

Jan. 25, 1944.

S. W. McKELLIP

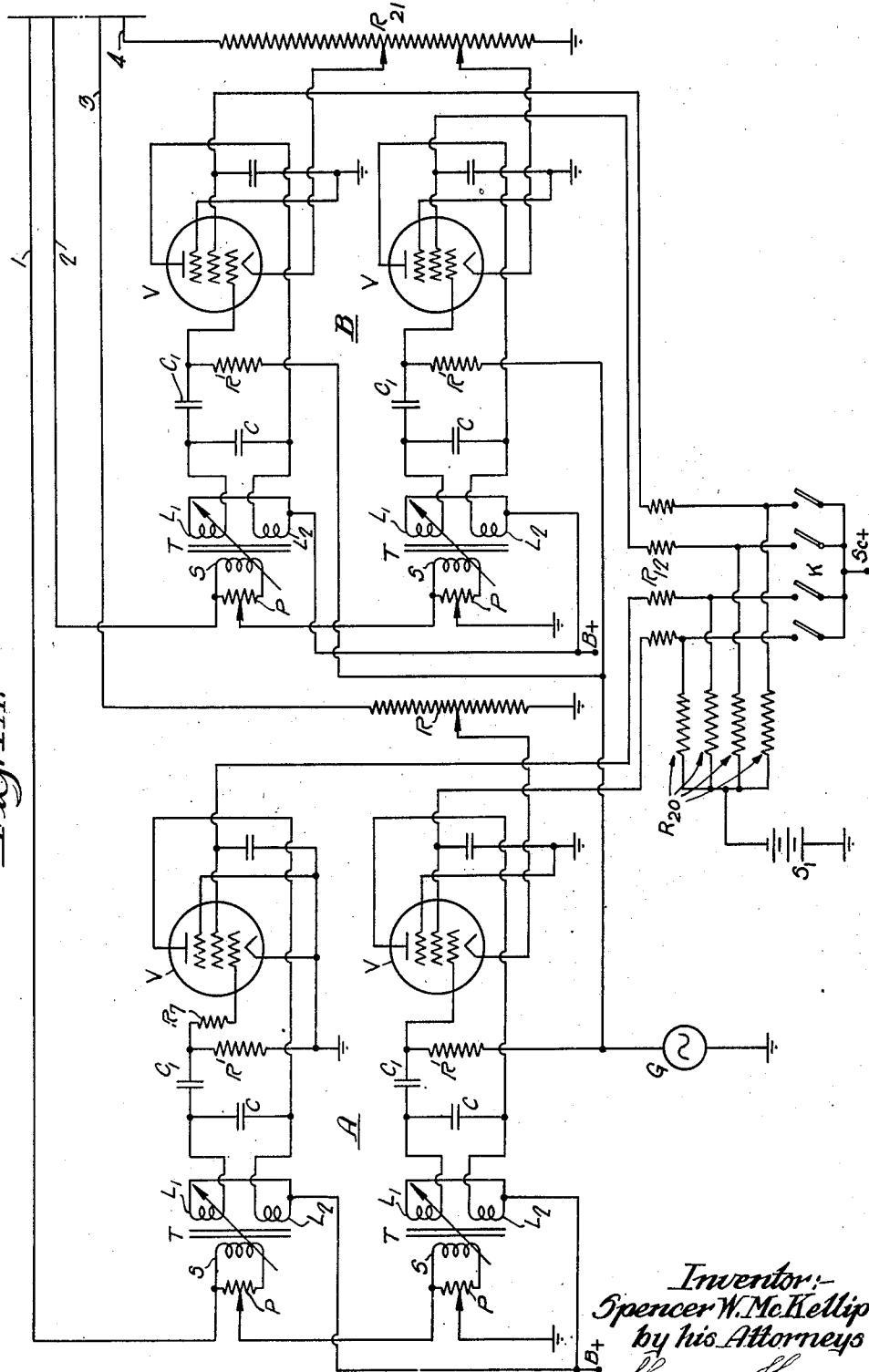
2,340,001

ELECTRICAL MUSICAL INSTRUMENT

Filed June 4, 1941

2 Sheets-Sheet 1

FIG. 1A.



