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Aug. 28, 1945. W. M. ROBINSON 2,383,890

ELECTRICAL FILTER

Filed Sept. 18, 1942

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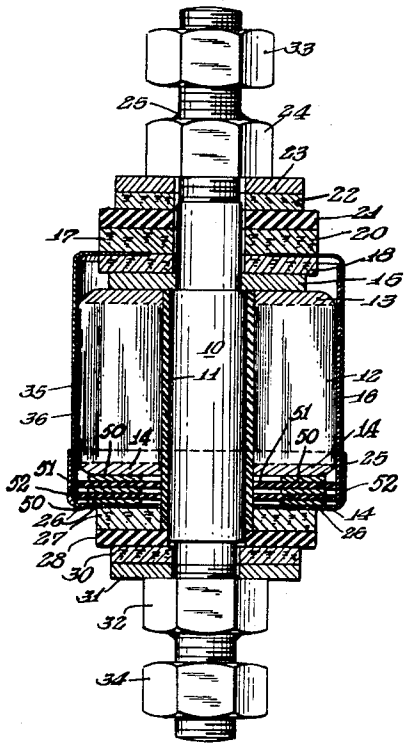


FIG. 1.

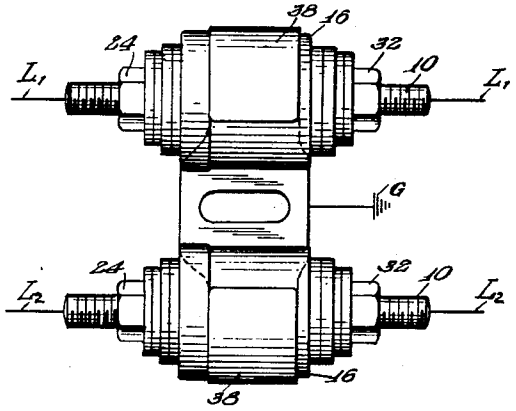


FIG. 3.

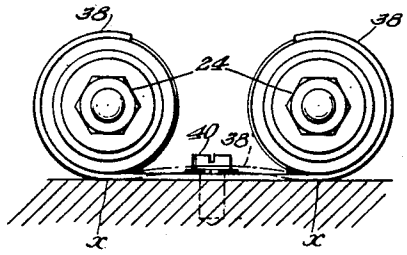


FIG. 4.

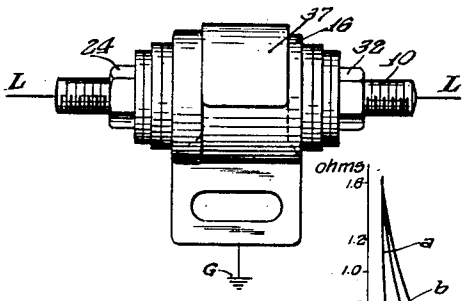


FIG. 2.

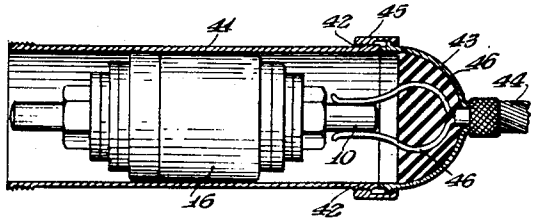


FIG. 5.

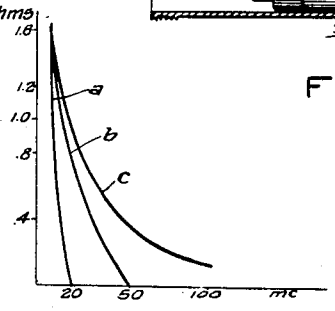


FIG. 6.

INVENTOR.
William M. Robinson
BY
ATTORNEY

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Patented Aug. 28, 1945 2,383,890

UNITED STATES PATENT OFFICE

2,383,890

ELECTRICAL FILTER

William M. Robinson, Plainfield, N. J., assignor to Cornell-Dubilier Electric Corporation, South Plainfield, N. J., a corporation of Delaware

Application September 18, 1942, Serial No. 458,892

4 Claims. (Cl. 178—44)

The present invention relates to electrical filters, in particular to anti-interference or noise filters of the type used in radio and other communication circuits for reducing or eliminating noise and other undesirable interference.

In the case of communication circuits such as radio receivers designed for high frequencies such as in the short and ultra-short wave bands and beyond and operated in the neighborhood of strong noise sources such as on airplanes, automobiles, trucks, etc., difficulties and very serious problems arise in practice. In the latter cases, expensive and cumbersome means were required in the past to properly shield all the devices capable of generating or radiating interfering or noise frequencies.

