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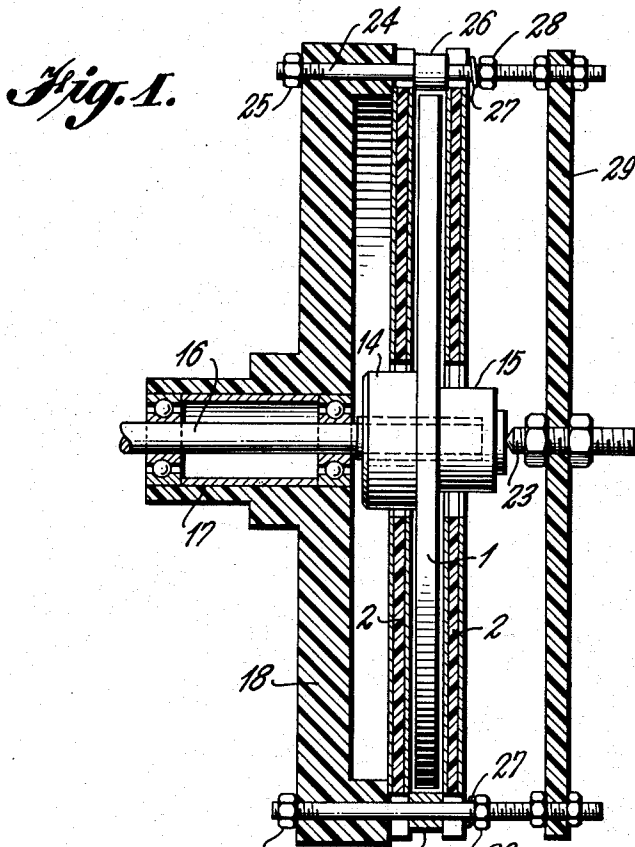
J. A. DEREUX

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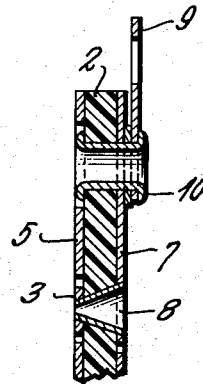
AUDIO SIGNAL GENERATORS AND THEIR METHOD OF MANUFACTURE

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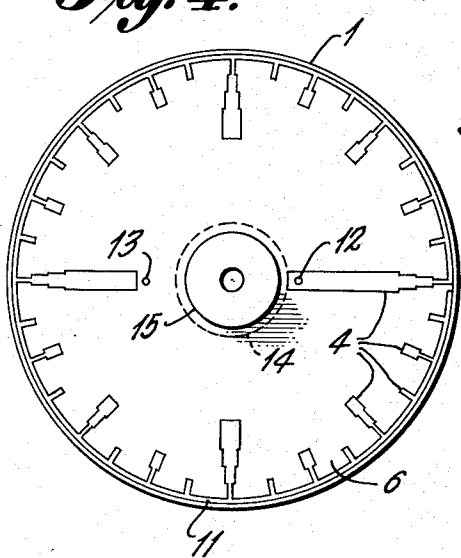
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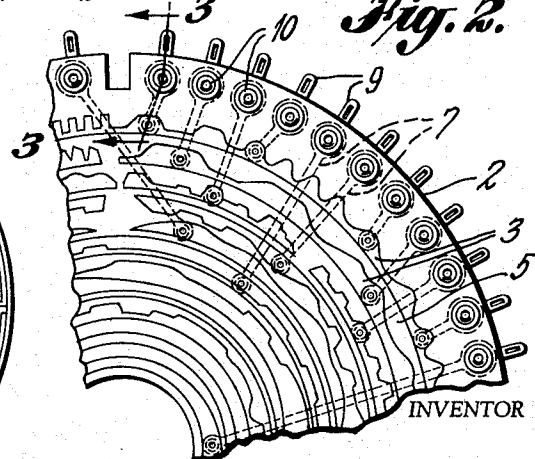
*Fig. 3.*



