

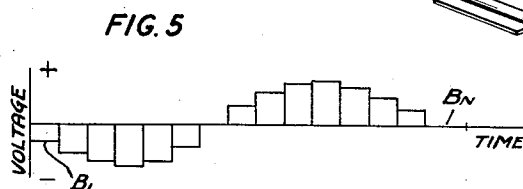
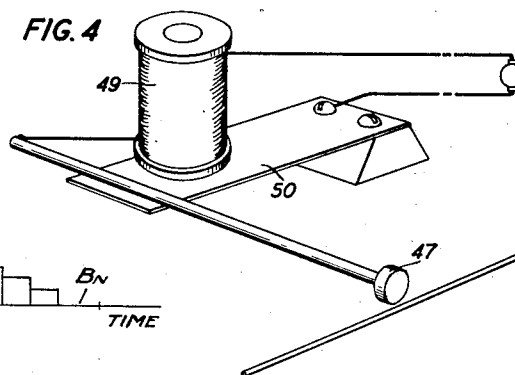
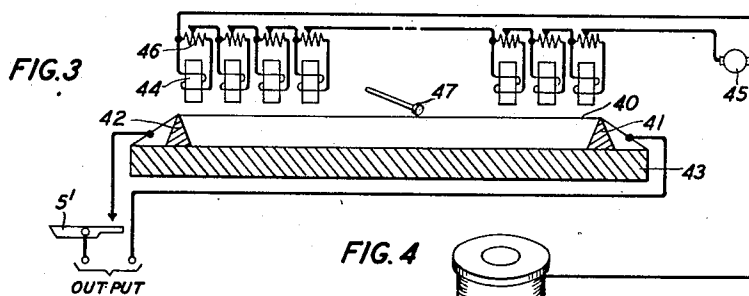
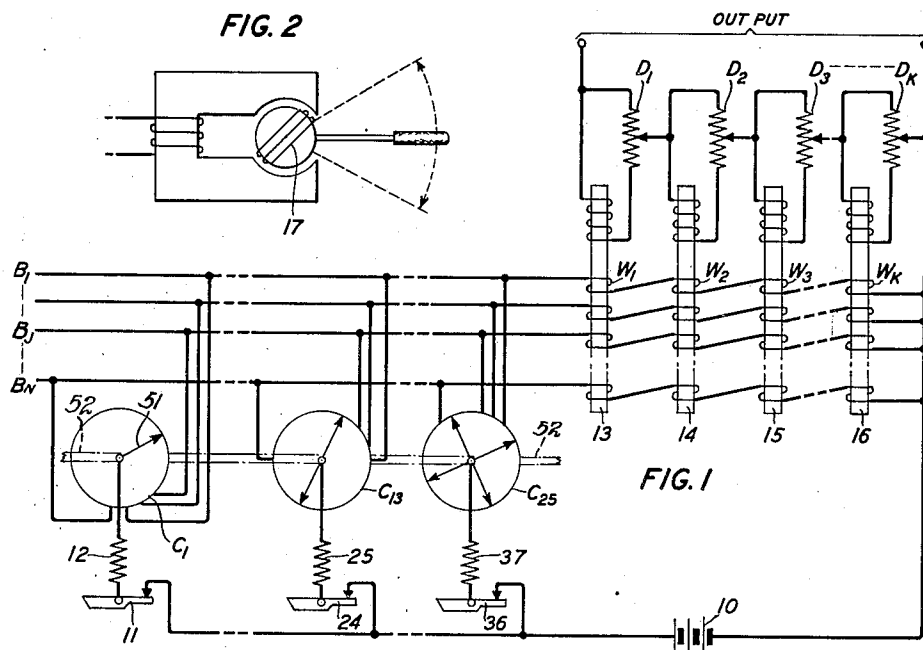
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tone generator

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TONE GENERATOR

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9 Claims. (Cl. 84-1.19)

This invention relates to methods and apparatus for synthetically producing tones of any predetermined wave form.

In electric organ devices such as are used for entertainment purposes, and in synthetic tone producers for the scientific investigation of sound, it is often desirable to be able to produce a sound wave of any form whatever. Thus, in the production of a musical note, it may be desirable to add certain harmonics, or to change the relative amplitudes of the harmonics already present, and thereby alter the form of the wave originally produced.

The object of this invention is to provide methods and apparatus for forming a sound wave by the linear addition of practically arbitrary component waves, each component wave being controllable in magnitude and sign.

The fundamental idea of the linear addition of component waves can be applied to waves generated in any one of several ways; (1) by a commutator which produces a succession of short voltage pulses, the linear addition of which is accomplished by means of transformers, (2) by a multi-winding electromagnetic generator which may be designed to produce a similar succession of short pulses, or other convenient wave-forms, the linear addition of which is again accomplished by means of transformers, and (3) by an electroconducting wire vibrating in a plurality of magnetic fields, the linear addition of required components being accomplished in this case by adjustment of the magnetic fields.

In accordance with the object of this invention, therefore, means are provided for generating a rapid succession of voltage pulses, each pulse being controllable in amplitude. The pulses are directed into a common circuit by means of a switch or key, amplified and then translated into sound waves by an electrical receiver.

