A New Inductor Having A Noise Filtering Capability

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***Abstract*-In this paper, we propose a new inductor having a noise filtering capability based on a resonant phenomenon between the two adjacent series connected coils. The resonant impedance and frequency of this inductor can be controlled by changing the inductance as well as capacitance. Simple theoretical and experimental consideration clarify that the resonant impedance takes a larger value at lower frequency when increasing the inductance. This means that it is possible to realize a noise filter without any external capacitors. Thus, we succeeded in realizing a new inductor having a noise filtering capability.**

I. INTRODUCTION

The modern electronic devices such as the book size computer, word processor and cordless telephone require to reduce the size and weight of their power suppliers, because the parts processing the signals have been reduced to small size by the developments of modern LSI technology. The magnetic parts, e.g. inductor and transformer, occupy a relatively large space and weight in the power supplies. The magnetic devices should be reduced into smaller size to develop the small electric power supplies. The most conventional way to reduce the size of the magnetic devices is to employ high frequency excitation. In such condition, a serious problem is that the major performance of the devices is dominated by the frequency characteristics of the core magnetic materials. To overcome this difficulty, we have previously exploited a new type of coreless high frequency transformer as well as thin film shape transformer[1,2]. Further, we have succeeded in realizing a 15W DC to DC converter employing a coreless transformer [3]. Nevertheless, there remains a noise problem which becomes more serious when employing a higher exciting frequency. Therefore, even if we succeed in realizing a small power supply with high frequency excitation, it should include, in essence, a noise filter.

This paper proposes a new inductor having a noise filtering capability based on a resonant phenomenon between the two adjacent series connected coils. A key idea to exploiting this inductor is that any conductors arranged in parallel have a capacitance between them, and its effect depends on a way of circuit connections. If we connect these parallel arranged coils in series, then the voltage difference becomes a half of entire impressed voltage on the two conductors. Further, the currents of both conductors are flowing in a same direction. This yields a common magnetic flux between them so that a parallel resonant phenomenon may be occurred at a certain frequency. The resonant impedance and frequency of the inductor can be controlled by changing the inductance or capacitance. Simple theoretical consideration clarifies that the impedance takes a larger value at lower frequency when increasing the inductance. This means that it is possible to realize a noise filter without any external capacitors. Thus, we succeeded in realizing a new inductor having a noise filtering capability.

II. RESONANT TYPE INDUCTOR

A. Key idea

Let us consider the two parallel arranged conductors shown in Fig. 1(a), then, consideration of the connection in Fig. 1(b) leads to an equivalent circuit shown in Fig. 1(c). This is because the connection in Fig. 1(b) makes it possible to impress the half of entire impressed voltage between the two conductors. Furthermore, the currents of both conductors are flowing in a same direction. This yields a common magnetic flux between them so that a parallel resonant phenomenon is evoked at a certain frequency. As shown in Fig. 2, the self inductance, resistance, mutual inductance and capacitance have been denoted by L, R, M and C, respectively.

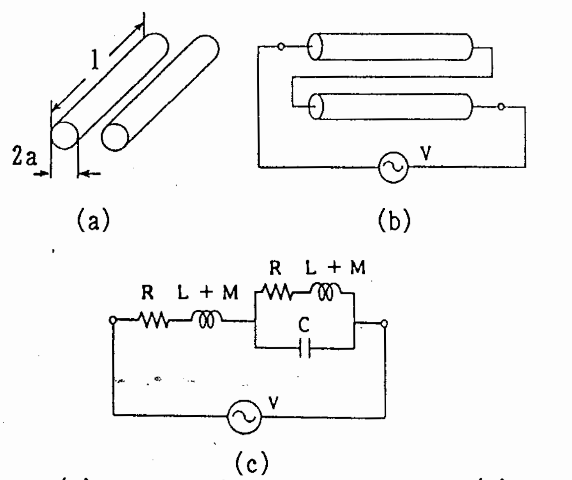

Fig. 1. (a)Two parallel conductors, (b) the method of circuit connection and, (c) lumped circuit model.

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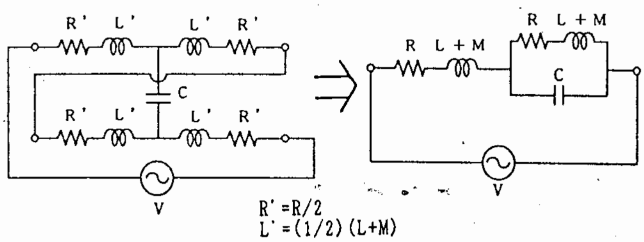


Fig. 2. Derivation of a lumped circuit model neglecting an impedance of connection wire and representing the capacitive effect by the capacitance C connected between the centers of two conductors.

