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HARMONIC TONE PRODUCTION FOR THE GENERATION OF MUSICAL TONE QUALITIES

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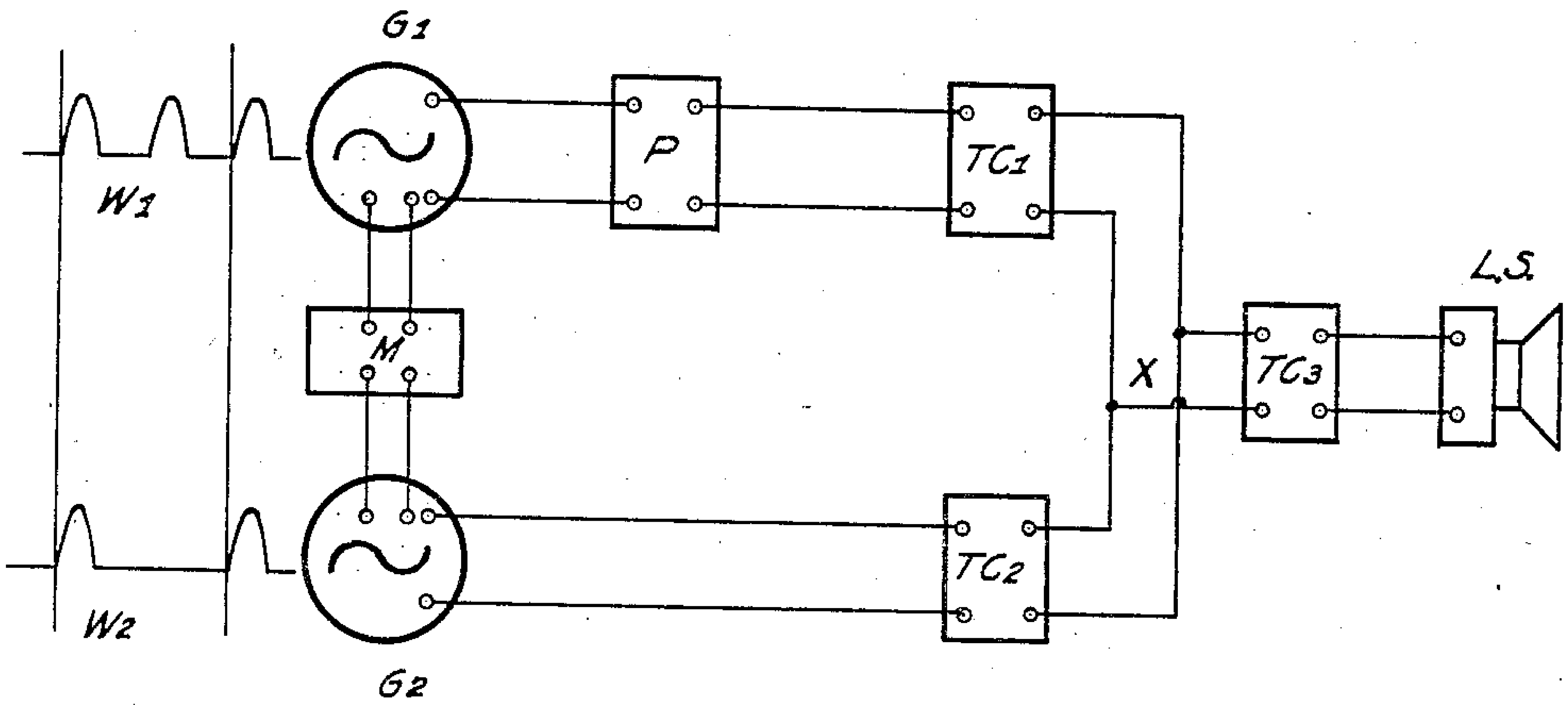

