United States Patent [19]

Ogasawara et al.

[11] **3,761,860**

[45] **Sept. 25, 1973**

[54] **PRINTED CIRCUIT RESISTOR**

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[73] Assignee: **Alps Electric Co. Ltd.,** Tokyo, Japan

[22] Filed: **May 20, 1970**

[21] Appl. No.: **51,028**

Related U.S. Application Data

[62] Division of Ser. No. 831,042, June 6, 1969, abandoned.

[52] **U.S. Cl.**................. **338/262,** 338/309, 338/322, 338/328

[51] **Int. Cl.**... **H01c 1/14**

[58] **Field of Search**.................... 338/308, 309, 226, 338/262, 328, 322; 174/52 PE

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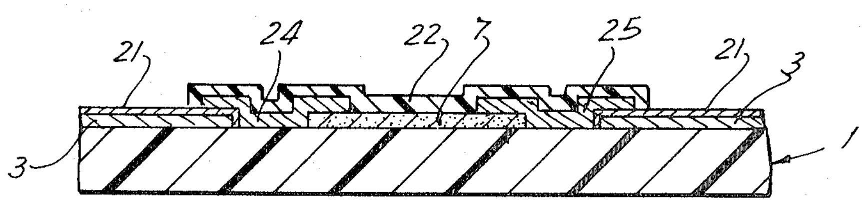
Primary Examiner—E. A. Goldberg
Attorney—James and Franklin

[57] **ABSTRACT**

A printed circuit resistor is formed by applying resistive paste between two conducting areas and forming an oxidation protecting film over the exposed surface of the resistive material. The conducting areas are so shaped that the thickness of the resistive layer is substantially uniform throughout.

