

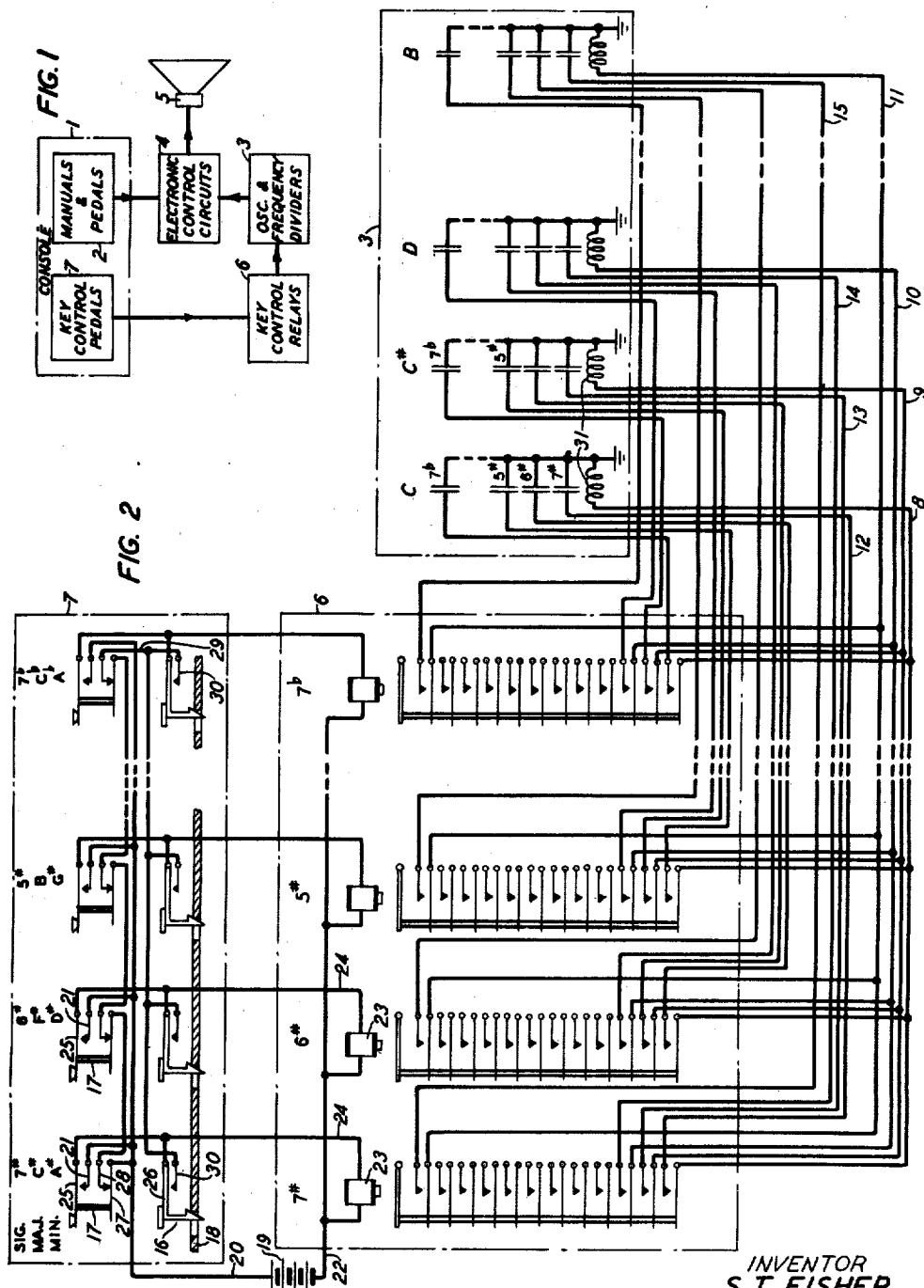
Aug. 18, 1942.

S. T. FISHER

2,293,499

MUSICAL INSTRUMENT

Filed Oct. 15, 1940



INVENTOR
S. T. FISHER

BY

G. H. Heydt
ATTORNEY

Patented Aug. 18, 1942

2,293,499

UNITED STATES PATENT OFFICE

2,293,499

MUSICAL INSTRUMENT

Sidney T. Fisher, Montreal, Quebec, Canada, assignor to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York

Application October 15, 1940, Serial No. 361,221

9 Claims. (Cl. 84—1.11)

This invention relates to electrical musical instruments and more particularly to an electrical musical instrument whose scale frequencies bear exact integral ratios to each other.