*Fig. 4.*



*Fig. 2.*



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ATTORNEYS

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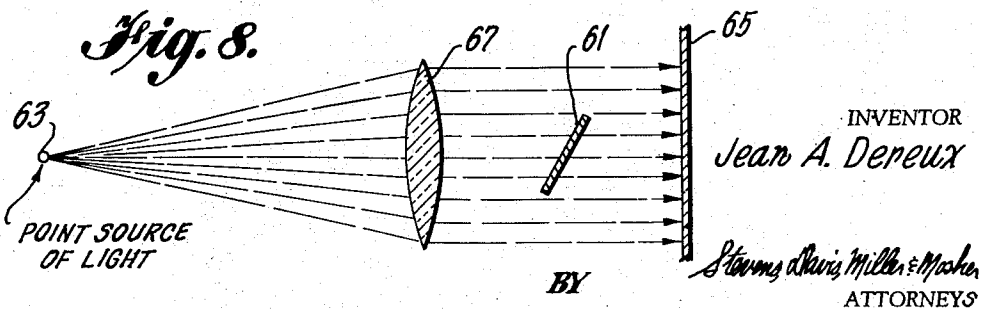
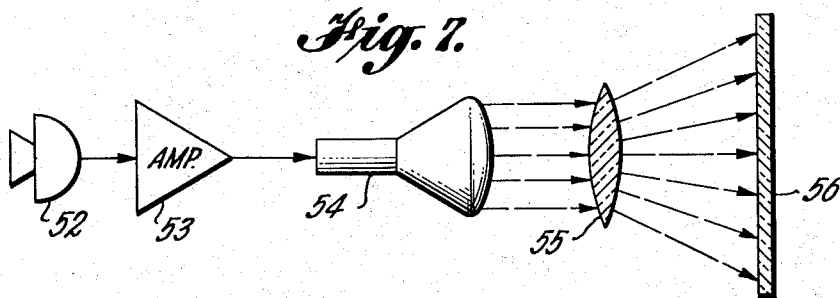
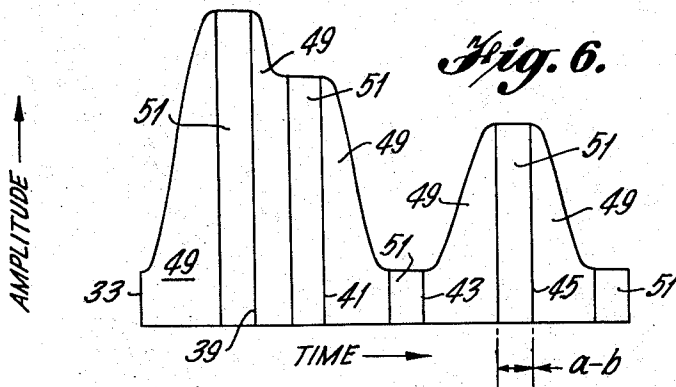
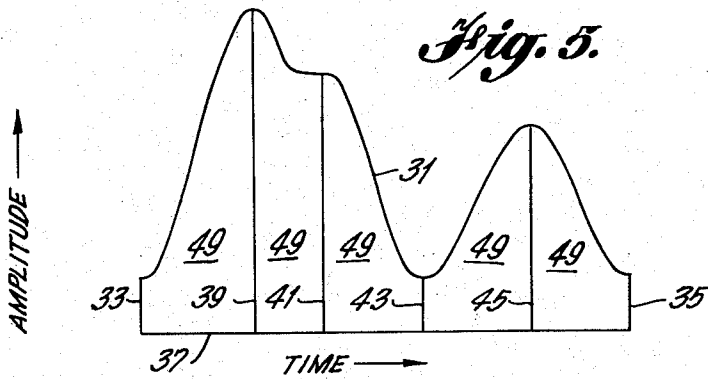
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AUDIO SIGNAL GENERATORS AND THEIR METHOD OF MANUFACTURE

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**AUDIO SIGNAL GENERATORS AND THEIR  
 METHOD OF MANUFACTURE**

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 Filed May 9, 1960, Ser. No. 27,676  
 8 Claims. (Cl. 84—1.28)

The present invention relates to an improved electrostatic musical instrument and a method of manufacturing this improved musical instrument and more particularly to audio signal generators in a recording electric organ and to the method of manufacturing of these generators.