5 Claims, 27 Drawing Figures



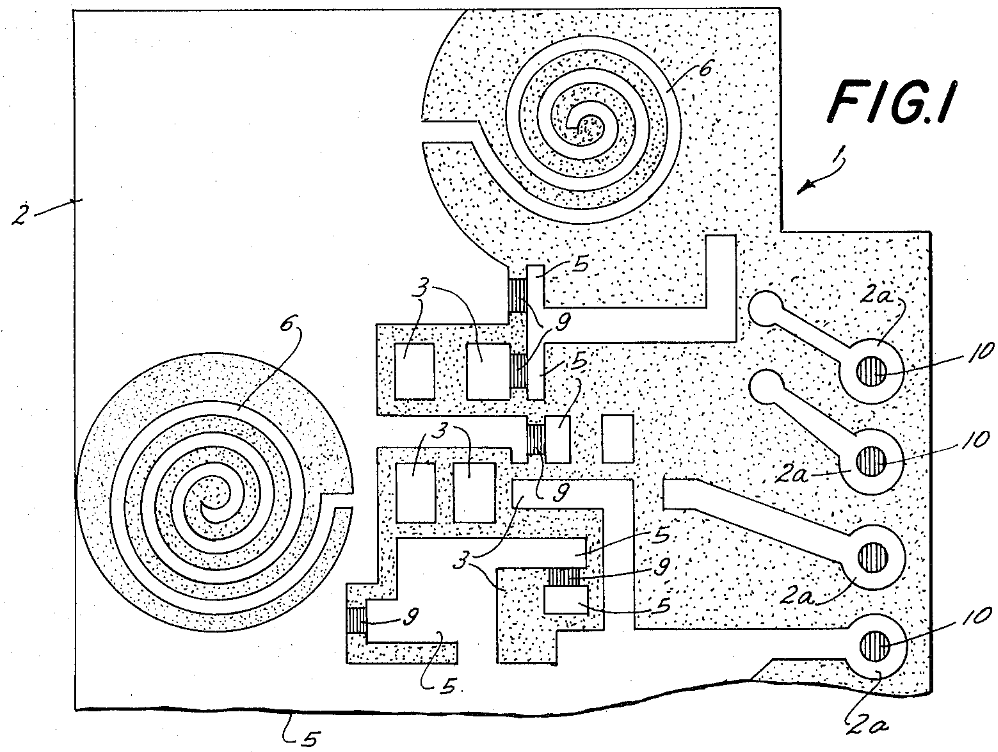


FIG.1

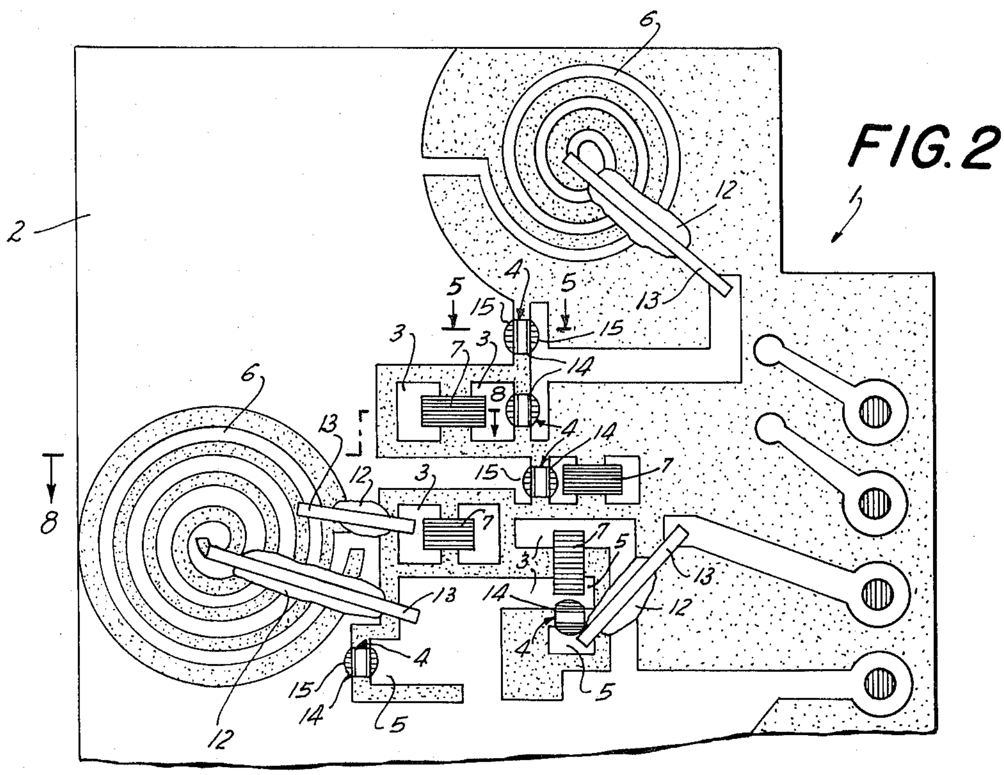


FIG.2

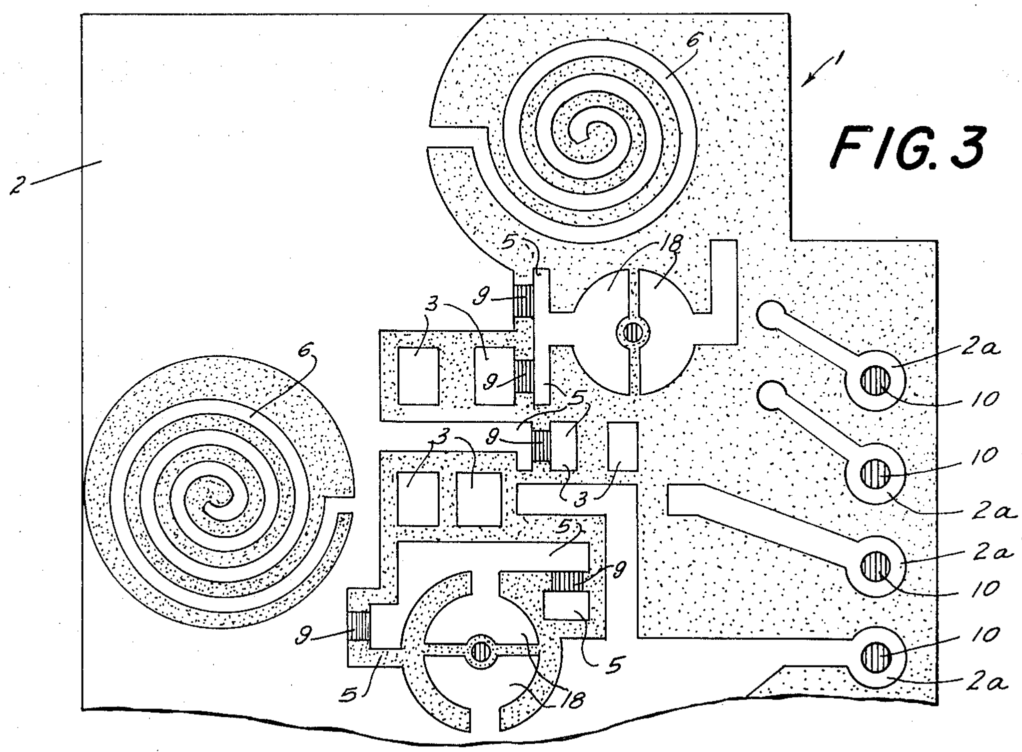


FIG. 3

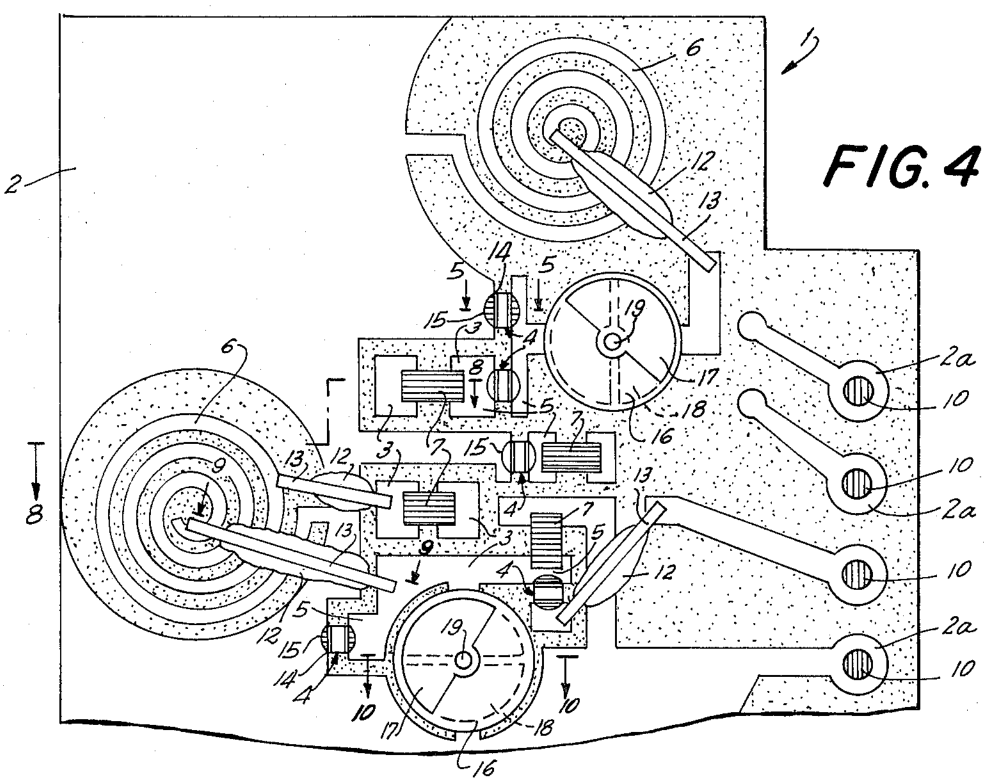


FIG. 4

FIG. 5

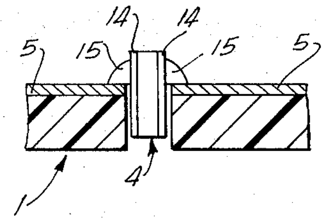


FIG. 6

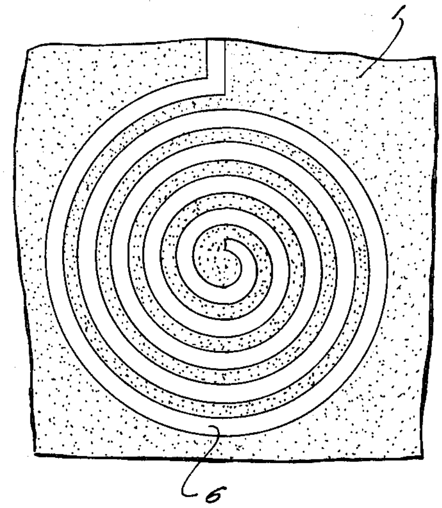


FIG. 7

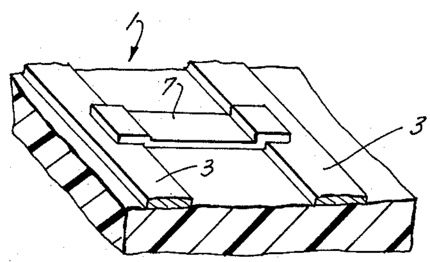