FIG. 1

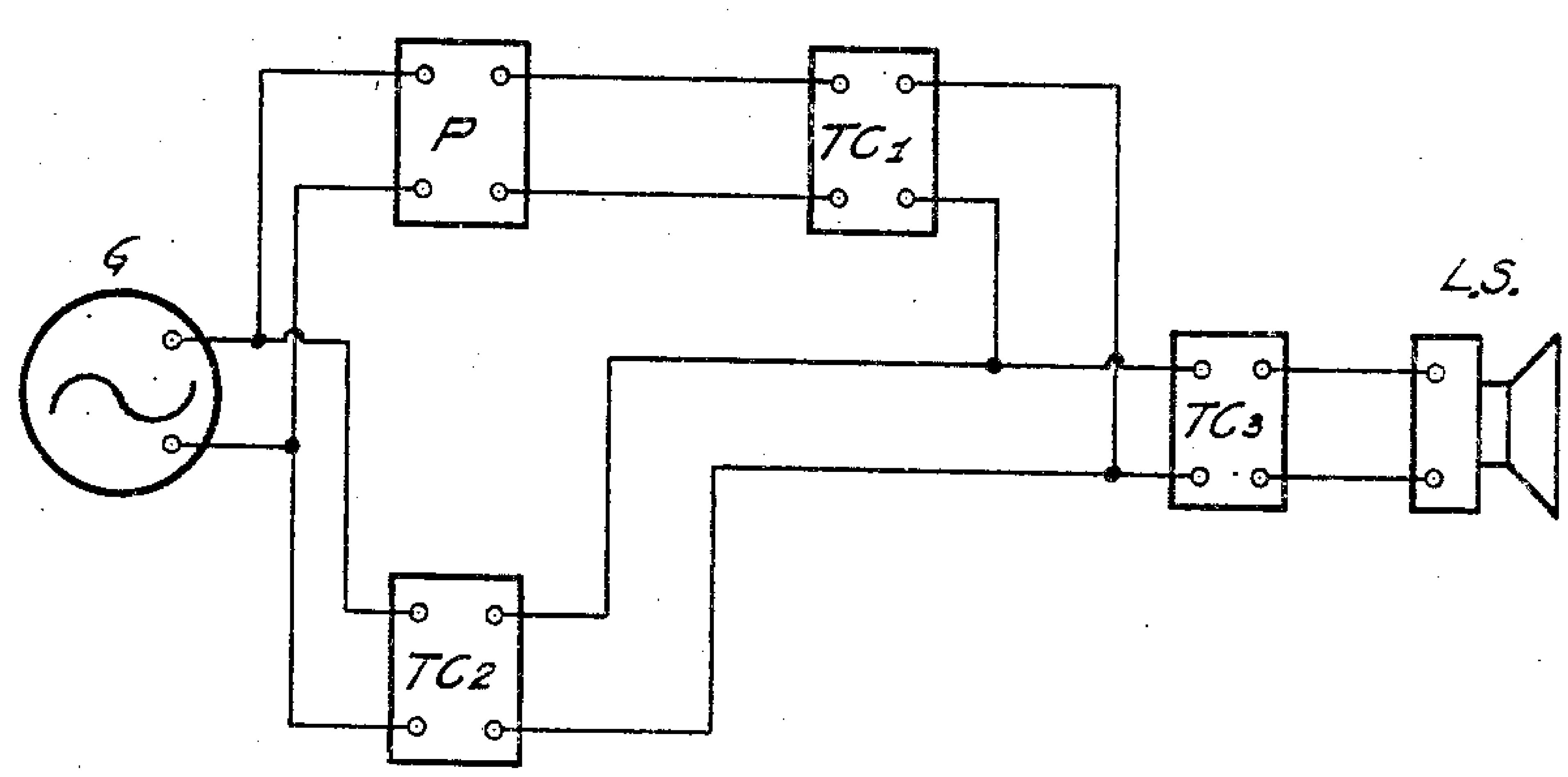

FIG. 2

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HARMONIC TONE PRODUCTION FOR THE GENERATION OF MUSICAL TONE QUALITIES

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It is well known that the timbre or tone quality of musical instruments depends upon the harmonic content of the wave form of the musical note produced. In particular, certain instruments are characterized by the absence or extreme weakness of certain harmonics. Thus many of the woodwind instruments such as the clarinet are known to have strong odd harmonics (fundamental 3rd, 5th, etc.) and weak even harmonics, (2nd, 4th, etc.). Various stopped organ pipes also show this property.