B. Basic equations

By means of the equivalent circuit shown in Fig. 1(c), the resonant frequency ω_r and resonant impedance Z_r are given by

$$\omega_r = 1/\sqrt{(L+M)C}, \quad (1)$$

$$Z_r = R + [(L+M)/(RC)]. \quad (2)$$

Equation (1) reveals that the resonant frequency ω_r can be reduced by increasing the inductance L+M or capacitance C. However, Eq. (2) suggests that a larger inductance increases the resonant impedance Z_r at lower resonant frequency ω_r.

III. EXPERIMENTAL

A. Resonance

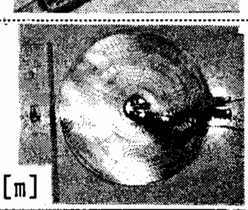
In order to verify the resonant phenomenon of our new inductor, we have carried out the frequency vs. impedance measurements for the inductors. Table 1 lists various constants and pictures of the tested inductors.

As shown in Figs. 3(a) and 3(c), it is obvious that our new inductors (two conductors in parallel) exhibit the clear and sharp parallel resonant phenomena until the 10MHz. On the other side, Figs. 3(b) and 3(d) show that conventional inductors (single conductor) composed of the same conductors never exhibit any resonant until the 10MHz frequency.

Table 1. Tested inductors.

Finite length solenoidal type inductor
SHAPE: CORELESS PARALLEL ARRANGED TWO COILS
WIRE DIAMETER: 0.3[mm]
ENTIRE COIL LENGTH: 5.0[m]
TURNS: 90[turns]

Film type inductor
SHAPE: CIRCULAR ARRANGED TWO FILM CONDUCTORS
CONDUCTOR WIDTH: 1[mm]
CONDUCTOR THICKNESS: 35[μm]
ENTIRE CONDUCTOR LENGTH: 5.6[m]



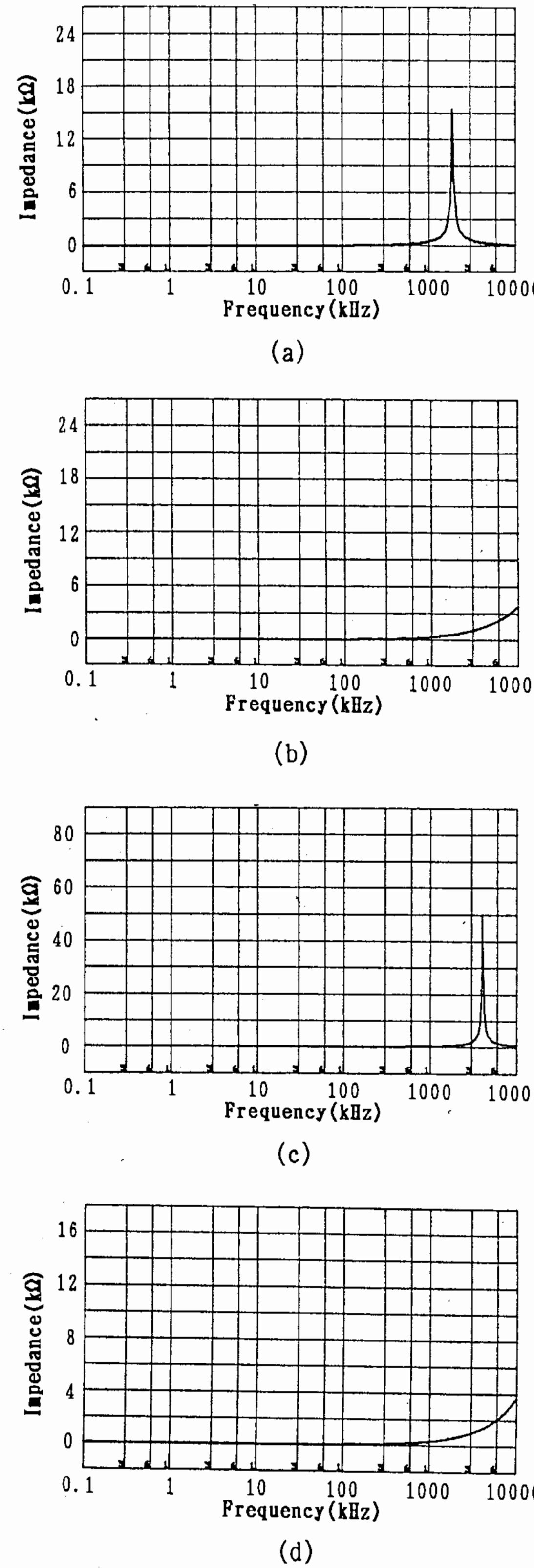
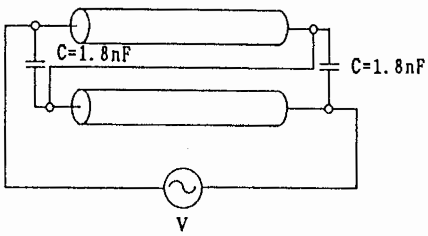
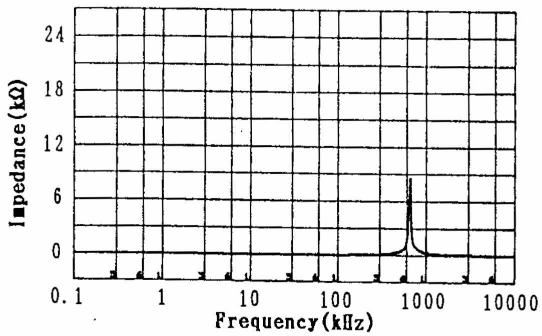