FIG. 10

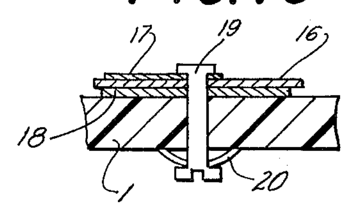
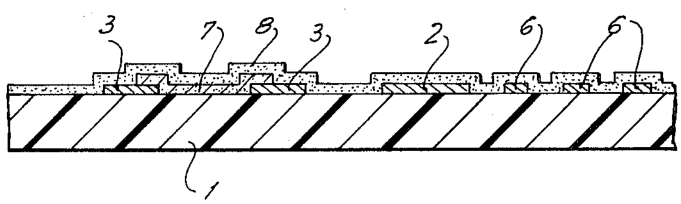


FIG. 8



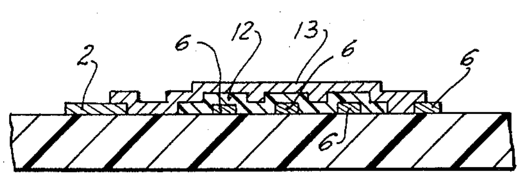


FIG. 9

FIG. 11

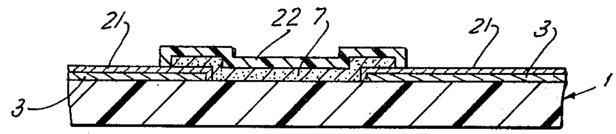


FIG. 12

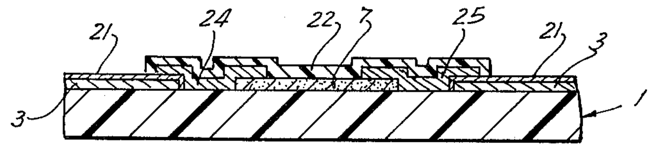


FIG. 13

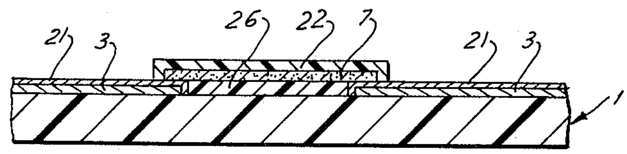
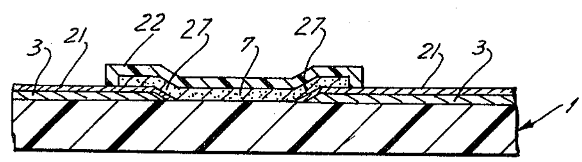


