April 7, 1942. O. S. MEIXELL 2,278,620

HARMONIC ATTENUATION FILTER

Filed May 29, 1940

Fig. 1

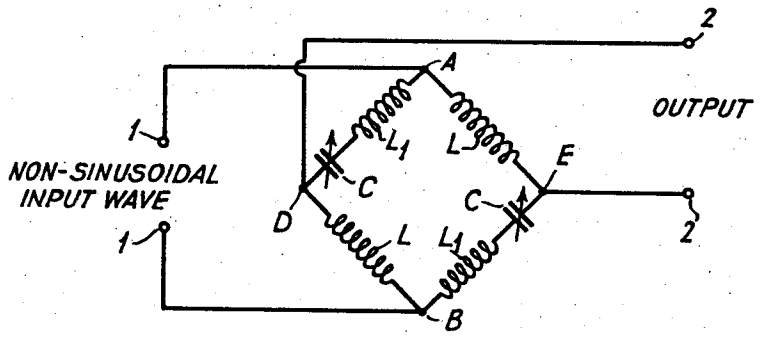


Fig. 2

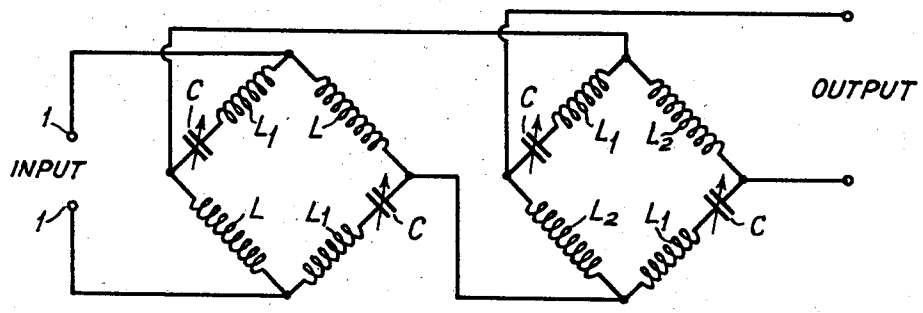
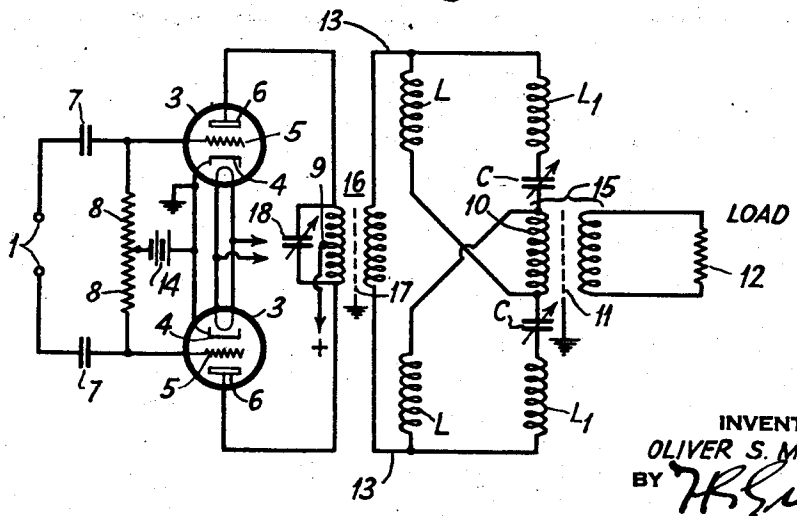


Fig. 3



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HARMONIC ATTENUATION FILTER

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4 Claims. (Cl. 178—44)

This invention relates to filter systems and more particularly to a filter suitable for attenuating one or more of the harmonics of a wave of non-sinusoidal characteristic.

It is an object of my invention to provide a simple filter which is suitable for passing a fundamental frequency while attenuating to a high degree the accompanying harmonics of said fundamental frequency.

It is another object of my invention to provide a filter system in which a non-sinusoidal input wave shall be so treated as to deliver on the output side of the filter a substantially pure sinusoidal wave of a fundamental frequency.

Circuit calculations in communication networks are based usually on the assumption of voltages and currents which vary sinusoidally with time. However, the sine wave is not the only one encountered. Very frequently a voltage does not vary as the simple sine function but is exceedingly complex. Fourier analysis demonstrates that no matter how complex a periodic function is, it can be resolved into an average value, fundamental and harmonics. The fundamental and each harmonic varies sinusoidally with time. In practice the need frequently arises that one or more of these components shall be removed from a complex or non-sinusoidal electric wave.