Electrostatic musical instruments of the type of which the present invention is an improvement comprise one or more sets of 12 audio signal generators corresponding to the twelve notes of the scale. Each generator comprises a rotor in the form of a disc, which rotates opposite a stationary plate, which forms a variable capacitor with the rotor. The capacitance of the capacitor thus formed varies as the rotor rotates and this variation in capacitance is converted into an electrical signal, which is amplified and applied to a transducer such as a loud-speaker. The stationary member has tonal patterns defined in conducting film concentrically about the axis of the rotor. These concentric tonal patterns are formed from oscillograms of the tones to be reproduced by the musical instrument. The tonal patterns form one plate of the variable capacitor and scanning arms defined in conducting film on the rotor form the other plate of the variable capacitor. The scanning arms are positioned to lie radially on the rotating disc so that, as the disc rotates, the scanning arms will pass over the tonal patterns in the correct direction.

Small imperfections in the tonal patterns, such as the surfaces of the tonal patterns not being perfectly plane or the contours of the tonal patterns being slightly ragged, will cause a substantial amount of undesirable noise. This noise can be eliminated by making the scanning arms wider as the imperfections are then averaged out. However, when the scanning arms are made wider, the high harmonics in the tonal patterns are eliminated or suppressed. The present invention is directed at eliminating this serious drawback.

According to the invention the tonal patterns are formed not exactly in accordance with the oscillograms of the tones to be reproduced but with a preliminary deformation so that the signals produced with wide scanning arms are identical to the signals transduced from the original tones. In this process the oscillograms of the desired tones are transposed anamorphically and the tonal patterns are formed in accordance with the resulting function. This anamorphic transposition is carried in such a manner that when a scanning arm rotates past a tonal pattern, the audio signal produced will be substantially identical to the original electrical signal from which the oscillogram was made even though a wide scanning arm is used to prevent distortion due to minute unevenness and raggedness of the tonal pattern. Thus, when the electrical signal produced by the audio signal generator is applied to a loud-speaker or other similar transducer, the sound produced will correspond with the original sound with extremely high fidelity.

The particular manner in which the oscillograms are anamorphically transposed will now be briefly described but a better understanding of this process will be obtained from the detailed description of the invention which follows.

The oscillogram is divided at its maxima and minima and at any other points of zero slope. The resulting parts of the oscillogram are contracted predetermined amounts depending upon their lengths in the direction of the time

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coordinates of the oscillogram. The contracted parts are then arranged in the same chronological order in which they originally occurred and joined by straight lines of zero slope and equal length. When the pattern derived from the function resulting from this transposition is scanned by a scanning arm having a width approximately equal to the length of the straight lines of zero slope and the resulting signal transduced into sound, this sound will be a very faithful reproduction of the original sound from which the tonal pattern was made.

Further objects and advantages of the present invention will become readily apparent as the following detailed description of the invention unfolds and when taken in conjunction with the drawings wherein:

FIGURE 1 shows a view in partial section of an audio signal generator of the type to which the present invention applies;

FIGURE 2 shows a partial view of the inner face of one of the stationary plates of the generator of FIGURE 1;

FIGURE 3 shows a sectional view of the plate of FIGURE 2 taken along the line 3—3;

FIGURE 4 shows a view of one face of the rotor of the generator of FIGURE 1;

FIGURE 5 shows an example of a tonal pattern formed in accordance with an oscillogram of a tone;

FIGURE 6 shows a tonal pattern formed in accordance with the function resulting after the oscillogram has been anamorphically transposed;

FIGURE 7 illustrates in block form the system according to the preferred embodiment of the invention for generating the oscillograms to be used in forming the tonal patterns; and

FIGURE 8 illustrates the preferred system for carrying out the anamorphic transposition.

As shown in FIGURE 1, the audio signal generator of the musical instrument comprises essentially a disc 1 rotating between two circular plates 2, disposed parallel to the disc and at equal and very small distances from the said disc. As shown in FIGURE 2, the plates 2 are provided on their inner faces with tonal patterns 3, which are distributed along concentric circles about the rotational axis of the disc 1. The disc 1 as shown in FIGURE 4 is provided on both its faces with radially extending scanning arms 4 having different lengths and widths. The disc 1 and the plates 2 each comprise a base of insulating material, which is coated with an electrically conducting metallic film on the order of a few microns thick. The tonal patterns 3 and the radial scanning arms 4 are defined and insulated from the remaining unused metallic coatings 5 and 6 by thread-like grooves which pass through the metallic film and lay exposed thin lines of insulating material.