Many of the aforementioned defects and difficulties encountered with noise filters of known type, especially when used in high and ultra-high frequency circuits may be traced to the presence of an appreciable inherent series inductance caused by the leads and connections from the capacitor section to its terminals as well as to poor contacts, which defects could not be reduced below a certain minimum where large and rugged condensers were necessary such as in automobiles, trucks and airplanes.

On the other hand, it is advantageous in many cases to provide a small inductance in series with the capacitor to obtain a filter which is most effective over a desired range of high frequencies to suit existing special conditions and requirements; in other words, it may be desirable to cause the inductance and capacity to resonate at series resonance so as to provide a minimum impedance for a desired frequency or frequency band, such filters being known as tuned noise filters.

In the case of tuned noise filters, the series inductance may be either a separate unit or structurally embodied in the capacitor by the provision of a few turns of insulated metal strip or wire connected between one end of the capacitor section and the adjacent terminal (casing or insulated terminal).

According to a known arrangement of tuned filters, it has been proposed to utilize the inherent series inductance due to the connecting leads from the section to the terminals in capacitors of heretofore known construction to obtain series resonance at a desired frequency or over a limited frequency band. Since, however, the series inductance is different in different types of capacitors and may even vary in capacitors of the same type, it is necessary to choose a capacity of proper value in order to obtain series resonance at a desired frequency. Since, in turn, the capacity determines the effectiveness of the filter action and, in particular, the range or band of the frequencies being suppressed or by-passed, at best, only a compromise solution may be obtained by using this method which provides little flexibility in adapting it and complying with the requirements of each particular case met in practice.

Accordingly, an object of the invention is the provision of a tuned noise or anti-interference filter wherein the inherent series inductance of the capacitor element of the filter has been reduced to a practically negligible value even for the highest frequencies, in the ultra-high frequency range and beyond, in such a manner that by the addition of an easily variable inductive element structurally combined with the capacitor element, the filter may be caused to resonate effectively at a desired frequency or limited frequency range to suit existing conditions and requirements.

Thus using a filter of the type according to the invention wherein the inherent series inductance of the capacitor has been substantially eliminated or reduced to a negligible value, series resonance for a desired frequency may be obtained by choosing the proper inductance in the form of additional turns of metal wire or strip embodied in the capacitor structure, said inductance having, furthermore, such a relation to the capacitance as to obtain a desired effective frequency for the filter.

In the majority of cases, the filters are used in connection with generators supplying heavy currents. If the latter assumed magnitudes of the order of from 20 to 100 amperes or more, the conductors and terminals present both an electrical and mechanical problem. To overcome some of the difficulties encountered, large and cumbersome devices were required, which in turn increased both costs and weight. The latter is especially serious in case of airplanes and other applications where low weight and bulk are of importance. When filters of the above type were used in such installations, they had to be of substantial size and bulk to withstand rough handling during installation and replacement as well as substantial vibrations and mechanical shocks during operation. Again, for this reason, the filters assumed substantial proportions as the capacitor and additional units usually mounted in a thin metal casing had to be provided with

heavy terminal structures. This in turn made it necessary to use a heavy container to avoid damage to the apparatus when handled by the ordinary workmen. For all these reasons, heavy and bulky arrangements had to be used to hold the terminals in place and prevent movements and loosening and other obvious drawbacks and defects well known to those skilled in the art.

Accordingly, it is a further object of the invention to provide a tuned electrical filter especially, though not limitatively, suitable as a noise filter or anti-interference device which is both rugged and compact and has a minimum of size and bulk to enable its use in all cases where rough handling and exposure to vibration and heavy mechanical shocks are to be expected, such as in automobiles, trucks, airplanes, etc.

With the aforementioned and other objects in view as will appear hereinafter, the invention involves basically the provision of a substantially heavy body member or support advantageously taking the form of a metal rod or stud, which simultaneously serves as a conductor of heavy electric current flowing through the line to which the filter is to be connected; said member also serving as a mounting support for the capacitor section which is advantageously of the non-inductive type, spirally wound around said stud and mounted in a thin metal casing snugly fitting the section and insulatingly supported by said stud. In this manner, the current carrying stud which may have a suitably large diameter and forms a part of the electrical circuit to which the filter is connected, passes directly through the center of the filter casing so as to present a minimum of electric impedance to the current flowing in said circuit. One side of the capacitor section is electrically connected to said stud, while the other side is connected to said casing, the connections being effected by direct soldering or clamping to avoid any connecting wires and resultant series inductance as in the case of the prior art filters heretofore known and used. If the casing is grounded, there is obtained in this manner a filter capacitor whose series inductance is reduced to a minimum, whereby the inclusion of one or more coils of wire or the like will result in any desired limited frequency response in the manner pointed out, while obtaining at the same time a compact unit of small size and weight capable of use with power or supply lines designed to carry heavy currents and possessing extreme ruggedness so as to withstand rough handling as well as heavy vibration and shocks, both during installation and in use.

