

Radio frequency interference suppression apparatus

This invention relates to radio frequency interference (RFI) suppression apparatus, and in particular, to a circuit arrangement which suppresses RFI radiation at an opening of an RFI-shielded enclosure.

Many electronic instruments, such as computers and radio and television receivers, contain circuits which produce or process electronic signals. In doing so, the circuits can also radiate radio frequency signals from their circuit elements and interconnections to other circuitry or even other instruments. The interfering radio frequency signals can intermodulate with other signals in the instrument, thereby creating noise signals or interference patterns on the screen of a television receiver. To prevent such undesirable radio frequency interference, steps must be taken to contain or prevent the radiation of RFI signals in the instrument.

A common step employed to suppress RFI interference is to enclose the source of RFI radiation in a metallic enclosure. The enclosure will confine RFI radiation within its boundaries, and is typically grounded to prevent the radiation of RFI signals by the enclosure itself. However, the enclosure will generally have openings in its walls to permit the entry of power and signal conductors. These openings can permit RFI radiation to escape from the interior of the enclosure, which can lead to RFI contamination of nearby circuitry. More significantly, the conductors which leave the enclosure will themselves act as RFI antennas for high frequency radiation. Even when all of the signal and power conductors are shielded, as by the use of coaxial cable, there will generally be some circuit points at which the conductors emerge from the shielding to become radiating antennas for RFI signals. Furthermore, extensive coaxial cabling is undesirable, since it is both expensive and cumbersome. Thus, other steps may be taken to suppress RFI radiation from conductors which emerge from an RFI-shielded enclosure.

In GB-A-809386 there is disclosed an arrangement for suppressing emanation of RFI at harmonic frequencies from conductors leading from a shielding enclosure housing a high frequency generator, such arrangement including within the enclosure a capacitor which is connected in parallel with part of an output conductor from the generator and forms, with the inductance of that conductor part, a tapped parallel resonance circuit which, together with another capacitance connected or existing between the conductor and the enclosure, helps to suppress the harmonics. In contrast to this, and with the result, inter alia, of suppressing interference over a wider bandwidth, the present invention employs, externally of a metallically surfaced circuit enclosure, in close

proximity to a metal surface thereof, a first capacitor having substantially planar dielectrically spaced plates one of which, disposed between the other plate and metal surface of the enclosure in substantially parallel spaced relationship with that surface, forms therewith an additional air-dielectric capacitor. The plates of the first capacitor have respective terminals of which the first is coupled to an external circuit connection point from which emanation of RFI is to be suppressed, and second coupled to a point of RF reference potential to which the circuit enclosure is also coupled. The arrangement is such that the connection point, first terminal and first capacitor form a first resonant circuit having a different maximum-impedance resonant frequency from a second resonant frequency formed by the connection point, the first terminal and the additional capacitor.

In the drawings:

FIGURE 1 illustrates, partially in block diagram form and partially in schematic diagram form, a circuit embodying the principles of the present invention;

FIGURE 2 illustrates, in block diagram form, the signal and RFI energy paths of the circuit of FIGURE 1;

FIGURE 3 illustrates a partial cross-sectional view and partial side view of an embodiment of the present invention;

FIGURE 4 illustrates, in schematic diagram form, the circuit elements of the embodiment of FIGURE 3;

FIGURE 5 illustrates typical response curves of the circuit of FIGURES 3 and 4; and

FIGURE 6 illustrates the perspective view of an embodiment of the present invention.

Referring to FIGURE 1, an RFI generator 10 is shown enclosed in a grounded, metallic enclosure 20. The RFI generator 10 may be, for example, an integrated circuit device, a diode, or a transistor which radiates RFI energy. A specific RFI generator to which the principles of the present invention have been applied to suppress RFI radiation is a clocked charge-coupled device (CCD) comb filter integrated circuit used to separate the luminance and chrominance signals in a television receiver, as described in U.S. Patent 4,096,516, issued June 20, 1978 to D. H. Pritchard. An incoming video signal is clocked through three CCD delay line stages of the comb filter, the outputs of which are combined to develop separate luminance and chrominance signals. The three CCD delay line stages are clocked at a 10.7 MHz rate. This clock frequency and higher order harmonics thereof appear at the power and output terminals of the CCD comb filter and its shielding enclosure and, unless suppressed, will be radiated to other circuits of the television receiver. While these radiated signals pose no radiation threat to the user of the receiver, the

radiated signals are of sufficient strength to cause intermodulation problems in other circuitry in the receiver. The harmonics of the 10.7 MHz clock signal extend through the I.F., VHF, FM and UHF bands of the radio frequency spectrum, and can intermodulate with received television signals to cause severe beat patterns on several viewed channels. The radiated RFI signals must therefore be suppressed to prevent this intermodulation distortion.