As shown in FIGURE 3 the tonal patterns 3 of the plates 2 are electrically connected to electrically conducting strips 7 provided on the outer faces of the plates 2 by means of holes 8 of flared form, converging towards the inner faces of the plates. The strips 7 are also defined and insulated from the unused metallic coating on the rear faces of the plates 2 by grooves passing through the metallic coating. The walls of the flared holes 8 are also coated with electrically conducting metallic film, which comprises the connections between the tonal patterns 3 and the strips 7. The strips are severally connected to terminals 9, which are riveted at 10 to the periphery of the plates 2.

The radial scanning arms 4 of the disc 1 are interconnected at their peripheral extremities by a circular electrically conducting strip 11, which is also insulated from the unused conducting film 6 by a threadlike groove. The scanning arms 4 on each face of the disc 1 are con-

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nected together by an electrically conducting metallic coating on the wall of a hole 12 and the unused conducting film 6 on each face of the disc 1 is connected together by an electrically conducting metallic coating on the wall of a hole 13.

At the center of disc 1 is a hub having ends designated 14 and 15. The hub ends 14 and 15 are each coated with electrically conducting metallic material. The disc 1 is driven at a constant speed by an electrically conducting shaft 16, which is electrically connected to the conducting film on the hub end 14. A carbon contact 23 is applied against the center of the hub end 15. The unused metallic film 6 is electrically connected to the conducting coating on the hub end 14 and by means of the electrical connection through the shaft 16 and conducting coating on the hub end 14, the unused metallic film 6 is grounded. The conducting coating on the hub end 15 is electrically connected to the scanning arms 4 on the disc 1 and by means of the connection through the carbon contact 23 and the conducting coating on the hub end 15 to the scanning arms 4, the output signal from the audio signal generator is taken.

The shaft 16 rotates in a roller bearing 17 housed in the center of a side plate 18. The two plates 2 are fixed to the side plate 18 by means of threaded rods 24 and nuts 25, small spacing rods 26 separating the two plates and keeping them at the desired distance apart. The coupling preferably comprises a spring 27 surrounding the threaded rod and supported on the one hand against a nut 28 and on the other hand against the adjacent plate 2, the parallelism of the plates being ensured by the spacing rods 26 which are regularly spaced apart and which, in one example of construction, are forty-four in number. The threaded rods 24 carry in addition a mounting strip 29, at the center of which is mounted the carbon contact 23.

The structure of the sound generator described above is disclosed in the copending application Serial No. 639,344, now Patent No. 2,959,083, filed February 11, 1957, issued on November 8, 1960, and invented by Jean A. Dereux, the inventor of the present application. In the musical instrument there are one or more sets of twelve of these audio signal generators like the one described above, one generator of each set of twelve for each note of the scale. The different tonal patterns 3 on the plates 2 of each generator are each used to generate tones of different harmonic content and tones of different octaves of the same note. The tonal patterns 3 toward the center of the plates 2, generate the tones of the lower octaves and the tonal patterns toward the outer edge of the plates 2 generate the tones of the higher octaves. It will be noted from FIGURE 2 that toward the outer edge of the plates 2 there are plurality tonal patterns distributed around each concentric circle and thus many of the tonal patterns cover only small arcs of the circles along which they are distributed.

In operation the disc 1 is rotated at a constant speed. In order to cause a tone to be generated one of the tonal patterns 3 will be energized by having a high potential applied thereto from the appropriate terminal 9. When one of the scanning arms 4 passes over the energized tonal pattern, the capacitance between the scanning arm and the selected tonal pattern will vary in accordance with the shape of the tonal pattern. Because a high potential is applied to the selected tonal pattern a varying voltage will be produced on the scanning arm 4 and this signal will appear as an audio output signal from the carbon contact 23.

The audio signal will be continuously produced from the carbon contact 23 even though the selected tonal pattern covers only a small arc of the circle along which it is distributed because when one of the scanning arms 4 has completed its traversal or scan of the selected tonal pattern another scanning arm will begin its scan of the selected tonal pattern. The output from the carbon

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contact 23 is amplified and applied to a loudspeaker system to produce the desired tone.