A feature of this invention is a commutator method of generating the pulses whereby a plurality of voltage sources are periodically connected to the common circuit in a predetermined sequence by means of brushes cooperating with conducting segments on a rotating drum or disc.

Another feature of this invention is an electromagnetic method of combining voltage pulses.

Still another feature is a method of generating voltage pulses in a predetermined sequence by means of electroconductive strings vibrating in a plurality of electromagnetic fields.

Although the invention is adaptable to a number of uses it will be described hereinafter as applied to an electronic organ,

In the drawing which accompanies this specification and forms a part thereof,

Fig. 1 is a schematic wiring diagram showing the principle of operation of the tone generators;

Fig. 2 is an alternate method of tone control;

Fig. 3 is another form of tone generator;

Fig. 4 is a driving means for the tone generator of Fig. 3; and,

Fig. 5 is a graph showing how the tone is built up from a series of voltage pulses added linearly.

Referring now to Fig. 1, 10 is a source of voltage which may be connected to bus-bars $B_1 \dots B_N$ through keys 11, 24, 36, and commutators $C_1 \dots C_{13} \dots C_{25}$. Each commutator is equipped with one or more brushes 51, the number depending upon the number of times that generator 10 is to be connected to each of the buses $B_1 \dots B_N$ per revolution of the associated commutator. It is understood that there are as many buses provided as there are individual pulses to be linearly added in each note cycle, and that there are as many commutators per row between commutators C_1 and C_{13} as there are notes between a fundamental and its first harmonic or octave. In the complete organ there is one such set of brushes to reach note in the entire scale. Since the octaves bear an even number relation to the fundamental, that is, the frequency is 2, 4, 8, etc., times the frequency of the fundamental, the commutators corresponding to a fundamental and its octaves, for example, C_1 , C_{13} , C_{25} , etc., may be mounted on one shaft 52 and driven simultaneously. Thus one shaft will be required for each fundamental note in the scale. The commutator corresponding to a fundamental such as C_1 will have N segments equally spaced around its circumference and one brush cooperating therewith; the commutator corresponding to the first octave such as C_{13} will have N segments equally spaced around one-half of the circumference and two brushes 180 degrees apart cooperating therewith; the commutator corresponding to the second octave such as C_{25} will have N segments equally spaced around one-quarter of the circumference and four brushes 90 degrees apart cooperating therewith; etc. High resistances 12, 25, and 37, are connected between the keys and commutators. When any key is depressed the corresponding circuit is closed between voltage source 10 and bus-bars $B_1 \dots B_N$. The opposite side of voltage source 10 is connected to bus-bars $B_1 \dots B_N$ through a series of windings on transformers 13, 14, 15 and 16, the windings on any one transformer being energized in sequence by the operation of a commutator.

The windings W_1 from the core of transformer 13 are so arranged that the winding connected to any bar B_j is proportional to

$$\cos \frac{2\pi j}{N}$$

where N = the total number of bars B .

Hence when a key such as 36 is closed, if the resistance 37 is large, the flux in transformer 13 is nearly sinusoidal and of the same frequency as the commutator associated with key 36. In a similar manner, the flux in transformers 14, 15, etc., can be made approximately proportional to the second, third, etc., harmonics of the frequency of commutator C_{25} . Assuming still that the resistance 37 is large, it is seen that the operations of the various keys are practically independent, so that when any number of keys is depressed, the flux in transformer 13 is the sum of the fundamental fluxes for the depressed keys, the flux in transformer 14 is the sum of the second harmonics, etc.

Control of the harmonics is obtained by means of voltage dividers D_1, D_2, D_k connected across coils wound around the cores of transformers 13, 14, etc. An alternative method of harmonic control is shown in Fig. 2 wherein a movable secondary can be rotated from a position in which zero flux passes therethrough, to a maximum position. The primary is connected in series with the secondary of the tone generating transformer.

An advantage of the type of generator just described is that harmonics may be grouped together for convenience in quality control. It is possible, for example, to wind a set of coils to produce the fifth, seventh, and ninth harmonics in a constant ratio, and control them simultaneously.

The obvious similarity of the output of the present device with that of the ordinary pipe organ suggests the use of similar methods of control. Two manuals and a set of keyboards may therefore be employed. To cover the range of harmonic variations covered by the usual musical instrument, the following numbers of windings for the various fundamental frequencies may be used:

Octaves	Frequency	Number of windings		
		Pedal	Great	Swell
1	32	6	0	0
2	64	6	8	8
3	128	0	8	10
4	256	0	8	11
5	512	0	6	8
6	1024	0	3	4

The output of the tone generators may be connected to a high impedance amplifier, such as a vacuum tube. It is possible that generators of sufficient power could be built to drive loudspeakers directly.