Just scale musical instruments have been under consideration by many investigators for many years and in recent years a number of articles have appeared in technical journals on this subject. Such an instrument due to anomalies in scale structure have been regarded by most authorities as being impossible from a practical standpoint. It has thus become to be regarded by most musicians as an ideal end to be sought after but which is impossible of practical attainment.

This invention therefore has for its object the provision of a structure capable of practical use whose scale frequencies bear exact harmonic relationships with one another to the end that maximum harmoniousness may be achieved.

The foregoing object is attained by this invention by providing an electrical musical instrument containing a plurality of octaves, each having twelve notes, tuned to a given key in Just intonation, and a means for substantially instantaneously returning the notes of each of these octaves to sound with Just intonation in any other desired key.

The invention may be better understood by referring to the attached drawing, in which:

Fig. 1 is a schematic diagram in block form showing the invention applied to an electronic musical instrument having a plurality of oscillators and frequency dividers; and

Fig. 2 shows a preferred embodiment of the invention.

Referring now to Fig. 1 which discloses a console 1 having mounted thereon the manuals, pedals, quality and volume controls 2, a system of oscillators and frequency dividers 3, an electronic control circuit 4 and speaker system 5. The instrument so far described in schematic form is preferably of the form disclosed in United States Patent 2,126,682 to Laurens Hammond, issued August 9, 1938. In this instrument a system of twelve oscillators is provided for the top octave and the frequencies for all lower octaves are obtained by a successive series of cascaded frequency divider systems. The electronic organ therein described is preferred in connection with this invention because of its inherent ability to change frequency with great rapidity.

According to this invention a system of key control relays 6, more particularly hereinafter

described, is adapted to have a controlling influence over the frequencies of the twelve oscillators in the oscillator and frequency divider unit 3. The action of these key-control circuits is under the control of a series of key-control pedals 7 mounted on the console 1.

Instead of tuning the twelve oscillators in the oscillator and frequency divider unit 3 in the scale of equal temperament they are preferably tuned according to this invention, for the key of C major, so as to bear the following frequency ratios to the tonic frequency C: 1, 17/16, 9/8, 6/5, 5/4, 4/3, 11/8, 3/2, 25/16, 5/3, 7/4 and 15/8. The foregoing series of intervals have been selected because they provide the greatest consonance in harmony, pleasing melodic intervals and the maximum of harmonic content in exact mathematical ratios.

In tuning the instrument in the manner above described, it is apparent that its use would be limited to playing music in the keys of C major and A minor only. Moreover, existing music is written with occasional chords that do not properly belong to the key indicated by its key signature. With present musical instruments tuned to the scale of equal temperament these chords are played in equal temperament as if they belonged to the key indicated. This invention proposes to avoid this difficulty on a justly intoned basis without changing the fingering technique, that is to say, the fingering will remain the same as for the scale of equal temperament but by the operation of an auxiliary pedal control these occasional chords are caused to sound correctly. This will be described more in detail in connection with Fig. 2.

As previously stated, the oscillator section 3 of Fig. 1 contains twelve oscillators one for each note of the octave which, according to the usual custom, have been denoted C, C $\sharp$, D, D $\sharp$, E, F, etc. Each of these oscillators contains a tank coil and a condenser to form the frequency determining network.

In Fig. 2 the circuits for the key-control pedals 7, key-control relays 6 and the tank circuits for the oscillators of oscillator section 3 are shown in detail. It will be noted that the tank circuits of the oscillators for notes C, C $\sharp$, D and B of the octave are shown, the remaining eight being deleted for the sake of clarity. Each of these tank circuits comprises a tank coil 31 and a plurality of condensers which may be individually connected in parallel with the coil by means of magnetic switches described later. To provide the natural keys of C major and A minor

and all the major keys and relative minor keys from seven sharps to seven flats, inclusive, it is necessary to provide fifteen condensers for each tank coil. Only four of these condensers are shown in the drawing, the rest being deleted for the sake of clarity. Likewise in the key-control relay unit 6 there must be fifteen relays supplied, one for each of the keys from seven sharps to seven flats, inclusive, including the natural keys. Switches in the key-control pedal unit 7 are adapted to operate any one of these relays at a time.