Further objects and advantages of the invention will become apparent from the following detailed description taken with reference to the accompanying drawing, forming part of this specification and wherein:

Figure 1 is a vertical cross-sectional view of a capacitor construction embodying the principles of the invention; Figure 2 is a top view on a reduced scale of the capacitor shown in Figure 1 and provided with a mounting lug or bracket for securing the same upon a panel or platform; Figure 3 shows a pair of capacitors with a common mounting bracket suitable for connection to a pair of power lines; Figure 4 is a side view of Figure 3; Figure 5 is a top view, partly in cross-section, of a capacitor according to the invention provided with means for connecting the same to a shielded cable; and Figure 6 is a theoretical diagram explanatory of the function of the invention.

Like reference characters refer to like parts in the different views of the drawing.

Referring more particularly to Figure 1, the capacitor structure shown and specially suited as a filter capacitor comprises a central support or stud **10**, which may serve as a conductor for the current flowing through the line or circuit to which the capacitor is to be connected and which may be designed with a sufficiently large cross-section to offer low impedance and enable the use of the filter in connection with power or supply circuits carrying heavy electric currents. An insulating tube **11** of cardboard or the like and forced over or otherwise secured to the central portion of the stud **10** serves as a core or mandrel for a rolled type capacitor section **12**, spirally wound thereon in a manner well understood by those skilled in the art. The capacitor section may comprise in a known manner a pair of metal strips, such as strips of tinfoil or aluminum separated by one or more layers of paper or equivalent insulating material, with the longitudinal edge of one strip projecting from one side and with the longitudinal edge of the other strip projecting from the other side of the completed roll. In the exemplification shown, the projecting upper foil edges are united by a layer of solder or in any other suitable manner as indicated at **13** to form one terminal of a so-called non-inductively wound capacitor in a manner well known in the art. Similarly, the lower projecting edges of the foil strip of opposite polarity are united as shown at **14** to provide a cooperating terminal for the capacitor.

The projecting foil edges or terminal **13** are electrically connected to stud **10** by the provision of a metal washer or flange **15**, secured to or integral with the stud and in electrical contact with the foil edges **13** by mechanical pressure or preferably by soldering in such a manner as to form a rigid and compact unit, comprising the stud **10**, the section **12** and the washer **15**. The capacitor section **12** is surrounded by a thin cylindrical metal casing **16**, snugly fitting over the roll and having an upper inturned annular flange **17** interposed between a pair of resilient washers **18** and **20** of cork or the like overlying the washer **15**. Washer **20** is in turn followed by a further relatively rigid insulating washer **21** such as of Bakelite or the like. A further resilient washer **22** and metal washer **23** are placed upon washer **21** and the entire assembly pressed into firm engagement with the flange or washer **15** by means of a clamping nut **24** engaging the upper threaded end of stud **10** and secured to or locked against the stud by a soldering joint as shown at **25** or in any other suitable manner.

This construction has the advantage of relieving the section **12** so as to allow of sufficient clamping pressure to be applied to washers **18**, **20—23** for effecting a hermetic seal for the casing **16**, **17** to prevent the penetration of moisture or other objectionable agents into the interior of the capacitor.

The lower projecting foil edges **14** of the section **12** forming the terminal of opposite polarity of the capacitor are electrically connected to the casing **16** through a small inductance coil **50** by the provision of a metal cap having a cylindrical portion **25** fitting over and soldered or otherwise connected to the lower portion of casing **16** and having an inturned flange **26** soldered to or otherwise electrically connected to one end of coil **50** whose other end is in contact with the foil edges **14**. In order to completely seal the lower side of

the capacitor against moisture penetration, there is further provided a resilient washer **27** engaging the flange **26**, said washer being in turn followed by a relatively rigid insulating washer **28**, a further resilient washer **30** and a metal washer **31**. The superposed washers are compressed by means of a clamping nut **32** engaging the lower threaded end of stud **10** and locked in the compressed position by a solder joint or the like similar to joint **25** for the nut **24** in such a manner as to hermetically seal the complete capacitor section.

There is thus provided by the construction afore-described a highly rugged and compact as well as completely sealed capacitor mounted in a thin metal casing and provided with heavy metal terminals and which is capable of withstanding rough handling as well as mechanical vibration and shocks and is especially adapted for use in electrical circuits carrying substantial currents.