The tonal patterns 3 are formed from oscillograms of the tones desired to be reproduced. If a precise oscillogram were used for the profile of each tonal pattern and the width of the scanning arms 4 were infinitesimal, theoretically the tones would be precisely reproduced. As a practical matter, however, the scanning arms 4 have to have a finite width. Furthermore, any slight unevenness or raggedness in the tonal patterns will cause intolerable distortion particularly in the lower notes. This kind of distortion can be eliminated by using wider scanning arms. The thinner the scanning arm the more precisely the tonal patterns have to be formed and if very thin scanning arms are used the expense of manufacturing the plates becomes very great. To keep the cost of manufacture of the plates within reason it is necessary that the scanning arms have considerable width, particularly the scanning arms which scan the tonal patterns of low tones. Thus as seen in FIGURE 4 the scanning arms are wider nearer the center of the disc 1 where the tonal patterns of the lower tones on the plates 2 are positioned.

The use of the wider scanning arms gives rise to another form of distortion in that the wider scanning arms suppress and eliminate the higher harmonics of a tone. It is this distortion which the present invention eliminates and thus permits high quality electrical musical instruments to be manufactured very inexpensively.

To make the tonal patterns, oscillograms of the tones desired to be reproduced are first generated. These oscillograms are graphical representations of one or more cycles of amplitude versus time of the electrical signals transduced from the tones or, in other words, the graphical representations of the air pressure versus time when the tones are generated. Since each cycle of a steady tone is identical, it is only necessary that one cycle of the tone be represented in an oscillogram.

An example of an oscillogram of a tone on a set of Cartesian coordinates is shown in FIGURE 5 designated by the number 31. In this oscillogram the amplitude coordinates are vertical and the time coordinates are horizontal. One complete cycle of the tone is graphically represented by that part of the oscillogram 31 between the vertical lines designated by the reference numbers 33 and 35.

To make a tonal pattern from the oscillogram 31, a horizontal line 37 is provided as shown in FIGURE 5 beneath the oscillogram 31 positioned so that it does not intersect the oscillogram 31 and is spaced a substantial distance from the oscillogram 31. The shape bounded by the oscillogram 31, the vertical lines 33 and 35, and the horizontal line 37 is a tonal pattern. If this tonal pattern were transferred to polar coordinates, defined in conducting film along one of the concentric circles of the plates 2, and scanned continuously by a scanning arm of infinitesimal width, theoretically the sound produced would be the precise tone represented by the oscillogram 31. However, for the reasons explained above, the scanning arm widths are not infinitesimal but on the contrary have substantial widths.

To compensate for the wide scanning arms, the oscillogram and tonal pattern shown in FIGURE 5 are anamorphically transposed. This transposition is carried out by dividing the tonal pattern along the time axis at each point of zero slope of the oscillogram 31. The vertical lines 33, 39, 41, 43, 45, and 35 divide the tonal pattern in this manner. The resulting parts of the tonal pattern, which are designated by the reference number 49, are contracted in the direction of the time coordinates predetermined amounts and separated so that each contracted part of the tonal pattern occupies the same position in time along the time coordinates but takes up less of a time interval as is illustrated in FIGURE 6. The resulting pieces are then connected together with rectangular pat-

tern inserts 51. The dimensions of these inserts 51 and of the parts 49 in the direction of the amplitude coordinates are referred to as amplitude dimensions and the dimensions of the parts 49 and the inserts 51 in the direction of the time coordinates are referred to as time dimensions. Similarly, the dimensions of the tonal patterns in the corresponding directions are referred to as amplitude and time dimensions. The rectangular inserts 51 each have an amplitude dimension equal to the amplitude dimension of the tonal pattern where such part is inserted so that the profiles of the adjacent contracted parts 49 are joined by lines of zero slope. The transposition is carried out in such a manner that the time dimension of each of the inserts 51,  $a-b$  in FIGURE 6, is equal substantially to the width of the scanning arm 4 which will scan the tonal pattern. Thus, since each of the contracted parts 49 do not change their position in time, but start from the same vertical lines 33, 39, 41, 43 and 45, the amount that each of the parts 49 are contracted depends upon its time dimension. Each part 49 must be contracted the precise amount to make room for the time dimension  $a-b$  of the inserts 51. Thus the parts 49 having the longer time dimensions will be contracted less and the parts having the shorter time dimensions will be contracted more.