Referring to the tank circuits again, it will be noted that one side of all the condensers and one side of the tank coil for each oscillator are connected to the chassis ground. If other types of oscillators are employed, this connection to chassis ground may not be required as is well known. The remaining circuits of these oscillators have not been shown but may be of any form such as, for example, the oscillator intended for use in the structure disclosed in the above-mentioned patent to Hammond 2,126,682. The other terminal of each of these tank coils is connected to one switch blade of each of the relays in relay section 6. For example, the ungrounded end of the tank coil for oscillator C is connected to its associated switch blade in the 1 $\sharp$ relay by way of conductor 8. It will also be noted that this conductor is multiplied to a similar switch blade in each of the remaining fourteen relays. A similar connection will be found for each of the other tank coils, for example, the tank coil for the C $\sharp$ oscillator is connected to its associated switch blades in relay section 6 by way of conductor 9.

Referring now to the ungrounded side of the tank condensers. It will be seen that they are connected to the complementary switch blades in each of the key-control relays in such a way that when any one of the relays is operated one condenser in each tank is paralleled with its tank coil and should this relay be released and a second relay operated another condenser in each tank is caused to replace the first condenser in parallel with its tank coil. By way of a specific example, assume that the relay marked 1 $\sharp$ in the key-control relay section 6 is operated. It will immediately be apparent that conductor 12 leading from a condenser in the C oscillator is connected to conductor 8 so that this condenser is caused to shunt its associated coil. Likewise, conductor 13 of the C $\sharp$ oscillator is connected to conductor 9 and conductor 14 is connected to conductor 10, and so forth. Similar circuits may be traced for each of the other relays.

The purpose of the above-described switching arrangement is to retune each of the oscillators in Just intonation for the key in which it is desired to play. Stated otherwise, each of these relays will select one of the notes of the octave as the key-note and will simultaneously retune the other eleven oscillators so that their musical interval with the key-note will follow the series 17/16, 9/8, 6/5, 5/4, 4/3, 11/8, 3/2, 25/16, 5/3, 7/4 and 15/8.

Referring now to the key-control pedal section 7 of Fig. 2, it will be noted that there are two rows of pedals 16 and 17. Switches 16 are of the locking type and are mechanically interlocked by locking bar 18 to permit the operation of but one at a time. Switches 17 are adapted for momentary operation only and remain operated only so long as they are pressed. It will be noted that there is one locking switch 16 and one momentary switch 17 for each of the fifteen relays in

key-control relay section 6. A source of electric energy 19, specifically disclosed herein as a battery, has one terminal 20 connected to an upper contact 21 of each of the momentary switches 17, while its other pole is connected by way of conductor 22 to one side of each of the relay magnets 23. The other terminal of each of the relay magnets 23 is connected by way of conductor 24 to one blade 25 of its associated momentary switch 17 and one blade 26 of its associated locking switch 16. A series circuit may also be traced through the lower normally closed contacts of momentary switches 17 from conductor 20 via contacts 27 and 28 of each of the switches 17. The other end of this series connection 29 connects to each of the lower contacts 30 of locking switches 16.

In operation it will be seen that if any one of the locking switches 16 is operated, it will automatically release through latch bar 18 any other locking switch which may have been previously operated. This switch will then be locked in place by latch bar 18 and will cause its associated relay winding 23 to be energized. This circuit may be traced from source 19 through conductors 20, normally closed series contacts 27 and 28, conductor 29, contacts 30 and 26, conductor 24 to coil 23 and back to source 19 via conductor 22.

Should it be desired to momentarily change the key in which the instrument is tuned, this may be done substantially instantaneously by operating any one of the other momentary contact switches 17, the operation whereof will open the series circuit through contacts 27, 28 to release the coil previously energized through the locking switch contacts 26 and 30 of the locking switch 16 and will close a new circuit through contacts 21 and 25 which may be more explicitly described as follows: From source 19 via conductor 20 through contacts 21 and 25 of the operated momentary switch 17, conductor 24 through the winding of relay 23 and back to source 19 via conductor 22.

Modulation from key to key is generally thought of as progressing by perfect fifths, for example, to modulate in the dominant direction from the natural key of C major renders the next adjacent key G major and to modulate again D major is reached, and so forth. The scale of equal temperament assumes only twelve notes to the octave with all intervals exactly equal to the twelfth root of 2. Key progression on the equal temperament basis results in the artifice of making twelve-fifths equal to seven octaves so that after the regular progression of twelve key modulations the tonic returns to the one from which the modulation started. A perfect musical fifth is an interval of 3/2 and twelve such fifths is the twelfth power of 3/2 or 129.75. On the other hand, seven octaves in either Just or equal temperament intonation is equal to the seventh power of 2 or 128 so that on an equal temperament basis there is the fallacy of assuming that 129.75 is equal to 128. Equal temperament therefore results in a limitation of twelve keys while Just intonation may theoretically have any number of keys; for example, assume the tonic of C major to be of a frequency of 264,000 cycles per second. After twelve modulations from C major in the dominant direction the key of B $\sharp$ major is reached having a tonic frequency of 267,603 cycles per second. With a keyboard instrument built on the twelve-note octave basis B $\sharp$ is the white digital denoted as C in C major. The result is that keyboard instruments tuned to equal temperament falla-

ciously identify B $\sharp$ major as synonymous with C major.