To do this the communication engineer resorts to some kind of filter network which allows the desired frequency or frequencies to pass through and to stop or attenuate all others. The basic purpose of the attenuator under consideration is to allow the fundamental frequency of any given complex wave to pass on to a load but to prevent any others from doing so.

Let us assume that a non-sinusoidal wave has the following components:

E_1=fundamental at a frequency fo

E_2=2nd harmonic at a frequency $2fo$

E_3=3rd harmonic at a frequency $3fo$

. .

. .

. .

E_n=nth harmonic at a frequency nfo

Depending on the complexity of the assumed wave the fundamental and a greater or less number of harmonics will be present. It is not necessary to ask which ones are present because the network to be designed must pass only the fundamental E_1 and stop (or attenuate) all the harmonics E_2, E_3, etc.

My invention will now be described in more detail, reference being made to the accompanying drawing in which

Figure 1 shows the elements of a filter system suitable for carrying out the invention;

Fig. 2 shows a modification in which filter elements are provided for substantially infinite attenuation of the second and third harmonics of a fundamental frequency; and,

Fig. 3 shows still another modification of the invention where the input to the filter is derived from electronic action in a push-pull vacuum tube system and the output load may be any desired impedance.

Referring to Fig. 1, I show a filter network having input terminals 1 and output terminals 2. The network includes two inductances L and two inductances L_1, the latter being in series with capacitors C.

The principal object to be attained in the design of this network is to infinitely attenuate the second harmonic and to suppress other harmonics as far as possible. In order to attain this end, the values of L_1 and C should be made series-resonant at the fundamental frequency fo, the latter being the fundamental frequency of a non-sinusoidal wave impressed upon the input terminals 1.

Theoretically the alternating current drop for the fundamental frequency in the L_1 C combination is zero, and accordingly the fundamental frequency will appear substantially unattenuated across the terminals 2.

Alternating current theory also teaches that if a combination of L_1 and C is resonant at the frequency fo, then at the second harmonic frequency $2fo$ their equivalent reactance is inductive and corresponds to that of an inductance equal to 3/4 L_1. Accordingly, I utilize inductive legs in the network such that the leg L=3/4 L_1. It is obvious, then, that at the frequency of the second harmonic $2fo$ the reactances of all four legs of the network are equal, and since this corresponds to a balanced bridge condition, there can be no second harmonic voltage appearing across the output terminals 2. Any such second harmonic voltage E_2 as may be a component of the non-sinusoidal input wave is substantially infinitely attenuated in the output.

In a similar way it can be shown that if the harmonic or frequency component which corresponds to three times the fundamental is to be removed, then the value of the inductance legs L should be made equal to 8/9 L_1, where L_1 resonates with C at the fundamental frequency fo.

Now with regard to the higher harmonics it

has been experimentally determined that they can be attenuated substantially in accordance with the following table:

Frequency	Attenuation in decibels ($\omega_0 L_1 = 10R$)	
	$L=\frac{3}{4}L_1$	$L=\frac{8}{9}L_1$
	Decibels	*Decibels*
f_o	0	0
$2f_o$	∞	39.8
$3f_o$	49	∞
$4f_o$	50	63
$5f_o$	51	62
$6f_o$	52	62

The types of non-sinusoidal waves, where the attenuator just described can be used, frequently have harmonics in a descending order of amplitude. Let us say that both odd and even harmonics of *fo* exist and that L=3/4 L_1. Under these conditons the 2nd harmonic will be removed completely and all the others (as far as shown) will experience about 50 db attenuation Actually, however, since the amplitudes of the higher harmonics are decreasing the voltages due to them which appear across the load are negligible. Some waves have a descending amplitude and no even harmonics. In this case L would be made equal to 8/9 L_1, under which condition the fundamental would experience no attenuation, the third harmonic infinite attenuation and the higher ones about 60 db.

This discussion has assumed that the resistances of the coils and condensers are negligible. Actually these resistances have little influence on the results, provided the Q values of the coils and condensers are adequately high (30 or more).

Fig. 2 shows a filter system in which it is practical to provide substantially infinite attenuation for both the second and third harmonics of a fundamental frequency Eo where both the fundamental and harmonic frequencies appear in the input. Two balanced bridge networks are here shown, one comprising the same elements as are given in Fig. 1, and the other comprising inductances L_2 in two of the legs, while series-resonant circuits L_1 C (resonant at *fo*) constitute the remaining two legs.