The tone generator of Fig. 3 differs from the one just described in that a vibrating string is used instead of a commutator to obtain a sequence of pulses. It is well-known that a transverse displacement imparted to a small region of a taut string takes the form of two waves of displacement traveling in opposite directions from the affected regions with a velocity depending upon the mass per unit length and the tension of the string. In this way such a string transforms a function of time at a given point into a function of distance at a given time, or vice versa. This property can be used to generate current func-

tions of a required form by means of proper spatial conditions. Thus a periodic force can be applied to a wire and the resultant velocity at various points along the wire can be used to generate voltage functions of any required form. A wire having the proper fundamental frequency is assigned to each note and is maintained in oscillation by a vibrator or other means. In one form, a set of electromagnets can be arranged along each wire and energized so as to obtain a field of any desired form in which the wires vibrate. The voltage generated in any wire by the vibration in the field so formed is applied to an output amplifier by means of a key. In another form the moving field may be generated by depressing a key which sends a steady current through the proper vibrating wire. The moving field so produced generates voltages in a set of fixed coils arranged along the wires. The quality of the resultant tone is controlled by using more or less of the voltages generated in the various coils as in Fig. 1.

Referring now to Fig. 3, 40 is a wire stretched between bridges 41 and 42 and secured to frame 43. Between bridges 41 and 42 are positioned a series of electromagnets 44 adapted to be energized from a source 45 through individual voltage dividers 46. The wire 40 is set into vibration by a hammer 47 (Fig. 4), which in turn is actuated by the operation of electromagnet 49 and armature 50.

It is clearly undesirable to attach any appreciable mass to wire 40 because of the resulting change in the ratios of the normal frequencies. In order to generate all the harmonics equally, the maintaining force should be applied in very short impulses, and to a small region of the wire. To make the effect of the impulse on the isochronism as small as possible, the impulse should be given as the affected portion of the wire 40 passes through its neutral position. Finally, the period of the applied impulse must be controlled by the natural frequency of the string itself. By properly proportioning wire 40, hammer 47 and driving mechanisms 49 and 50, it is possible to attain all of these objects.

Wire 40 is connected to the output through a key 51. In operation, hammer 47 is operated continuously to obtain a constant vibration of wire 40. Thus electromagnets 44 are variously energized through voltage dividers 46, a correspondingly varying voltage will be generated in wire 40 by the vibrations thereof in proximity to electromagnets 44. The voltage wave generator therefore may be made to contain any number of harmonics in any desirable degree.

Thus in both forms of tone generators, a voltage wave is propagated by the linear addition of successive short voltage pulses as shown in Fig. 5, and each pulse, by virtue of voltage dividers, is susceptible to individual control. It is understood the variants of the above tone generators may suggest themselves to those skilled in the art and the invention therefore is not to be limited to the disclosure herein contained but is to be determined by the appended claims.

What is claimed is:

1. Means for producing a tone electrically comprising a source of voltages, commutator means for selecting the voltages in a predetermined sequence, each voltage comprising an elementary portion of a cycle of the tone, and an external circuit comprising a large resistance, a key, and an electromechanical sound translating device in series with the commutator and voltage source.

2. Means for producing a tone electrically comprising an electric circuit including a source of potential, means for periodically interrupting the circuit to said source of potential, means for translating said interruptions into voltage surges occurring at the fundamental frequency of the tone, and into voltage surges occurring at frequencies which are harmonically related to said fundamental frequency, said translating means comprising a plurality of transformers, one for the fundamental and one for each harmonic, primaries on the transformers, secondaries inductively related to the primaries and individual voltage dividers on said secondaries for controlling the relative amplitudes of the fundamental and harmonics.

3. Means for producing a tone electrically comprising a taut electroconductive string, means for producing a magnetic field of adjustable shape cutting the string, and means for causing the string to vibrate, thereby generating electromotive forces of any desired wave form in the string.

4. Means for producing a tone electrically comprising a taut electroconductive string, means for producing a magnetic field of adjustable shape cutting the string, said means comprising electromagnets located at intervals along the string, and means for vibrating the string to generate electromotive forces of any desired wave form in the string.

5. Means for producing a tone electrically comprising a taut electroconductive string, means for producing a magnetic field of adjustable shape cutting the string, said means comprising electromagnets located at intervals along the string, means for controlling the strength of each elec-

tromagnet, and means for vibrating the string to generate electromotive forces therein of a wave form corresponding to the strength of the electromagnets.

6. Apparatus as in claim 5, and a switch for controlling the electromotive forces in the wire.

7. Means for producing a tone electrically comprising an electric circuit including a source of potential, means for periodically interrupting the circuit to said source of potential, means for translating said interruptions into voltage surges occurring at the fundamental frequency of the tone and into voltage surges which are harmonically related to said fundamental frequency, said translating means comprising a plurality of transformers, one for the fundamental and one for each harmonic thereof.

8. A synthetic tone producer comprising for each complex tone pitch a single generator adapted to generate each half cycle of said tone as a single series of successive pulses along the time axis, a plurality of electromagnetic devices associated with said generator, and a separate voltage divider for each electromagnetic device connected in shunt with a winding thereof.

9. A synthetic tone producer comprising for each complex tone pitch a single generator adapted to generate each half cycle of said tone as a single series of successive pulses along the time axis, a plurality of electromagnetic devices associated with said generator, a separate voltage divider for each electromagnetic device having its resistor connected in shunt with a winding thereof and interconnecting means connecting the several voltage dividers in a series relation.

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