RFI signal radiation is reduced to acceptable levels in accordance with the apparatus of the present invention. A typical signal conductor from the RFI generator 10 is shown leaving the metallic enclosure 20 by way of an impedance Z_R . The impedance Z_R is coupled to a second impedance Z_1 in series with the signal path, and a capacitor Z_C coupled in shunt to ground, at a node 30. The other end of impedance Z_1 is coupled to ground by a second capacitor C_2 , and to a utilization circuit 40. When employed in conjunction with the CCD comb filter device described above, the circuit elements Z_R , Z_C , Z_1 and C_2 cooperate to form a low pass filter in the luminance or chrominance signal paths. The luminance information, for instance, is contained in a bandwidth extending from zero to four MHz. This low pass filter rolls-off at frequencies above four MHz so that only the luminance information is contained on the signal conductor which is coupled to the utilization circuit 40.

Impedances Z_R and Z_1 present high impedances to RFI energy contained on the signal path from the RFI generator 10. These components may comprise elements such as ferrite beads, resistors, or inductors. In the illustrative embodiments shown in the FIGURES, Z_R is a resistor and Z_1 is an inductor. Resistor Z_R minimizes the conduction of RFI energy from the interior of the enclosure 20 to the node 30, and inductor Z_1 minimizes the conduction of RFI energy to the utilization circuit 40.

The capacitor Z_C presents a low impedance to RFI energy at node 30. Without this capacitor, RFI energy would be freely radiated by the leads of resistor Z_R and inductor Z_1 to other areas of the instrument. At higher harmonic frequencies of the 10.7 MHz clock signal, for instance, these small leads act as antennas for RFI energy. However, capacitor Z_C effectively acts as a bypass capacitor for most of the RFI energy at node 30, conducting it harmlessly to ground. Furthermore, capacitor Z_C is so oriented that its RFI "hot" plate (i.e., the plate coupled to node 30) is closely spaced to and faces the metallic enclosure 20. RFI energy which is radiated from this plate of the capacitor is narrowly confined to the area between the capacitor Z_C and the enclosure 20. Energy radiated from the capacitor to the enclosure is then conducted to ground by the metallic enclosure.

This flow of signal and RFI energy is more fully shown in FIGURE 2. An output signal and

RFI energy are coupled from the RFI generator 10 to the Z_R impedance as shown by arrow 12. The output signal and some of the RFI energy are coupled to impedance Z_1 and Z_C at the exterior of the low enclosure 20 from impedance Z_R . Since Z_1 presents a high impedance to the RFI energy, the output signal is coupled to the utilization circuit 40 substantially free of RFI. The RFI energy flows to the low RFI impedance Z_C by way of the signal path indicated by arrow 32. The RFI energy is then directly coupled back to the grounded enclosure 20 through the impedance Z_C as shown by arrow 36, and is radiated back to the enclosure 20 from the impedance Z_C as shown by arrow 34.

An arrangement of circuit elements in accordance with the principles of the present invention is shown in FIGURE 3. A metallic enclosure 20 is mounted on a printed circuit board 120 by inserting tabs 22 and 24 into holes in the board. The enclosure 20 contains an integrated circuit 100 which is a source of RFI energy. RFI radiation through the printed circuit board 120 is contained by a metallic shield 26 which is connected to the tabs beneath the circuit board. Signals from the integrated circuit 100 are coupled outside the enclosure 20 by a resistor 110, which is coupled to the integrated circuit 100 by a copper printed circuit connection on the printed circuit board (not shown). One terminal 112 of the resistor 110 is located external to the enclosure and is soldered to a printed circuit connection 122 on the surface of the board 120. A ceramic disc capacitor 130 is located external to the enclosure 20 and has a terminal 136 soldered to the printed circuit connection 122, and a terminal 138 connected through a hole in the printed circuit board 120 to the enclosure tab 24 at solder connection 140.

The ceramic disc capacitor 130 comprises a ceramic wafer dielectric 133 located between two metallic plates 132 and 134. The RFI energy present at resistor terminal 112, printed circuit connection 122, and capacitor terminal 136, is coupled to plate 132, making this plate "hot" with RFI energy. The capacitor plate 134 is "cold" with respect to RFI energy, since it is connected to the enclosure 20 by terminal 138. Thus, the "hot" plate will radiate RFI energy, whereas the plate 134 will not. RFI energy on plate 134 will be returned to the enclosure 20, which is at the RFI reference potential (e.g., ground).