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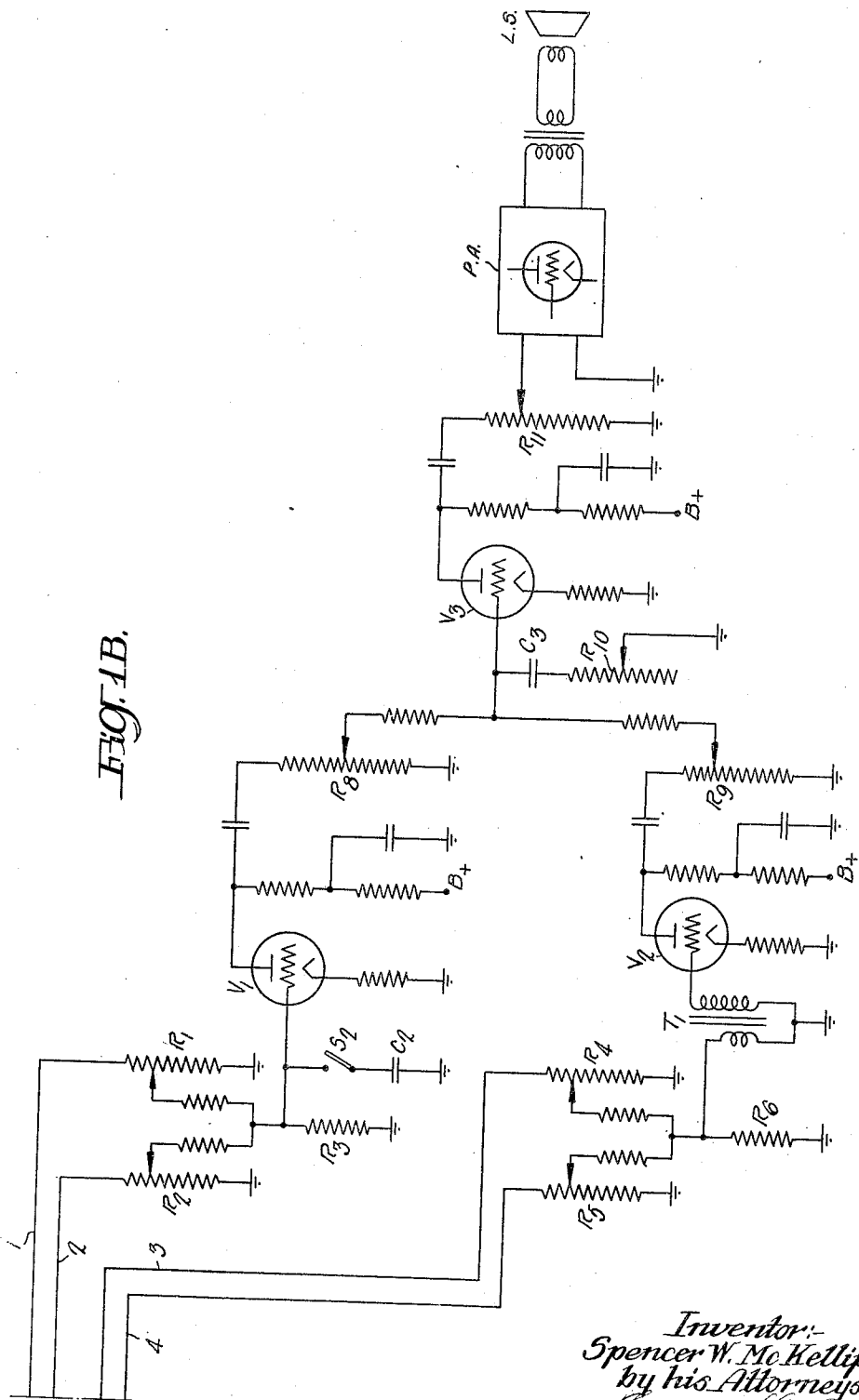
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2 Sheets-Sheet 2



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2,340,001

ELECTRICAL MUSICAL INSTRUMENT

Spencer W. McKellip, Wynnewood, Pa.

Application June 4, 1941, Serial No. 396,610

10 Claims. (Cl. 84—1.12)

This invention relates to electrical musical instruments, and more particularly to electronic musical instruments of the organ type.

The principal object of the invention is to provide a novel electronic organ of the keyed oscillator type which lends itself very readily to economic production and assembly, and which is particularly adaptable to a one-manual type of organ.

Another object of the invention is to provide a novel adaptation and control of an electron tube oscillator in a musical instrument of this character.

A further object of the invention is to provide a novel output arrangement for a group of oscillators each of which constitutes a tone current source.

Another object of the invention is to provide a novel method of keying an oscillator in a musical instrument.

A further object of the invention is to provide a novel method of obtaining tremolo effects in an instrument of this character.

Other objects and features of the invention will be apparent hereinafter.