The inductance element **50** advantageously takes the form of a metal strip wound edgewise into a spiral having, in the example shown, three turns separated by insulating spacers in the form of rings **51** and **52** consisting of cardboard or the like and being suitably slit for passing the strip **50**. The innermost turn of the spiral is directly soldered to the projecting foil edges **14** of the capacitor section **12** and the outer spiral turn is soldered to the flange **26** of cap **25**, the remaining elements and connections being substantially similar to the upper end construction and well understood from the above. This leaves a single effective spiral turn to provide a desired inductance and series resonance frequency for the capacitor. If required, the number of spiral turns may be increased or the diameter of the spiral varied within limits to provide a desired series inductance.

In order to connect the filter capacitor in an electrical circuit, there are provided a pair of further clamping units **33** and **34** engaging the free threaded ends of the stud **10**. If the stud is connected in series with the circuit to be protected and the casing **16** grounded, the capacitor will act as a filter for undesired interfering such as noise frequencies in the manner described hereinabove.

The capacitor may be vacuum impregnated with oil, wax, or an equivalent substance in the usual manner for which purpose there is provided a filling hole **35** in the outer casing **16** which, after completion of the impregnation, may be closed by filling it with solder thereby eliminating any moisture penetration which may affect the electrical characteristics of the capacitor. Preferably, a single layer wrapper **36** of paper or the like is placed around the section **12**, in which case the adjoining edges of said wrapper are preferably in line with the hole **35** to facilitate the impregnating process.

Another feature of the capacitor construction described consists in the direct connection of the foil edges or terminals of the section to the stud **10** on the one hand and the casing **16** on the other hand in such a manner as to provide the shortest possible section-to-terminal current path and resulting in a minimum or practically complete elimination of the inherent series inductance of the capacitor. In the connection of the section to the stud and housing, a large cross-section of the projected foils or edge surface insures a direct contact to substantially all the foils, resulting in substantial symmetrical current paths of uniform impedance to the various points of the capacitor section and in turn reducing the series inductance.

If it is desired to mount the capacitor filter upon a panel or platform, suitable mounting means may be provided, such in the form of a mounting lug or bracket **37** soldered or otherwise secured to the casing **16**, as shown in Figure 2. In the latter, the bracket **37** is shown to be grounded at G and the stud connected in series with line L to be protected. If both lines of a power or supply circuit are to be protected in the manner described above, two capacitor units are advantageously provided with a single grounded mounting bracket as shown in Figure 3 and 4, wherein one line L_1 is passing through stud of one unit and the other line L_2 passes through the stud of the other unit, both units being substantially identical.

In the arrangement according to Figures 2 to 4, the mounting lug **37** or **38** is advantageously kept as short as possible to prevent any appreciable conducting or current path from the capacitor to ground and consequent increase of the series inductance. Alternatively, means may be provided to cause the current to directly enter the panel or platform upon which the unit is mounted. An arrangement of this type is shown in Figure 4 wherein the common bridging member **38'** of the brackets **38** of both capacitor units is slightly curved upwardly as indicated in dotted lines and possesses sufficient resiliency so that upon screwing or clamping it against the platform such as by means of screw **40**, points of increased pressure will be established directly underneath the units **38** as indicated at x in the drawing. Accordingly therefore, the electric current will directly pass from the casing of the capacitors to ground through the shortest possible path, thereby maintaining the series inductance at a minimum.

Another mode of construction, especially useful where complete shielding of the line is desired, is shown in Figure 5. In the latter, provision is made to connect the capacitor filter to the connecting plug of a shielded cable. For this purpose the unit is mounted in a cylindrical metal tube **41**, rigidly secured such as by a press-fit, soldering or the like to the outside of the casing **16**. Tube **41** extends sufficiently in both directions and has its ends provided with outer threaded portions **42** adapted to cooperate with a threaded locking ring **45**, slidably mounted upon the plug **43** of a flexible cable or any other electrical conductor **44**. In this manner the plug **43** may be tightly screwed against the tube **41** to electrically connect the casing **16** with the cable shield which is usually at ground potential. In order to establish electrical contact between stud **10** and the inner cable conductor, the plug **43** is provided with suitable flexible connectors **46** insulatingly mounted inside the plug and adapted to engage the projecting end of the stud when the plug is applied to and tightened against the capacitor unit.