Without the ceramic disc capacitor, resistor terminal 112 and printed circuit connection 122 would act as an antenna for RFI energy, radiating this energy to nearby circuitry. However, the capacitor 130 prevents this radiation by conducting a portion of the RFI energy through the ceramic wafer 133 to the "cold" plate 134, and thence to ground by way of terminal 138. The balance of the RFI energy at the terminals 112, 136 and the connection

22 is radiated from the surface of the plate 32 toward the metallic enclosure 20, as shown by arrows 150. This RFI energy is thus confined to the area between the ceramic disc capacitor 130 and the enclosure 20, and is returned to ground by way of the enclosure 20.

As a matter of fact, the circuit arrangement of FIGURE 3 actually includes two filter circuits for RFI energy. The resistor terminal 112, the printed circuit connection 122, and the capacitor terminal 136 together comprise a conductor with an inductive reactance. This inductive reactance is coupled to ground by the ceramic disc capacitor body, including the plate 132, and wafer 133, the plate 134, and terminal 138. The inductive reactance is also coupled to ground through the plate 132 and the enclosure 20 by way of the air dielectric therebetween. Consequently, it is seen that the plate 132 and the enclosure 20 serve as the plates of a second capacitor, which has a dielectric consisting of the air between them.

The filter circuits thus formed by these elements is shown in FIGURE 4. The inductive reactance is shown as L_{130} , and the air dielectric capacitor is shown as C_{RFI} . The two filter circuits, which share the same inductor L_{130} and which will have resonant frequencies determined by the effective lengths of the inductively reactive elements and the values of the capacitors. Typical response curves for the two filter circuits are shown in FIGURE 5. For example, if the ceramic disc capacitor 130 has a value of 150 pf, and the combined length of terminal 112, connection 112, and terminal 136 is 0.75 inches (19 mm), this filter circuit will have a resonant frequency between 50 and 60 MHz, as illustrated by response curve 230. (This resonant frequency can be increased or decreased by decreasing or increasing the length of the inductively reactive elements, respectively.) Furthermore, if the ceramic disc capacitor 130 has a diameter of approximately one-half inch (12.50 mm) and is closely spaced with respect to the enclosure 20, capacitor C_{RFI} will have a value on the order of 10 to 20 pf, and the filter circuit containing this capacitor will have a resonant frequency of approximately 200 MHz, as shown by response curve 250. Since the two resonant frequencies are separated by approximately 150 MHz, the impedance of the circuits over the range of RFI frequencies will always be low, since the lower impedance circuit will predominate at any particular frequency. For instance, in the case of the CCD comb filter device described above, it is desirable to prevent RFI radiation over the range of VHF television frequencies (55 to 216 MHz) and over the range of UHF television frequencies (470 to 890 MHz) to prevent interfering beat patterns in the received television image. It is seen that a low RFI impedance is provided by response curve 230 (L_{130} and capacitor 130) from 55 MHz to approximately 90 MHz, and that above 90 MHz, response

curve 250 predominates (L_{130} and C_{RFI}). Therefore, the circuit arrangement of FIGURES 3 and 4 is seen to provide a low impedance for RFI energy over the full range of VHF and UHF television frequencies.

A perspective view of an arrangement in accordance with the present invention is shown in FIGURE 6. A terminal of a resistor 100 extends through an opening in metallic enclosure 20 and into a hole in printed circuit board 120. A metallic printed circuit connection 122 on the surface of the board 120 connects the resistor 110 to a capacitor 130 and an inductor 160. The junction of these three circuit elements comprises the radiating node 30, shown in FIGURE 1. Capacitor 130 has a terminal 136 connected to the printed circuit connection 122 and to the "hot" side of the capacitor, which faces the enclosure 20. The "cold" side terminal 138 is connected through a hole in the circuit board 120 to the enclosure 20 on the underside of the board (not shown in this illustration). The inductor 160 is coupled between the printed circuit connection 122 and a second metallic printed circuit connection 162, which is a signal path to other utilization circuitry (not shown). RFI energy from node 30 is bypassed to the grounded enclosure 20 through the capacitor 130, and is radiated back to the enclosure from the "hot" side of the capacitor.

The impedance Z_R , Z_L and capacitor C_C , which form the low pass filter described in FIGURE 1, may be omitted if low pass filtering is not desired on the radiating conductor. This could be the case, for instance, when capacitor Z_C is used to suppress RFI radiation from a power conductor which enters the enclosure 20.