Figure 3. Impedance vs. frequency characteristics. (a) New finite length solenoidal type inductor, (b) conventional finite length solenoidal type inductor, (c) new film type inductor, and (d) conventional film type inductor.

In order to reduce the resonant frequency, we attached the capacitor to the resonant type inductor in Fig. 3(a) as shown in Fig. 4(a).

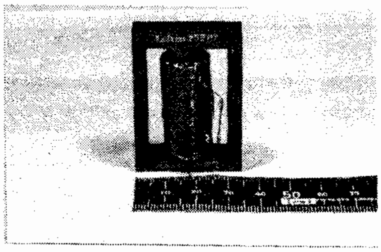


(a)

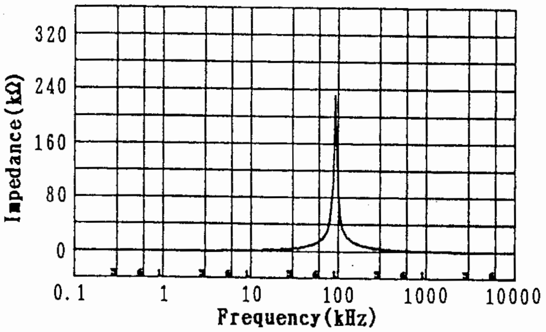


(b)

Figure 4. Reduction of the resonant frequency by attaching the capacitors. (a) Circuit diagram, and (b) impedance vs. frequency characteristic.



(a)



(b)

Figure 5. Reduction of the resonant frequency by increasing the inductance. (a) Picture of the resonant type inductor attached to the EE ferrite core, and (b) impedance vs. frequency characteristic.

The consideration of the impedance vs. frequency characteristic in Fig. 4(b) reveals that the resonant frequency is considerably reduced. However, the resonant impedance is also reduced to a small value comparing with the result in Fig. 3(a). Figure 5 shows the resonant type inductor in Fig. 3(a) attached to the EE ferrite core and its impedance vs. frequency characteristic. From Fig. 5(b), it is found that the resonant impedance becomes a larger value at lower resonant frequency. Thus, the lumped circuit model is verified

B. Filter characteristic

As an application of the resonant type inductor shown in Fig. 5(a), we measured the filter characteristic of this inductor using a HP 4194A analyzer. Figure 6 shows the gain vs. frequency characteristic of this inductor. Obviously, the result of Fig. 6 reveals a typical band elimination type filter characteristic.

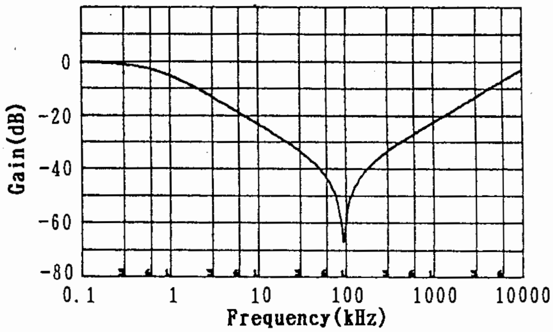


Figure 6. Filter characteristic using HP 4194A analyzer.

IV. CONCLUSION

As shown above, we have proposed a new inductor having a noise filtering capability. Our resonant type inductor is based on the circuit connections so that it may have a lot of applications for electronic as well as electric circuits. In this paper, we have demonstrated the noise filtering capability of our inductor as a typical application.

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