The filter arrangement as shown in Fig. 2 may readily be understood from the foregoing description of Fig. 1. It is here assumed that L=3/4 L_1 and that L_2=8/9 L_1. The first of these balanced bridge networks is effective to substantially infinitely attenuate the second harmonic and to pass the fundamental frequency, while the second of these networks substantially infinitely attenuates the third harmonic while still passing the fundamental frequency.

Referring to Fig. 3, I show a filter system which is arranged with a push-pull discharge tube amplifier coupled to its input leads 13. The push-pull tubes 3 are here shown each having a cathode 4, a grid 5 and an anode 6. Other types of tubes may, of course, be used, if desired. The cathodes 4 are preferably grounded and are connected through a grid biasing source 14 to resistors 8 which are respectively connected to the control grids 5. The use of the bias potential source 14 is optional, however, and its use depends somewhat upon whether the tubes are to be operated as class B or class C amplifiers. Input potentials impressed upon the terminals 1 may be coupled to the grids 5 across condensers 7. The anodes 6 are connected to the primary terminals of a transformer 16. Anode potential is supplied by any suitable direct current source connected to a center tap 9 on this transformer. The secondary terminals of transformer 16 are connected to the filter input leads 13. A grounded electrostatic shield 17 is interposed between the primary and the secondary of the transformer 16. The filter network in this case, as in the embodiment of Fig. 1, comprises two inductances L and two inductances L_1, the latter being series-connected with capacitors C. The series-resonant condition of the elements L_1 C at the fundamental frequency is obtained by suitable adjustment of the capacitors C. The transformer 15 is preferably provided with an electrostatic shield 11 interposed between the primary and the secondary. Any suitable load 12 may be connected to the secondary terminals of the transformer 15.

The arrangement shown in Fig. 3 is one well suited to the purification of a wave and the operation has been found satisfactory when the tubes 3 are operated either as a class B amplifier or as a class C amplifier.

In accordance with still another modification of the invention similar to Fig. 3, the filter proper may be directly fed with energy from the output circuit of a single electron discharge tube amplifier. In this case the transformer 16 is dispensed with. The anode 6 of the tube 3 (Fig. 3) is directly connected to the upper one of the filter input leads 13. The cathode 4 is connected through the anode supply source to the lower one of the input leads 13. In other respects the combination of amplifier and filter remains the same as shown in Fig. 3.

It can be shown that where the effective resistance values of the coils and condensers of the filter network become appreciable, balancing means well known in the art may be applied.

I claim:

1. A harmonic suppression filter comprising a network having input terminals A and B, and output terminals D and E, series-resonant branches, one connected between input terminal A and output terminal D, the other series-resonant branch connected between input terminal B and output terminal E, an inductive branch connected between terminals A and E, a second inductive branch connected between terminals B and D, said series resonant branches being tuned to a fundamental component of a non-sinusoidal wave to be filtered, and each of said inductive branches having a value equal to substantially three-fourths of the value of the inductive element in each series-resonant branch, whereby a low order harmonic component with respect to said fundamental component is substantially infinitely attenuated.

2. A harmonic suppression filter comprising a network having input terminals A and B, and output terminals D and E, series-resonant branches, one connected between input terminal A and output terminal D, the other series-resonant branch connected between input terminal B and output terminal E, an inductive branch connected between terminals A and E, a second inductive branch connected between terminals B and D, said series resonant branches being tuned to a fundamental component of a non-sinusoidal wave to be filtered, and each of said inductive branches having a value equal to substantially eight ninths of the value of the inductive element in each series-resonant branch, whereby a low order harmonic component with

respect to said fundamental component is substantially infinitely attenuated.

3. A filter for attenuation of harmonic components of a non-sinusoidal wave comprising a balanced bridge network having two input terminals and two output terminals, a series-resonant circuit interconnecting one input and one output terminal, a second series-resonant circuit interconnecting the other input and output terminals, both series-resonant circuits being tuned to the fundamental frequency of said wave, an inductive branch connected between said one input terminal and said other output terminal, and a second inductive branch connected between said other input terminal and said one output terminal, each of said inductive branches having a value substantially 75% as great as that of the inductance in each of said series-resonant circuits.

4. A filter for attenuation of harmonic components of a non-sinusoidal wave comprising a balanced bridge network having two input terminals and two output terminals, a series-resonant circuit interconnecting one input and one output terminal, a second series-resonant circuit interconnecting the other input and output terminals, both series-resonant circuits being tuned to the fundamental frequency of said wave, an inductive branch connected between said one input terminal and said other output terminal, and a second inductive branch connected between said other input terminal and said one output terminal, each of said inductive branches having a value substantially eight-ninths as great as that of the inductance in each of said series-resonant circuits.

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