FIG. 14



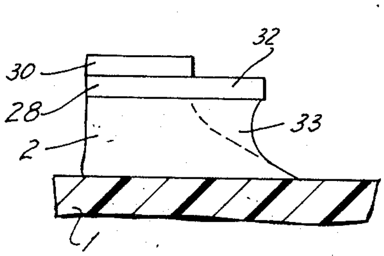


FIG. 16a

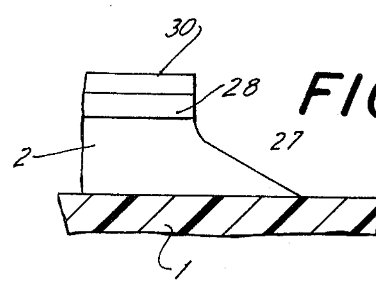


FIG. 16b

FIG. 15a

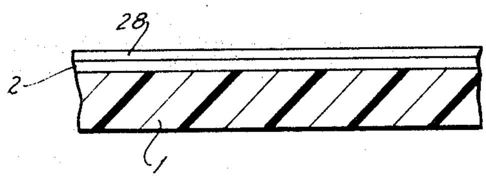


FIG. 15b

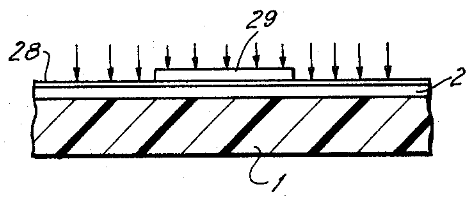


FIG. 15c

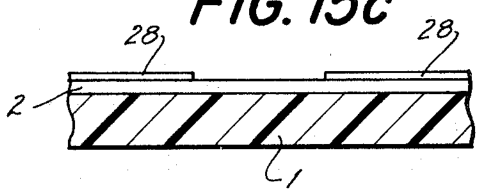


FIG. 15d

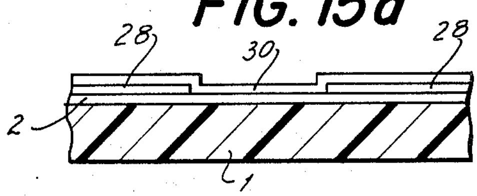


FIG. 15e

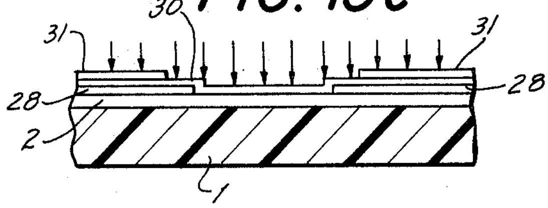


FIG. 15f

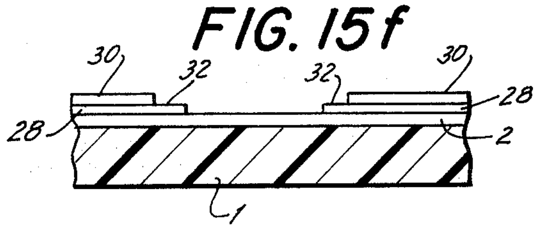


FIG. 15g

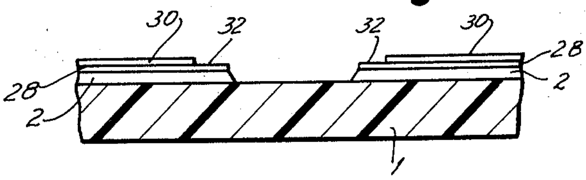


FIG. 15h

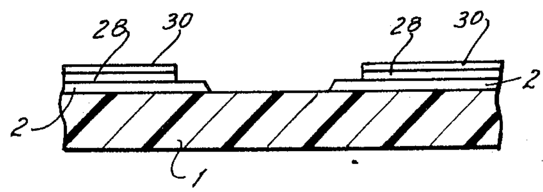


FIG. 15i

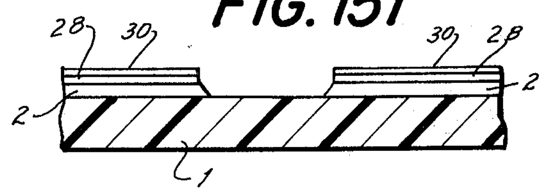


FIG. 15j

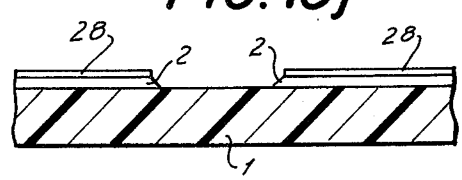
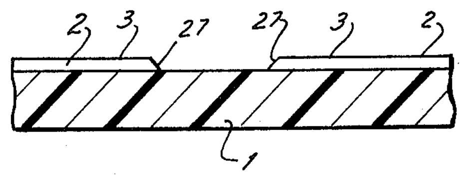


FIG. 15k



PRINTED CIRCUIT RESISTOR

This application is a division of our application Ser. No. 831,042, filed June 6, 1969, now abandoned entitled "High Frequency Circuit, Components Therefor and Method of Fabricating Same" and assigned to the assignee of this application.

The present invention relates to printed circuits having resistive and capacitive components and a method for fabricating same.