The above-described anomaly is easily overcome by this invention. While some musicians may be right in their assertion that twelve keys are sufficient to satisfy all aesthetic requirements, there has been some disagreement on this point. This discussion, however, is for the purpose of demonstrating the flexibility of the structure of this invention as the structure herein disclosed may be made to fully satisfy these theoretical considerations. In the previous description of Fig. 2, it was said that only fifteen tank condensers were associated with each oscillator coil to provide key modulations from seven flats to seven sharps. This is because this covers the field of key modulations as they appear in existing writings. However, additional keys could be added by adding an additional condenser to each oscillator tank, one relay to key-control unit 6 and one pair of pedal switches 16, 17 for each additional key desired. In this way the conventional keyboard with a twelve-note octave could be retained for the additional key modulations. Moreover, in equal tempered intonation the same frequencies are employed for F $\sharp$ major (6 $\sharp$) as are used for G $\flat$ major (6 $\flat$) thereby rendering these two keys practical identities. In Just intonation if the digital denoted C has the frequency of 258,425 cycles per second for F $\sharp$ major, it will have a frequency of 254,947 cycles per second for G $\flat$ major thereby rendering them different keys as they should be. The structure of this invention also accomplishes this as the separate condensers in the oscillator tank for each key makes it possible to correctly tune every note.

In using the key-control pedals above described, the organist operates the appropriate locking key 16 corresponding with the key signature noted on the music. Assume, for example, the organ to be tuned for the key of C major so the twelve notes of the middle octave will have the frequencies shown for that key in the following table:

Digital	Frequency		Interval from tonic	
	Key of C major	Key of G major	Key of C major	Key of G major
C.....	264,000	264,000	1/1	4/3
C $\sharp$ (D $\flat$).....	280,500	272,250	17/16	11/8
D.....	297,000	297,000	9/8	3/2
D $\sharp$ (E $\flat$).....	316,800	309,375	8/5	25/16
E.....	330,000	330,000	5/4	5/3
F.....	352,000	348,500	4/3	7/4
F $\sharp$ (G $\flat$).....	363,000	371,250	11/8	15/8
G.....	396,000	396,000	3/2	1/1
G $\sharp$ (A $\flat$).....	412,500	420,750	25/16	17/16
A.....	440,000	445,500	5/3	9/8
A $\sharp$ (B $\flat$).....	462,000	475,200	7/4	6/5
B.....	495,000	495,000	15/8	5/4

¹ Tonic note.

Now assume the key signature for the music to be played is G major (1 $\sharp$). Upon operating the locking switch 16 labeled "G major" or "1 $\sharp$ " the frequencies of the oscillators will be changed to those indicated for the key of G major in the table above. At this point a practical consideration may be noted. It will be seen from the above table that five of the digitals will not change in frequency when modulating from C major to G major. While separate condensers can be used as previously described, it is obvious that the same condensers may be used wherever there is no change in frequency thereby reducing materially the number of condensers required per oscillator. The invention has been disclosed

using separate condensers to simplify the description.

Much existing music may be played as now written. However, there are occasional chords which have been written into modern music that do not properly belong to the key in which they are written. While these chords as well as all others have inherent harmonic dissonances when played on an equally tempered instrument, they are not quite so noticeable on such instruments because both listeners and musicians alike have become accustomed to them. However, on a Just scale basis these chords are inherently more sharply dissonant but may be played in a very pleasing manner by operating an additional pedal switch simultaneous with playing the chord. For example, in C major and A minor the D minor triad involving digitals D, F and A must be played in D major or B minor to obtain the desired frequency ratio of 10:12:15. Likewise the G7 chord must be played in G major or E minor. In the relative key of A minor the E7 chord must be played in E major or C $\sharp$ minor. This is easily accomplished by operating the appropriate momentary pedal control switch 17 simultaneous with playing these chords.