The resulting shape shown in FIGURE 6 is transferred to polar coordinates and then defined in metallic film along one of the concentric circles of the plates 2 to provide one of the tonal patterns of the plates 2. Each of the many tonal patterns of the plates 2 of the sound generator are formed in this manner. The resulting sound produced when these tonal patterns are energized by having a high potential applied thereto will be a faithful reproduction of the original sound from which the sound was made.

The variation of the capacity between the scanning arm 4 and the tonal pattern 3 over which it is passing varies linearly with the radial dimensions of the tonal pattern only if the dimension in this direction is not negligible. For this reason each of the tonal patterns 3 have a substantial radial dimension throughout their length. This substantial radial dimension is provided in the tonal pattern in FIGURE 5 by spacing the horizontal line 37 apart from all parts of the oscillogram 31. Because the line 37 is spaced apart from the oscillogram 31, the anamorphically transposed tonal pattern in FIGURE 6 will have a substantial vertical dimension throughout its length and after it is transferred to polar coordinates it will have a substantial radial dimension throughout its length.

According to the preferred embodiment of the invention, the tones or notes which are to be reproduced by the musical instrument of the present invention are originally generated by a pipe organ, which is selected to be the best available instrument of this type. Each note to be reproduced is generated individually by the pipe organ, transduced into a corresponding audio electrical signal, and an accurate oscillogram is made of each of the tones. The oscillogram of each tone is produced by detecting each note with a microphone, which is placed in the mouth of the pipe producing the tone. In FIGURE 7, which illustrates in block form the preferred system for reproducing the oscillograms of the tones, the microphone is designated by the reference number 52. The microphone 52 transduces the note into an electrical signal, which is amplified by an amplifier 53 and applied to an electron beam tube 54. The electron beam tube 54 is a special kind of oscilloscope, which is a two inch projection TV tube of the type having 100 line definition. The projection tube is operated like an oscilloscope to produce the oscillogram of the tones. The sweep on the electron beam tube 54 is adjusted so that at least one full cycle of the waveform is shown on the face of the tube. The waveform of the tone thus produced on the face of the projecting tube 54 is enlarged by lens 55 and focused on a ground glass screen 56. The tonal pattern such as

that shown in FIGURE 5 is then made from the image of the oscillogram on the ground glass screen.

According to the preferred embodiment the tonal patterns such as that shown in FIGURE 5 are anamorphically transposed into tonal patterns such as that shown in FIGURE 6 by a method illustrated in FIGURE 8. According to this method opaque planar members are prepared having silhouettes identical to the parts 49 of the tonal pattern after it is divided. In FIGURE 8 one of these planar members is shown and is designated by the number 61. According to the method as illustrated in FIGURE 8 the planar member 61 is positioned between a point source of light 63 and a sheet of film 65. A long focal length lens 67 is positioned between the point source of light 63 and the planar member 61. The lens 67 is positioned so that the point source 63 is at its focal point. The rays from the point source 63 therefore become parallel after passing through the lens 67. The lens 67 is positioned so that the parallel rays emanating from it impinge perpendicularly on the film 65. When the point source of light 63 is energized, the opaque planar member 61 will cast a shadow on the sheet of film 65 and thus the shadow will be photographed. The planar member 61 is positioned so that it is not parallel with the plane of the film 65 but so that the edges of the planar member 61 which correspond to the amplitude dimensions of the parts 49 of the divided tonal pattern are parallel to the plane of the film 65. In the tonal pattern of FIGURE 5 these edges would correspond to a pair of the lines 33, 39, 41, 43, 45, and 35. In other words, the planar member 61 is slanted with respect to the film 65 so that the shadow is contracted along the dimension that corresponds to the time dimension of a part 49 but not along the other dimension corresponding to the amplitude dimension of such part. This operation is performed on each planar member and thus a photograph of the shadow of each planar member is provided. The shapes of these photographed shadows are the contracted parts, which are joined together to make up an anamorphically transposed tonal pattern such as that shown in FIGURE 6. Thus from the photographs of the shadows the anamorphically transposed tonal pattern may be easily derived. The amount that the part 49 is contracted depends upon the slant of the planar member 61 and thus the correct contraction for each part 49 can be provided simply by controlling the slant of each planar member when its shadow is photographed by the process of FIGURE 7. It is important that the planar members provide accurate silhouettes of the divided parts of the tonal pattern so it is important that the planar members be truly planar.