Printed circuit boards are widely used in electrical and electronic circuits to facilitate fabrication and reduce the space requirements of the system. Electrical components, such as resistors, capacitors and inductors, are commonly mounted on the board by passing connecting leads extending from these components through appropriately formed openings in the board. The board is then dipped into a solder bath to solder these connecting leads to the appropriate areas on the board. The mounting of these components in this manner has heretofore been a troublesome and hence expensive operation as it requires numerous fabricating operations. The complexity and cost of these operations have made the fabrication of printed circuit boards less suitable for mass production techniques than would be most desirable.

Moreover, as each component is mounted by means of its leads, that mounting is fragile and sensitive to vibration and shock so that great caution is required in the handling of the board and the electrical equipment in which the board is utilized. It is also difficult and often impossible in boards fabricated in this manner to prevent the relative movement of the components with respect to one another and thus variation in the electrical properties of these components is practically unavoidable. This prior art component assembly and mounting techniques create the possibility of wiring errors when the components are mounted on the boards by relatively unskilled or semi-skilled personnel as is common. Another source of possible difficulty in the fabrication of printed circuit boards in the known manner is that the connecting leads in the circuit create intolerably high values of capacitance. This is particularly troublesome at high frequencies and for this reason it has been difficult in the past to fabricate printed circuits useful in high frequency electronic circuits, such as those used in the tuning stage of FM, AM, and TV receivers.

It is the object of the present invention to provide a method for forming components such as resistors or capacitors on a printed board or the like in which the use of connecting leads is eliminated.

It is another object of this invention to provide an improved method for fabricating a resistor on a printed circuit.

It is yet another object of this invention to provide a method for etching metallic foil to form electrodes on a printed circuit board, or the like.

It is a further object of the present invention to provide a variable capacitor which can be readily fabricated on a printed circuit board or the like.

It is a general object of this invention to provide a printed circuit board capable of effectively operating at high frequencies such as in a tuning stage of a communications receiver, and a method for fabricating same.

To these ends the present invention provides a method for fabricating a high frequency electrical circuit on a printed circuit board or the like, in which the electrical components in that circuit such as resistors and capacitors are formed on the board without the use of connecting leads. A resistor is formed on the board by painting resistive paste between two spaced and insulated conducting areas or electrodes formed on the board, and a capacitor of the wireless type is formed by inserting a capacitor into an opening formed in the board between two similarly spaced and insulated conducting areas. The electrodes of the capacitor are then connected to these conducting areas such as by painting solder between the electrodes and the conducting areas. An intersecting conducting pattern may be implemented between two spaced conducting areas on the board separated by other conducting areas by forming a conducting wire connected to the two spaced conducting areas over an insulating layer provided atop these other conducting areas.

The present invention further provides a method for fabricating a variable capacitor on a printed circuit board by initially forming a stator electrode on the board and rotatably mounting a rotor electrode for rotation with respect to that stator electrode. A dielectric film is formed on one of said electrodes. By rotating the rotor electrode to a predetermined position with respect to the stator electrode a specified value of capacitance is established between these electrodes.

The present invention also provides a method for fabricating a printed resistor in which the resistive path between a pair of electrodes or conducting areas is made in a positive manner which also reduces the number of steps required for the fabrication of the resistor. The resistor is free from many of the difficulties commonly found in such resistors in that the peeling off of the resistor while it is being soldered to the conducting areas on the board, the variation of its value of resistance, and the unreliability of the connection between the resistive material and the conducting areas caused by deflection of the board are all substantially eliminated. Moreover, by the practice of this method, the thickness of the resistive material may be made uniform and the electrical connection between the resistive material and its associated electrodes more effectively maintained by forming these electrodes by an etching technique which creates a sloping cross-section at the ends of these electrodes.

In one method of forming the printed resistors as herein disclosed, insulating material is coated on the board between a pair of electrodes formed on the board by the aforesaid etching technique. In another resistor fabrication technique herein disclosed, the upper surface of a layer of insulating material lies in a substantially common plane with the upper surfaces of the electrodes, and the resistive layer is formed on that plane. In the resistor formed by these techniques the resistive material has a substantially uniform thickness and makes secure electrical contact with the electrodes.

To the accomplishment of the above and to such other objects as may hereinafter appear, the present invention relates to a printed circuit having resistive and capacitative components and a method for fabricating same, as defined in the appended claims and as described in the specification taken together with the accompanying drawings in which:

FIGS. 1 and 2 are respectively plan views of a typical printed circuit board before and after performing the fabrication of electrical components thereon by the method of the present invention to form an electrical circuit for use in a high frequency apparatus;

FIGS. 3 and 4 are respectively plan views of a second typical printed circuit board shown before and after performing the component fabrication method of the present invention;

FIG. 5 is a cross-sectional view illustrating the mounting of a capacitor on the board of FIGS. 1 or 3, taken along the line 5—5 of FIGS. 2 and 4;

FIG. 6 is a plan view of an inductor fabricated on the printed circuit board of FIGS. 1–4;

FIG. 7 is a perspective view of a printed resistor on the printed circuit board of FIGS. 2 and 4;

FIG. 8 is a cross-sectional view taken approximately along the line 8—8 of FIGS. 2 and 4;

FIG. 9 is a cross-sectional view taken approximately along the line 9—9 of FIG. 4;

FIG. 10 is a cross-sectional view taken along the line 10—10 of FIG. 4 illustrating a variable trimmer capacitor fabricated on the printed circuit board of FIG. 4;

FIGS. 11–14 are cross-sectional views illustrating different types of printed resistors which may be fabricated for use on the printed circuit boards of FIGS. 2 and 4;

FIGS. 15*a–k* illustrate the various steps used in the fabrication of the printed resistor of FIG. 14; and

FIGS. 16*a–16b* are respectively portions, on an enlarged scale, of FIGS. 15*g* and 15*f*.

