths are the same with respect to radio frequency currents. Accordingly, the radio frequency current when in the inductance coil will divide substantially equally among the several parallel conductive paths, thereby providing an increased number of conductive edges at which the current will tend to concentrate due to the skin effect. This is shown in Figure 3 which is a section taken across the coil at the line 3—3 wherein the relation of the conductors to each other and to the base is shown in magnified form. It will be apparent that if the conductive path is considered to be a wide rectangle in cross section its subdivision into two parallel sections as shown will double the number of edges available for conduction.

As illustrated in Figure 2, the preferred embodiment of the invention employs two such parallel paths. Therein the two closely spaced parallel conductors **15** and **16** are arranged in a rectangular spiral form and are connected between terminals **13** and **14**. The parallel conductors are of course at all times kept closely adjacent to each other. The effective impedances of the parallel conductors **15** and **16** can be made equal by arranging the conductors appropriately. For example, it will be apparent that the inner conductor with respect to the spiral will have a shorter path than will the outer. The correction in impedance can be made by extending the conductor **16** at **22**, outwardly near the terminal **13** and similarly making an extension **26** at the inner terminal **14**.

Other techniques for altering the effective impedance path are illustrated in Figs. 4 and 5. Fig. 4 depicts the removal of material from the coil path near either of the terminals, thereby reducing the thickness or width of one of the conductors as indicated by **24** in the drawing. Another embodiment is depicted in Fig. 5 wherein the addition of material to the coil path near either of the terminals increases the thickness or width of one of the conductors as indicated by **25** in the drawing. Where the desire is to increase the impedance of the path, material is removed, and where it is desired to decrease impedance of the path for correction purposes, material may be added thereto to increase its width or thickness.

Coils constructed in accordance with the present invention provide substantially improved electrical results in that the Q of a coil thus formed is increased, in the 2-strand embodiment shown, by a maximum factor of 2. Other numbers of parallel paths will provide differing amounts of improvement. At the same time, the coil can be produced at no appreciable difference in cost from the production of conventional single printed coils, for once a master circuit printing plate has been prepared no additional technical or practical difficulties are involved in producing the coil.

Though the invention has been described with reference to a particular preferred embodiment thereof, variations which may be practiced without departing from the spirit or scope of the invention may be apparent to those skilled in the art. The scope of the invention is defined in the following claims.

What is claimed is:

1. In a planar printed circuit inductance for radio frequency use, having a spiral conductive means fixed to an insulating support, said conductive means being thin and rectangular in cross section, the improvement including in said conductive means a plurality of conductors in parallel connection, said conductors having a total cross sectional area no greater than the cross sectional area of said conductive means and means rendering the effective electrical impedance of all said conduc-

tors substantially equal, said means applied to at least one of said plurality of conductors to change the effective electrical impedance thereof to equal the impedance of the other said conductors whereby the number of sharp edges on which radio frequency currents are concentrated is multiplied and the current carrying capacity of said coil is increased.

2. In a planar printed circuit inductance for radio frequency use, having a spiral conductive means fixed to an insulating support, said conductive means being thin and rectangular in cross section, the improvement including in said conductor means a pair of conductors in parallel connection, said conductors having a total cross sectional area no greater than the cross sectional area of said conductive means, and means rendering the effective electrical impedance of both said conductors substantially equal, and means applied to one of said pair of conductors to change the effective electrical impedance thereof to equal the impedance of the other of said pair of conductors whereby the number of sharp edges on which radio frequency currents are concentrated is multiplied and the current carrying capacity of said coil is increased.

3. An improved printed circuit radio frequency inductance coil as claimed in claim 2 wherein said parallel connection comprises means joining said pair of conductors at the end thereof, said joining means being of considerable length parallel to both conductors at one end thereof to increase the effective electrical length of the inner conductor of said pair of conductors at one end thereof whereby the electrical impedance of both said conductors is rendered substantially equal.

4. An improved printed circuit radio frequency inductance coil as claimed in claim 2 wherein said parallel connection comprises means joining said pair of conductors at both ends thereof, said joining means being of considerable length parallel to both conductors at both ends thereof to increase the effective electrical length of the inner conductor of said pair of conductors at both ends thereof whereby the electrical impedance of both said conductors is rendered substantially equal.

5. An improved printed circuit radio frequency inductance coil as claimed in claim 2, characterized in that the inner conductor of said pair of conductors has a notch in the edge thereof comprising said means changing said impedance, said notch increasing the impedance of said conductor and making it substantially equal to the impedance of the outer conductor of the spiral.

6. An improved printed circuit radio frequency inductance coil as claimed in claim 2, characterized in that the outer conductor of said pair of conductors has a projection on the edge thereof comprising said means changing said impedance, said projection decreasing the impedance of said conductor and making it substantially equal to the impedance of the inner conductor of the spiral.

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