In this invention I shall set forth various means applicable in the electrical production of music, of obtaining tone qualities of new types including the woodwind timbre just described. The principle involved consists in utilizing the property of destructive interference of wave motion. When two sine waves which are displaced in phase by 180° (or an odd multiple thereof) are added together, both are canceled and the resulting amplitude is zero. This principle furnishes a means of canceling out various undesirable harmonics from a given complex tone.

Various methods of tone production have heretofore varied the harmonic structure of a note by varying the relative phases of two or more notes of the same fundamental frequency and then combining them. However, in all of these cases either the two or more complex tones used were of the same fundamental frequency or the method of tone production was such as to enable the harmonics to be selected individually (such as vibrating strings). This imposed a limitation either on the tone qualities which could be obtained or on the type of tone generators which could be utilized.

By utilizing notes of different fundamental frequency an entirely new effect can be obtained. In this case the two or more notes must be harmonically related and furthermore must be of exactly related frequencies. For example let us consider two notes which are exactly at octave separation, and which possess wave forms of the saw tooth type, that is, where the amplitudes of the harmonics decrease directly as the number of the harmonic. If these are caused to be exactly 180° out of phase the higher note, whose fundamental, 2nd harmonic, 3rd harmonic, etc., correspond to the second harmonic, 4th harmonic, 6th harmonic, etc., of the lower note, will act to destructively interfere with the even harmonics of the lower note to give the characteristic woodwind tone when the two are added together. By adjusting the amplitudes of the two notes the tone quality can be varied greatly. It is essential, however, that the two notes be exactly an octave apart and locked into step. As a second example of this feature let us consider two notes whose frequency relation is exactly 1 to 3, and which are displaced 180° in phase and added. The harmonics which are multiples of the 3rd harmonic of the lower note can be removed, to provide a novel musical effect.

Another feature of this invention is the utilization of but one single generator to destructively interfere with itself. If a tone which is rich in harmonics is heavily filtered to yield a pure tone and this pure tone is reversed in phase and added to the original tone, a note rich in harmonics and lacking the fundamental can be obtained.

The phase displacement can be accomplished by vacuum tubes or other well known means.

As an example of the way in which the effects just described may be accomplished I refer to the drawing.

In the drawing, Fig. 1 is a schematic representation of one feature of the invention, in which feature two generators are employed; and

Fig. 2 is a schematic representation of another feature, utilizing a single generator.

In Fig. 1 is shown two electrical oscillation generators G_1 and G_2 producing signals at octave separation as shown in the adjacent wave forms W_1 and W_2. The oscillation generators may be any of various types, for example vacuum tube, glow discharge, rotating disk or the like. As pointed out however, the two notes must be locked into step at the desired harmonic separation. If the generators are of the rotating disk type, this synchronization can be accomplished mechanically. However, if the generators are of the vacuum tube or glow discharge type, some sort of coupling means M is advisable to keep the signals locked into step. One of the signals is then fed into a phase shifting device P, by means of which the phase of the note is shifted relative to the second generator G_2. If this phase shifting device is a vacuum tube, the shift will ordinarily amount to about 180°. Both signals can have their wave shape varied by means of the tone coloring devices $T.C_1$ and $T.C_2$. If desired these devices may be set so that no change in tone color takes place. At the point X, the signals are combined and if desired the combined tone may be colored by means of the tone coloring device $T.C_3$. The final tone is then heard at the loud speaker L.S. By means of varying the relative intensities of the signals (by means of the devices $T.C_1$ and $T.C_2$) and the relative phase of the two signals (by means of the phase shifter P) very pronounced woodwind and other timbres can be obtained. T.C₃ permits the addition of formants or other characteristic properties of certain orchestral qualities.