The present invention provides an improved method for fabricating a printed circuit of the type having electrical components such as resistors, and fixed and variable capacitors. As the components are fabricated on the board without the use of connecting leads, the board is admirably suited for use in a high-frequency circuit such as in the tuner section of an AM, FM or television receiver.

Referring to FIGS. 1 and 3, the circuit is formed on a board made of a suitable insulating material, that board being generally designated **1**. A conducting area **2** having a predetermined configuration and area, and electrodes **3** and **5** are initially formed on board **1** by any of the known methods, such as the use of a photo resist and etching technique.

A coiled inductor **6** is also formed on board **1** and has one end connected to area **2** and to selected ones of electrodes **3** and **5**. Inductor **6**, shown in detail in FIG. 6, comprises a number of conducting loops or spirals which define an inductance.

Rectangular openings **9** are formed through board **1**, and circular openings **10** adapted for receiving external input and output circuitry (not shown) are formed through terminal conductors **2***a* and through board **1**.

The prepared board of FIG. 3 is substantially the same as that of FIG. 1 with the exception that a pair of additional semi-circular conducting areas which define stator electrodes **18** are formed on board **1** to be subsequently used in the fabrication of variable or trimmer capacitors as will be described below. The board **1**, as shown in either FIG. 1 or FIG. 3, is prepared to have the required electrical components (e.g., resistors and capacitors) formed thereon to complete the desired high frequency electrical circuit.

As shown best in FIG. 7 a resistor is formed or printed on the printed circuits of FIGS. 2 and 4 by applying or painting a resistive paste **7** between a pair of spaced and thus insulated electrodes or foils **3**, which have previously been formed on the board **1**. The resistive paste makes contact with each of the adjacent electrodes and defines a resistor therebetween. As shown in FIG. **8** a coating of solder resist **8** is then painted over the electrodes **3,3** and the resistive paste **7**, and as shown in FIG. **8**, that solder may be painted over the inductance coil **6**.

The method of fabricating the capacitance on the printed circuit boards of FIGS. 2 and 4 is shown in FIG. 5 in which a wireless circular capacitor, generally designated **4**, having a dielectric positioned between a pair of electrodes **14** is inserted into one of the openings **9** previously formed through board **1** between a pair of electrodes **5,5**. A quantity of solder **15** is then used to electrically connect and physically secure the electrodes **14** to the printed electrodes **5,5** respectively. A capacitance is thus formed between the adjacent electrodes **5,5** without the use of a connecting wire.

It may be desired in the fabrication of the printed circuit to electrically connect two spaced conducting areas which have other conducting areas formed therebetween. This is accomplished in the printed circuit of the present invention without the use of conducting wires by first forming, as shown in FIG. 9, an insulating layer **12** of varnish or the like over the region between the two conducting areas of interest. Insulating layer **12** does not contact the to-be-connected conducting areas but does overlie each of the conducting areas therebetween. That varnish is then cured and hardened by heating, after which a conduction path **13** is formed over the insulating layer **12** by means such as a silver paste printed thereon between the two conducting areas that are to be connected. As shown in FIGS. 2 and 4, crossing or traversing connections of this type are made between the inner loops of inductors **6** and remote conducting points of conducting areas **2**, those connections being made over the other loops of inductances **6** but insulated therefrom by means of the insulating layer **12**. Other such crossing connections are formed between an outer loop of one of inductors **6** and one electrode and between one electrode **5** and one of the terminal connectors **2***a*.

In another aspect of this invention a variable or trimmer capacitor may be formed on a printed circuit as shown in FIGS. 3 and 4, once again without the use of conducting wires. The board is initially prepared as shown in FIG. 3 by forming two spaced semi-circular conducting regions by means of etching or the like, which define a stator electrode **18** of the trimmer capacitor. A semi-circular rotor electrode plate **17** having a dielectric film **16** formed thereon is rotatably mounted on board **1** by means of a pin **19** extending through the board **1** and having rotor electrode plate **17** secured at its upper end. The lower end of pin **19** has a slotted portion and a spring **20** is provided between the slotted portion of spring **19** and the board **1** to secure pin **19** and thus the stator electrode **17** to the board. A capacitance exists between rotor electrode plate **17** and stator electrode **18** and the value of that capacitance may be varied simply by rotating pin **19** as by inserting and rotating a screw driver tip in the slotted end of pin **19**, thereby to vary the relative position of rotor plate **17** with respect to stator electrode **18** and hence the effective capacitance of that variable capacitor.

FIGS. **11–14** illustrate other possible methods of fabricating a resistor on a printed circuit board of the type shown in FIGS. 1–4. In FIG. **11** a resistor is formed between the spaced electrodes **3,3** which are initially formed on the surface of board **1** as described above. An oxidizing protecting film **21** such as a silver film is formed over the surface of electrodes **3,3** as by electroplating. Resistive paste **7** is then printed or painted between the thus coated electrodes **3,3** and a protecting film **22**, formed from a material such as an epoxy resin, is then coated over the surface of resistive paste **7**.