Claim

Apparatus for suppressing emanation of radio frequency interference radiation from a circuit connection point (122) of a circuit contained in a circuit enclosure (20) coupled to a point of radio frequency reference potential, with a capacitor (130) coupled between said circuit connection point and said point of radio frequency reference potential, characterised in that said capacitor (130), comprising substantially planar dielectrically spaced first and second plates (132, 134) with respective first and second terminals (136, 138) coupled thereto, has said first and second terminals coupled to said connection point (122) and to said point of radio frequency reference potential, respectively, and is located externally of said enclosure (20) in close proximity to a metallic surface thereof, with said first plate (132) disposed between said metallic surface and said second plate (134) is substantially parallel spaced relationship with said surface whereby to form therewith an additional capacitor (CRFI) having an air dielectric, such that said connection point (122), said first

122 is radiated from the surface of the plate 132 toward the metallic enclosure 20, as shown by arrows 150. This RFI energy is thus confined to the area between the ceramic disc capacitor 130 and the enclosure 20, and is returned to ground by way of the enclosure 20.

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The impedance Z_R , Z_L and capacitor C_2 , which form the low pass filter described in FIGURE 1, may be omitted if low pass filtering is not desired on the radiating conductor. This could be the case, for instance, when capacitor Z_C is used to suppress RFI radiation from a power conductor which enters the enclosure 20.

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terminal (136), and said capacitor (130) form a first resonant circuit, and that said connection point (122), said first terminal (136) and said additional capacitor form a second resonant circuit, said first and second resonant circuits having different resonant frequencies at which they exhibit maximum admittances.

Revendication

Appareil pour supprimer l'émanation d'un rayonnement d'interférence à haute fréquence d'un point de connexion de circuit (122) d'un circuit contenu dans une enceinte de circuit (20) couplée à une point de potentiel de référence à haute fréquence, avec un condensateur (130) couplé entre ledit point de connexion du circuit et ledit point de potentiel de référence à haute fréquence, caractérisé en ce que ledit condensateur (130), comprenant des première et seconde armatures (132, 134) diélectriquement espacées et sensiblement plates avec des première et seconde bornes respectives (136, 138) qui leur sont couplées, a ses première et seconde bornes couplées audit point de connexion (122) et audit point de potentiel de référence haute fréquence respectivement, et se trouve à l'extérieur de ladite enceinte (20) très près d'une surface métallique de celle-ci, ladite première armature (132) étant disposée entre ladite surface métallique et ladite seconde armature (134) en relation sensiblement parallèle et espacée avec ladite surface pour former ainsi avec elle un condensateur supplémentaire (CRFI) ayant un diélectrique à air de façon que ledit point de connexion (122), ladite première borne (136) et ledit condensateur (130) forment un premier circuit résonant, et que ledit point de connexion (122), ladite première borne (136) et ledit condensateur supplémentaire forment un second circuit

résonant, lesdits premier et second circuits résonants ayant des fréquences différentes de résonance auxquelles ils présentent des admittances maximales.

Patentanspruch

Einrichtung zum Unterdrücken einer Abstrahlung von Hochfrequenzstörstrahlung von einem Schaltungsanschlußpunkt (122) einer Schaltung, welche in einem mit einem Hochfrequenzreferenzpotentialpunkt gekoppelten Schaltungsgehäuse (20) angeordnet ist, mit einem zwischen den Schaltungsanschlußpunkt und den Hochfrequenzreferenzpotentialpunkt gekoppelten Kondensator (130), dadurch gekennzeichnet, daß der Kondensator (130), welcher eine erste und eine zweite Platte (132, 134), die im wesentlichen eben, durch ein Dielektrikum getrennt sowie mit einem ersten bzw. einem zweiten Anschluß (136, 138) gekoppelt sind, enthält, mit dem ersten bzw. dem zweiten Anschluß mit dem Anschlußpunkt (122) bzw. dem Hochfrequenzreferenzpotentialpunkt gekoppelt und außerhalb des Gehäuses (20) in naher Nachbarschaft einer metallischen Fläche hiervon angeordnet ist, wobei die erste Platte (132) zwischen der metallischen Fläche und der zweiten Platte sowie im wesentlichen parallel und im Abstand von dieser Fläche angeordnet ist, um mit dieser einen zusätzlichen Kondensator (CRFI) mit Luftdielektrikum zu bilden, so daß der Anschlußpunkt (122), der erste Anschluß (136) und der Kondensator (130) einen ersten Resonanzkreis bilden, und der Anschlußpunkt (122), der erste Anschluß (136) und der zusätzliche Kondensator einen zweiten Resonanzkreis bilden, wobei der erste und der zweite Resonanzkreis verschiedene Resonanzfrequenzen aufweisen, bei denen sie maximal Scheinleitwerte haben.



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