In Fig. 2 is shown an example of the way in which one generator can be utilized to produce a wide variety of tone colors. An oscillation generator G feeds into a phase shifting device P and into a tone coloring device $T.C_2$. The phase shifted signal can then be varied in timbre by means of $T.C_1$ and fed into $T.C_3$ along with the signal from $T.C_2$. The final tone is heard from the loud speaker L. S. By adjusting the phase shift and relative intensity, it is possible to decrease the amount of the fundamental frequency considerably. The various devices P, $T.C_1$, $T.C_2$, and $T.C_3$ permit a great variety of tone colors to be obtained.

What I claim is:

1. In a musical instrument, at least two electrical oscillation generators developing complex wave forms of substantially the same harmonic values, means for maintaining the fundamental frequencies of said generators in exact octave relationship, means for altering the phase of the output oscillations of one of said generators so as to give them a substantially 180° out-of-phase relationship with the oscillations of the other of said generators, and means for combining said oscillations so altered in phase with the output oscillations of the other of said generators.

2. In a musical instrument, at least two electrical oscillation generators developing complex wave forms of substantially the same harmonic values, means for maintaining the fundamental frequencies of said generators in exact octave relationship, means for altering the phase of the output oscillations of one of said generators so as to give them a substantially 180° out-of-phase relationship with the oscillations of the other of said generators, means for combining said oscillations so altered in phase with the output oscillations of the other of said generators, and means for altering the wave form of the oscillations so combined.

3. In a musical instrument, at least two electrical oscillation generators developing complex wave forms and separately having different fundamental frequencies, means for causing said different fundamental frequencies of said generators to assume an exact ordinal relationship, means for altering the phase of the output oscillations of the one of said generators having the higher fundamental frequency so as to give them a substantially 180° out-of-phase relationship with the oscillations of the other of said generators, and means for combining said oscillations so altered in phase with the output oscillations of the other of said generators having the lower fundamental frequency, whereby in the resultant oscillations harmonics of a given order as referred to the oscillations of the generator having the higher fundamental frequency are attenuated by harmonics of a higher order as referred to the generator having the lower fundamental frequency.

4. In a musical instrument, including at least two sources of oscillations having inherently different fundamental frequencies and wherein said sources produce oscillations at least more complex than those corresponding to pure tones, means whereby the fundamental frequencies of said sources are caused to be maintained in exact octave relationship, means for altering the phase by substantially 180° electrically of one of said sources, and means for combining the two said sources after such alteration.

5. In an electrical musical instrument, a source of electrical oscillations of complex wave form, means providing a plurality of paths for said electrical oscillations, means in at least one of said paths for modifying the character of said complex wave form, means in said path for shifting the phase of said oscillations by substantially 180°, and means for recombining the oscillations in said several paths.

6. In an electrical musical instrument, means for providing tones characterized by a preponderance of large numbers of odd harmonics and comprising means for combining in an output circuit a plurality of electrical oscillations of complex wave form, said oscillations being of octavely related frequency and one of said oscillations at least being substantially 180° out of phase with at least one other of said oscillations, whereby with respect to said oscillations harmonics therein of equal frequency tend to attenuate each other, and means in said output circuit for converting said electrical oscillations into sound.

7. In an electrical musical instrument, means for producing musical tones characterized by a new character of harmonic content which comprises means providing a plurality of paths for an electrical oscillation of complex wave form, means in one of said paths for modifying the character of said oscillation, means for shifting by substantially 180° the phase of said modified oscillation, means for recombining said oscillations in out of phase relationship whereby attenuation of certain harmonics is produced, and means for converting said recombined oscillations into audible sound.

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