A resistor is formed on the oxidizing protecting film **21** on the electrodes **3,3** and a positive electrical connection is thus realized between a resistive paste **7** and the electrodes **3,3**. The provision of the protecting film **21** over the electrodes **3,3** prior to the application of the resistive paste prevents oxidation of the electrode surfaces, for example, when the board is subjected to a drying operation after the resistive paste is applied thereto. As a result the soldering of the electrical components on the board is readily performed since no oxidation layer is formed on the protected electrode areas. The value of the resistor so formed is substantially constant and the surface of that resistor is not deleteriously affected in the subsequent fabrication steps performed on the printed circuit.

The resistor fabricated according to the method illustrated in FIG. **12**, is similar to that in FIG. **11** except that a pair of conducting strips **24** and **25** made of conductive material such as silver paint are formed on the ends of each of the electrodes **3,3** and extend inwardly therefrom toward the other of the electrodes. Resistive paste **7** is then applied between the conducting strips **24** and **25** and a protecting film **22** is applied over resistive paste **7**, strips **24** and **25** and the ends of electrodes **24** and **25**. A resistor formed on a printed circuit board in this manner is not affected by the heating of the board, such as when components are being soldered to the board. The heat generated during soldering does not act on the resistive paste **7** but rather is conducted away from resistive paste **7** by the conducting strips **24** and **25**. This prevents the peeling off of the resistive paste **7** from the electrodes and thus provides a resistor having a substantially constant value. The resistive paste **7** is securely retained on the conducting strips **24** and **25** because the binding material included in the resistive paste **7** and the conducting strips makes for a secure retention between these components and thus prevents separation between the resistive material and the conducting strips.

Moreover, the resistive value of the resistor fabricated as shown in FIG. **12** is not varied when the board **1** is deflected or warped, such as when it is heated; the electrodes **3,3** and the conducting strips **24** and **25** are both good electrical conductors so that a partial separation between electrodes **3,3** and the conducting strips **24** and **25**, which may be caused by a warping of the board, does not materially affect the conduction between paste **7**, strips **24** and **25** and the electrodes **3,3**. A common defect of the prior art printed circuit boards, i.e., the change of resistance in a printed resistor caused by the deflection of the board, is thus substantially eliminated.

Referring back to the resistor shown in FIG. **11**, it will be seen that each of the end sections of electrodes **3,3** as formed by conventional fabrication techniques, is substantially vertical to the board **1**. As the resistive paste **7** used to form the printed resistor is relatively viscous, it flows down from these vertical sections before the resistive paste has had the opportunity to dry and harden. The layer of resistive paste formed at the end of electrodes **3,3** is thus somewhat thinner than the portion thereof between the electrodes so that the electrical connection between electrodes **3,3** and the resistive material **7** is often not completely secure. While in many applications the resistor of FIG. **11** is suitable for use, there are some applications in which the connection between the resistive paste and the electrodes must be made more secure. A resistor formed on the printed circuit board according to the fabricating technique illustrated in either FIGS. **13** or **14** achieves an optimum electrical connection between the resistive material and the electrodes in that the thickness of the resistive paste remains substantially uniform across its entire length between and over the electrodes.

Referring to FIG. **13**, an insulating layer **26** initially formed on board **1** extends between the electrodes **3,3** and is of substantially the same thickness as electrodes **3,3**. Layer **26** thus has its upper surface lying in a substantially common plane with the upper surfaces of the electrodes. Thereafter the resistive paste **7** is printed on that common plane and thus overlies insulating layer **26** and the ends of electrodes **3,3**. As before, a protecting film **22** is formed over the resistive paste **7**. By means of this fabrication technique the resistive paste is electrically connected to the electrodes and, as the vertical spacing between the upper surfaces of the electrodes **3,3** and the board **1** is eliminated by the provision of the insulating layer **26**, there is no reduction of the thickness of resistive paste **7** near the ends of the electrodes thereby achieving the desired uniform thickness of the resistive paste.

In FIG. **14** the resistive paste **7** is formed to substantially uniform thickness by initially forming the end sections **27,27** of the electrodes **3,3** so that they incline down towards the board, as opposed to the substantial vertical drop of the electrodes as in the embodiments of FIGS. **11–13**. The inclined electrode end sections **27** are formed by a novel etching technique which is described below with reference to FIGS. **15** and **16**. Since the end sections are not vertical but rather are inclined, the resistive material, while still in its viscous state, does not fall down from these end sections. This produces a resistor having uniform thickness as is desired for optimum electrical contact.

The etching technique used to form the electrodes **3,3** having the inclined end sections **27** is illustrated in FIGS. **15*a*–15*k***. An alkali resistant photosensitive layer **28** (e.g., a negative-positive type photosensitive layer) is first deposited over selected portions of the conducting area **2** formed on board **1** (FIG. **15*a***). A resist or negative film **29** is then formed over a selected portion of layer **28** and board **1** is then exposed to a source of ultraviolet rays as indicated by the arrows in FIG. **15*b***. The board is then treated with an organic solvent such as chlorobenzene which removes negative film **29** and that portion of layer **28** over which the film **29** was formed. This process produces a first electrode pattern shown in FIG. **15*c*** in which spaced portions of photosensitive layer **28** are formed over the conducting area **2**.