After the anamorphically transposed tonal pattern has been derived it is then a simple matter to transfer the tonal pattern to polar coordinates and then define its shape in the conducting film on the plates 2. In this manner the tonal patterns 3 are provided on the plates 2. The tonal patterns 3 are thus defined in the conducting film as shapes whose radial dimension varies in accordance with a function of angular displacement, which function is derived from the oscillogram of the tone desired to be reproduced by dividing the oscillogram along its length at its points of zero slope, contracting the resulting parts of the oscillogram predetermined amounts and joining the contracted parts with equal length lines of zero slope, the predetermined amounts of contraction being selected so that each part of the function comprising one contracted part and one straight line of zero slope occupies the same time interval as the original such part occupied before it was contracted and the length of the straight lines of zero slope being selected to approximately equal the width of the scanning arm which scans the tonal pattern.

In this manner audio generators are provided which very faithfully reproduce the original tones even though wide scanning arms are used and a relatively inexpensive electric organ is provided producing tones comparable

with the tones produced from the best available pipe organs.

Many modifications may be made to the above described embodiment of the invention without departing from the spirit and scope of the invention, which is limited only as defined in the appended claims.

What is claimed is:

1. An audio signal generator comprising a rotor having radially extending scanning arms of conducting material, a stator having a plurality of tonal patterns defined in conducting material and distributed along perimeters of concentric circles about the axis of said rotor, said tonal patterns each positioned to form a variable capacitance with one of said scanning arms, which capacitance varies as said rotor rotates, said tonal patterns having radial dimensions which vary as predetermined functions of angular displacement along said tonal patterns, said predetermined functions comprising the functions that result when oscillograms of the different audio signals desired to be produced are each divided at their points of zero slope, the resulting parts of said oscillograms are contracted predetermined amounts in the direction of the time coordinates of said oscillograms, and the contracted parts of each of said oscillograms are connected together again in the same chronological order with lines of zero slope, said lines of zero slope for each tonal pattern having lengths equaling the width of the respective ones of said scanning arms positioned to form a variable capacitance with such tonal pattern, said predetermined amounts of contraction being such that each contracted part of said oscillograms together with an adjacent one of said lines of zero slope occupies the same time interval that such part occupied before it was contracted.

2. An audio signal generator comprising a rotor having a radially extending scanning arm of conducting material, a stator having a tonal pattern defined in conducting material distributed along the perimeter of a circle about the axis of said rotor, said tonal pattern being positioned to form a capacitance with said scanning arm which varies as said rotor rotates, said tonal pattern having a radial dimension which varies as a predetermined function of angular displacement along said tonal pattern, said predetermined function comprising the function that results when an oscillogram of the audio signal desired to be produced is divided at each of its points of zero slope, the resulting parts of said oscillogram are contracted predetermined amounts in the direction of the time coordinates of said oscillogram, and the contracted parts are connected together in the same chronological order with lines of zero slope, said lines of zero slope having lengths approximately equal to the width of said scanning arm, said predetermined amounts of contraction being such that each contracted part of said oscillogram together with an adjoining one of said lines of zero slope occupies the same interval that such part occupied before it was contracted.

3. An audio signal generator comprising a variable capacitor, one plate of said capacitor having its surface area in the shape of a tonal pattern, said tonal pattern having a first dimension parallel to a first set of coordinates which varies as a predetermined function of displacement along a second set of coordinates, said predetermined function being derived from an oscillogram of the audio signal desired to be produced by dividing said oscillogram along its length at its points of zero slope, contracting the resulting parts of said oscillogram predetermined amounts in the direction of the time coordinates of said oscillogram, and connecting the resulting contracted parts together in the same chronological order with lines of zero slope and equal length, said predetermined amounts of contraction being such that each contracted part of said oscillogram together with an adjoining one of said lines of zero slope occupies the same time interval as such part of said oscillogram occupied before

it was contracted, the other plate of said capacitor comprising a conducting scanning arm movable with respect to said tonal pattern in the direction of said second set of coordinates, the width of said scanning arm being approximately equal to the length of said lines of zero slope.