Figure 6 represents a graph illustrating the effects of the series inductance of a filter capacitor as an anti-interference device. The reactance in ohms of a capacitor of .01 mfd. is plotted as a function of the frequency. Curve a corresponds to a series inductance of about 6 millimicrohenries, curve b corresponds to a series inductance of about 1 millimicrohenry, while curve c represents the case where the series inductance is zero. As is seen in the latter case, the capacitor provides a path of low impedance up to fre-

quencies in the highest ranges at present being used and beyond. If an appreciable series inductance exists, series resonance will occur at definite frequencies (at 20 and 50 megacycles, respectively, in the example shown).

From the above it is seen that the use of a substantially inductance-free capacitor according to the invention makes it possible to properly choose both the capacity and series inductance so as to result in most cases, especially within the higher frequency ranges, in an appreciable reduction of the capacity or size of the filter. Thus, for instance, where according to the previous cumbersome methods a capacity of .1 mfd. was required, the same effect was found obtainable when using a filter according to the invention having a capacity of .01 mfd., i. e. $\frac{1}{10}$ of the previous value.

It will be evident from the foregoing that the invention is not limited to the specific construction and details described and shown herein for illustration, but that the basic principles disclosed will be susceptible, such as by the substitution of equivalent elements, of numerous variations and modifications coming within the broader scope and spirit of the invention as defined in the appended claims. The specification and drawing are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. An electrical capacitor construction comprising a relatively heavy metal stud, a non-inductively wound capacitor section comprising inter-leaved metallic foil and insulating strips and being concentrically mounted upon the central portion of said stud, a metal washer soldered to the projecting foil edges at one side of said section and electrically and mechanically connected to said stud, a relatively thin cylindrical metal casing snugly fitting the outside of said section and having an inturned annular flange at one end thereof, resilient insulating washers encircling said stud at opposite sides of said flange, means including a nut engaging a threaded portion of said stud for compressing said resilient washers against said metal washer to provide an insulating hermetic seal between said stud and casing, a metal cap having a cylindrical portion hermetically secured to the other end of said casing and an inturned annular flange, a metal strip wound edgewise into a spiral interposed between said section and said last mentioned flange, insulating spacers inserted between the turns of said spiral, the innermost turn of said spiral being in electric contact connection with the projecting foil edges at the opposite side of said section and the outer turn of said spiral being in electric contact connection with said last mentioned flange, further resilient washer means encircling said stud and engaging said last mentioned flange, and means for compressing said last washer means into hermetic engagement with said flange and said stud.

2. An electrical capacitor construction comprising a relatively heavy metal stud, a non-inductively wound capacitor section comprising inter-leaved metallic foil and insulating strips and being concentrically mounted upon the central portion of said stud, a metal washer soldered to the projecting foil edges at one side of said section and electrically and mechanically connected to said stud, a relatively thin cylindrical metal casing snugly fitting the outside of said section and having an inturned annular flange at one end thereof, resilient insulating washers encircling said stud at opposite sides of said flange, means including a nut engaging a threaded portion of said stud for compressing said resilient washers against said metal washer to provide an insulating hermetic seal between said stud and casing, a metal cap having a cylindrical portion hermetically secured to the other end of said casing and an inturned annular flange, a metal strip wound edgewise into a spiral interposed between said section and said last mentioned flange, insulating spacers inserted between the turns of said spiral, the innermost turn of said spiral being soldered to the projecting foil edges at the opposite side of said section and the outermost turn of said spiral being soldered to said last mentioned flange, and further resilient washer means encircling said stud and engaging said last mentioned flange, and means for compressing said last washer means into hermetic engagement with said last mentioned flange and said stud.

3. An electrical capacitor structure comprising a cylindrical metal core having an annular flange at an intermediate point thereof, a non-inductive wound capacitor section mounted upon said core and having the protruding foil ends of one polarity directly soldered onto one side of said flange, a relatively thin metal tube enveloping and projecting beyond the opposite ends of said section, means to effect a liquid-tight seal between said core and the projecting open end of said tube adjacent to said flange, a cylindrical cap secured to the opposite open end of said tube and having a central perforation spaced from and passing said core, a metal strip wound edgewise into a spiral and interposed between the projecting foil ends of opposite polarity of said section and the inside of said cap, insulating spacers inserted between the turns of said spiral, and means to provide a hermetic seal between said cap and said core.

4. An electrical capacitor structure comprising a non-inductive wound capacitor section, a cylindrical metal casing having an end wall enclosing said section, and a metal strip wound edgewise into a spiral having one of its end turns in electrical connection with the protruding foil ends of one polarity of said section and having its other end turn in electrical connection with said end wall, insulating spacers inserted between the turns of said spiral, whereby to connect said section to said casing through said spiral forming an induction coil, and insulated terminal means connected to the foil ends of opposite polarity of said section.

WILLIAM M. ROBINSON.