An acid proof photosensitive layer **30** (positive-positive type photosensitive layer) is then deposited over the entire surface of the patterned electrode as shown in FIG. **15*d***. A resist or negative film **31** is then placed over the selected portions of layer **30** and the board is once again subjected to ultraviolet radiation as shown in FIG. **15***e*. Film **31** prevents exposure to these rays of those areas of layer **30** underlying the film **31.** The exposed portion of photosensitive layer **30,** i.e., that portion over which the negative film **31** was not formed, is removed along with film **31** by a solvent such as a 5 percent alkali aqueous solution to reproduce the second electrode pattern shown in FIG. **15***f*. In that pattern an intermediate portion of conducting area **2** is exposed as are portions **32** of the photosensitive layer **28.** The exposed portion of conducting area **2** is then treated as by an aqueous solution of iron peroxide to carry out a first etching as shown in FIG. **15***g* which removes most of the exposed portion of the conducting area. The exposed portions **32** of the photosensitive layer **28** are then removed by a suitable material such as trichloroethylene to expose parts of the conducting area **2** as shown in FIG. **15***h*. Those exposed parts of conducting area **2** are again subjected to an etching process, such as by aqueous solution of iron perchloride, to form the electrode area shown in FIG. **15***i*, after which the photosensitive layer **30** is removed, as by a 20 percent alkali aqueous solution to produce the structure shown in FIG. **15***j*. To complete the fabrication of the electrodes having the desired inclined end sections **27,** the remaining photosensitive layer **28** is removed with a suitable material, such as tricholorethylene, to produce the final shape of the electrodes shown in FIG. **15***k*.

The initial etching process of FIG. **15***g* produces a substantially perpendicular end section of the electrode area as shown best in FIG. **16***a*. The second etching process removes that portion of the electrode indicated at **33** in FIG. **16***a*, defined by the broken line in that figure, to form a gentle inclined slope to the surface of the board as indicated at **27** in FIG. **16***b*. The resulting electrode formed by this double etching process has the desired inclined end sections **27** which, as described above, enables the printing of a resistor having a substantial uniform thickness between the electrodes.

The printed circuit of this invention thus provides an improved circuit which has particular utility in circuits operating at high frequency signals, since there are no connecting wires between the electrical components on the circuit. The components, such as resistors, inductors and fixed and variable capacitors are all fabricated in a manner which does not require complex initial preparatory processes such as the cutting and bending of the conducting leads and the penetration of these leads through mounting holes formed in the board. As compared to the steps required to fabricate printed circuit boards according to the prior art techniques the printed circuit of the present invention is far better suited for mass production. Moreover, the cost of fabricating the board of the present invention is lower than that of the known printed circuit board fabrication techniques. Each of the components is either printed on the board or, as in the case of a capacitor, inserted through an opening in the board. The components are mounted flat on the board so that they are not significantly affected by vibration and shock and special protection against shock and vibration is thus not required in the handling of the completed circuit. As the inductors, resistors and capacitors, as well as the crossing connectors are all made without the use of conducting leads, inductive potential drop and relative movement between the components is eliminated and thus the stray capacitance of these components remains substantially constant. As a result improved reliability and stability of circuit operation is obtained.

A resistor having a desired value of resistance is readily and quickly fabricated by a single process by a proper selection of the area of the resistive paste material formed between the spaced electrodes. As a solder resist is painted over the surfaces of the printed resistors and inductors, these components do not absorb moisture and dust so that the leakage from the conducting elements and the decrease of the Q of the inductor due to oxidation, rust, or the like, is also prevented. As a result reliable performance of the circuit is ensured over long periods of use and exposure to dust and moisture. The resistors may be printed on the board by one of several disclosed fabrication techniques and each resistor so formed is reliably secured to the board and to the electrodes with which it is formed. The value of resistance of the resistor remains substantially constant over long periods of use even if the board is flexed, warped or heated as during fabrication.

While several embodiments of this invention have been herein specifically disclosed, it will be apparent that many variations may be made thereto without departing from the spirit and scope of the invention.

We claim:

1. A resistor of the type formed on a printed circuit board or the like, said resistor comprising a pair of electrodes formed on said board, a quantity of resistive material interposed between and spaced from said electrodes, means interposed between said resistive material and said electrodes and effective to operatively connect said resistive material to each of said pair of electrodes and having one exposed surface, said means being formed of heat-conductive material, and an oxidation protecting film formed over said exposed surface and said resistive material.

2. The resistor of claim **1,** in which said protecting film is an epoxy resin.

3. The resistor of claim **2,** in which said resistive material connecting means comprises a strip of conducting paint extending from each of said electrodes to said resistive material.

4. In a printed resistor of the type formed on a printed circuit board in which a pair of electrodes are formed on one surface of said board and a resistive layer is formed on said board and operatively connected to each of the electrodes, the improvement which comprises; said electrodes having end sections which incline downward towards said board so that the thickness of said resistive layer is substantially uniform throughout.

5. A printed resistor of the type formed on one surface of a printed circuit board, said resistor comprising a pair of electrodes formed on and extending up from said board surface, and insulating layer on said board and extending between said electrodes, the upper surface of said insulator layer lying in a substantially common plane with the upper surfaces of said electrodes, and a resistive layer of substantially uniform thickness formed on said plane over said insulating layer and extending between said electrodes.

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