It will be clear from the foregoing description that the simple structure comprising this invention is capable of playing existing music on a conventional keyboard with no change in fingering technique and yet materially improve its consonance by rendering the melodic and harmonic content on a Just scale basis. The only additional manipulation is to operate the appropriate locking key-control pedal before playing the composition and occasionally operating a momentary key-control pedal where extraneous chords are encountered.

An important prerequisite to maximum consonance and harmonic content is a properly designed musical scale to which the instrument must be tuned before the full advantages of this invention can be realized. It is preferred that the musical intervals be those shown in the above table. An analysis of these intervals will disclose that the various triads which may be built thereon make for maximum consonance and, moreover, the instrument will have available a large number of harmonics. It can be shown that up to the twentieth harmonic only the thirteenth and nineteenth are absent. This will enable the production of a very large number of tone colors or timbres. Heretofore, keyboard instruments tuned in the scale of equal temperament and capable of playing in more than one key were limited to either equally tempered "harmonics" or to a dissonant mixture of equally tempered tones and natural harmonics with the worst offenders being greatly suppressed by special design of the instrument. It will be apparent that for the musical scale above described, the various component harmonics may be employed without restriction since there are no dissonances produced by a confusing mixture of natural harmonics and "harmonics of equal temperament."

What is claimed is:

1. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, and means for substantially instantaneously retuning the notes of each of said octaves to sound with Just intonation in any other desired key.

2. A non-transposing keyboard musical instrument comprising a plurality of octaves each con-

taining twelve notes tuned to a given key in Just Intonation, means for generating the frequencies for said notes comprising a plurality of oscillators each having frequency determining elements as parts thereof, and means for substantially instantaneously retuning said frequency determining elements to cause said instrument to sound with Just intonation in any other desired key.

3. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, and a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just intonation for any other desired key.

4. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just Intonation for any other desired key, and a second key-control means for momentary operation adapted to similarly retune said instrument to any other desired key in Just intonation so long as it is held in its operated position and to transfer control to the first-named control means instantly upon its release.

5. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, and a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just Intonation for any other desired key, said control means being so constructed as to permit the operation of but one control means at a time.

6. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, and a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just Intonation for any

other desired key, said control means being so constructed as to permit the operation of but one control means at a time and upon the operation thereof to automatically release any other control means which may have been previously operated.

7. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, and a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just Intonation for any other desired key, said control means being so constructed as to permit the operation of but one control means at a time, and a second key-control means for momentary operation adapted to similarly retune said instrument to any other desired key in Just Intonation so long as it is held in its operated position and to transfer control to the first-named control means instantly upon its release.

8. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes tuned to a given key in Just Intonation, a separate oscillator for generating each of said notes, a frequency determining means for each oscillator, and a key-control means adapted to substantially instantaneously retune each of said oscillators to cause the instrument to sound in Just Intonation for any other desired key, said control means being so constructed as to permit the operation of but one control means at a time and upon the operation thereof to automatically release any other control means which may have been previously operated, and a second key-control means for momentary operation adapted to similarly retune said instrument to any other desired key in Just Intonation so long as it is held in its operated position and to transfer control to the first-named control means instantly upon its release.

9. A non-transposing keyboard musical instrument comprising a plurality of octaves each containing twelve notes so tuned that their fundamental frequencies bear the following ratios to the tonic frequency: 1, 17/16, 9/8, 6/5, 5/4, 4/3, 11/8, 3/2, 25/16, 5/3, 7/4, and 15/8, and means for substantially instantaneously retuning the instrument to sound in any other desired key but retaining the said frequency ratios.

SIDNEY T. FISHER.

Certificate of Correction

Patent No. 2,293,499.

August 18, 1942.

SIDNEY T. FISHER

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 68, for "264,000" read *264.000*; line 71, for "267,603" read *267.603*; page 3, first column, line 30, for "258,425" read *258.425*; line 31, for "254,947" read *254.947*; and lines 50 to 58 inclusive, in the table, second and third columns thereof, for

264,000	264,000		264,000	264,000
280,500	272,250		280,500	272,250
297,000	297,000		297,000	297,000
316,800	309,375		316,800	309,375
330,000	330,000		330,000	330,000
352,000	348,500	read	352,000	348,500
363,000	371,250		363,000	371,250
396,000	396,000		396,000	396,000
412,500	420,750		412,500	420,750
440,000	445,500		440,000	445,500
462,000	475,200		462,000	475,200
495,000	495,000		495,000	495,000

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 30th day of March, A. D. 1943.

[SEAL]

HENRY VAN ARSDALE,
Acting Commissioner of Patents.

5

84-1.1