4. A method of manufacturing an audio signal generator of the capacitive type comprising the steps of generating an oscillogram of the audio signal desired to be reproduced by said audio signal generator, deriving a function from said oscillogram by dividing said oscillogram at its points of zero slope, contracting the resulting parts of said oscillogram predetermined amounts in the direction of the time coordinates of said oscillogram, connecting the resulting contracted parts together in the same chronological order with lines of zero slope and equal length, said predetermined amounts of contraction being such that each resulting contracted part together with an adjoining one of said lines of zero slope occupies the same interval occupied by such part before it was contracted, and forming a pattern on a set of amplitude and time coordinates having one dimension in the direction of the amplitude coordinates which varies in accordance with said function along the time coordinates, shaping the surface area of one plate of a capacitor in the form of said pattern, and providing as the other plate of said capacitor a scanning arm capacitively coupled to and movable with respect to said one plate and having a width approximately equal to the length of said lines of zero slope.

5. A method of producing an anamorphically transposed tonal pattern of an audio signal for use in an audio signal generator comprising the steps forming on a set of time and amplitude coordinates a first tonal pattern of said audio signal having an amplitude dimension in the direction of said amplitude coordinates which varies in accordance with the oscillogram of said audio signal along said time coordinates, dividing said first tonal pattern along lines parallel to said amplitude coordinates at each point along said time coordinates where said oscillogram of said tone has a zero slope, contracting the resulting parts of said first tonal pattern predetermined amounts in the direction of said time coordinates, connecting the resulting contracted parts of said first tonal pattern together in the same chronological order with additional pattern inserts having equal time dimensions in the direction of said time coordinates and each having a constant amplitude dimension in the direction of said amplitude coordinates equal to the amplitude dimension of said first tonal pattern at the point where such additional pattern insert joins two contracted parts of said first tonal pattern to thereby provide a second tonal pattern anamorphically transposed from said first tonal pattern.

6. A method of producing an anamorphically transposed tonal pattern of an audio signal for use in an audio signal generator in accordance with the method of claim 5 wherein said step of contracting the divided parts of said first tonal pattern predetermined amounts in the direction of the time coordinates comprises the steps of making members having silhouettes corresponding to the shapes of said divided parts, generating parallel rays of light impinging perpendicularly upon a flat surface, placing said members separately in the path of said parallel rays of light to cast a shadow on said flat surface, and slanting the silhouettes of said members predetermined amounts with respect to said parallel rays of light in the direction of the time dimension of said members to thereby provide as a shadow on said flat surface the shapes of said contracted parts of said first tonal pattern, the predetermined amount of slanting for each member being determined by the amount of contraction necessary for the divided part of said first tonal pattern corresponding to such member.

7. A method of producing an anamorphically transposed tonal pattern of an audio signal for use in an audio signal generator comprising the steps of generating an oscillogram of said audio signal, deriving a function from

said oscillogram by dividing said oscillogram at its points of zero slope, contracting the resulting parts of said oscillogram predetermined amounts in the direction of the time coordinates of said oscillogram, connecting the resulting contracted parts together in chronological order with lines of zero slope and equal length, said predetermined amounts of contraction being such that each resulting contracted part together with an adjoining one of said lines of zero slope occupies the same time interval occupied by such part before it was contracted, and forming a pattern having a silhouette corresponding to said function.

8. A method of producing an anamorphically transposed tonal pattern of an audio signal for use in an audio signal generator comprising the steps of generating an oscillogram of said audio signal, deriving a function from said oscillogram by dividing said oscillogram at its points of zero slope, contracting the resulting parts of said oscillogram predetermined amounts in the direction of the time coordinates of said oscillogram, connecting the resulting contracted parts together in the same chronological order with lines of zero slope and equal length, said predetermined amounts of contraction being such that each re-

sulting contracted part together with an adjoining one of said lines of zero slope occupies the same interval occupied by such part before it was contracted, and forming a pattern on a set of amplitude and time coordinates having one dimension in the direction of the amplitude coordinates which varies as said function of displacement along said time coordinates.

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