In the drawings:

Fig. 1A is a diagrammatic illustration of a portion of an electronic organ embodying the features of the invention; and

Fig. 1B is a similar illustration of the remainder of said instrument.

In order that the complete instrument may be considered in connection with the following description, the two drawing sheets would be placed end-to-end with Fig. 1A at the left.

Certain features of the electronic organ illustrated in the drawings hereof form the subject of a joint application of John R. Ford and myself, and such features are claimed in a copending joint application, Serial No. 398,468, filed June 17, 1941.

In the following description, I shall first describe the electronic organ in general terms, and then I shall describe in detail the various features thereof.

Referring to the drawings, there is illustrated schematically a complete organ embodying the features of the invention, but for simplicity of illustration only a few of the oscillator circuits are shown, as these are representative of all such circuits employed in any instance. In the illustrated embodiment, the oscillator circuits, which constitute sources of tone currents, are divided into two groups designated generally at A and B. While any suitable form of oscillator may be used, I prefer to employ oscillators of the inductance coupled type for reasons which will appear later. The essential component elements of the oscillators are substantially the same and are designated similarly.

Each oscillator comprises an electron tube or

space discharge device V of conventional form and an associated resonant or tank circuit L_1L_2C . Each oscillator tube is of the type employing a screen grid, and preferably pentode type tubes are employed as illustrated. The screen grid of each tube is connected through a key K and a keying resistor R_{12} to a suitable potential source. Further, the screen grid of each tube is preferably biased negatively by means of a biasing source S_1 . Normally, the key K is open and the negative bias is effective; but when the key is closed, the positive screen potential overrides the negative bias and charges the screen to the desired voltage.

Each oscillator is tuned to a particular tone frequency, and tone frequency current is derived therefrom by means of a variable inductor or transformer T comprising coils L_1 and L_2 as a split primary and a secondary or output winding S. Winding L_1 constitutes the input coil of the oscillator and is connected to the control grid of tube V, while winding L_2 is the feedback coupling coil and is connected to the anode of the tube. C_1 is a blocking condenser serving to isolate the grid from the plate supply source, while R' is a leak resistor. The condenser C, which is the capacitive element of the tank circuit, is shunted across the serially-connected inductances L_1 and L_2 . Vernier tuning is accomplished by varying the reluctance of the magnetic flux path of the transformer, thereby varying the mutual inductance of the coils and consequently varying the resonant frequency of the tank circuit. It will be understood that each oscillator is tuned to a particular fundamental tone frequency, and the entire instrument will comprise as many oscillators as are necessary to give the desired tone or note range. Across each of the output coils S, there is connected a potentiometer P by means of which the output voltage may be varied.

The output coils S (or potentiometers P) of group A are connected in series with each other and with a common load resistor or voltage divider R_1 via conductor 1. Likewise, the output coils of group B are serially connected with one another and with a load resistor R_2 via conductor 2. The output coils and associated potentiometers are of low impedance (about 300 ohms), while the load resistor is of relatively high impedance (about 250,000 ohms). The voltage dividers R_1 and R_2 constitute a fader, by means of which the relative signal strengths of the group A and group oscillators may be varied at will. Preferably the dividers R_1 and R_2 are arranged to constitute a dual potentiometer so that increase of R_1 is accompanied by decrease of R_2 and vice versa. Thus, the keyboard is effectively divided into two parts, and the relative tone strengths thereof may be varied, as described more fully hereinafter. The tone frequency currents de-

rived from both groups of oscillators as above described are combined across resistor R₃ and thence supplied to a mixer tube V₁. A filter condenser C₂ and a switch S₂ are serially connected across the output resistor R₃ to enable attenuation of harmonics.

Returning to the oscillators, tone frequency currents are also derived from the cathode circuits of certain of the oscillators. Each of the oscillator groups A and B has an associated resistor R having one end grounded. The cathodes of certain of the oscillator tubes are connected to this resistor at tap points. The resistors in turn are connected respectively via conductors 3 and 4 to resistors or voltage dividers R₄ and R₅ of a fader control similar to the fader R₁—R₂. The voltages across R₄ and R₅ are combined across resistor R₆ and applied to a mixer tube V₂ via transformer T₁.

The output circuits of tubes V₁ and V₂ are connected, respectively, to volume control resistors R₈ and R₉ which in turn are connected to the grid of a mixer tube V₃. A high frequency attenuator comprising condenser C₃ and variable resistor R₁₀ is shunted across the input of tube V₃ to permit the attenuation of high frequencies in the entire instrument. The output circuit of tube V₃ is connected to a volume control resistor R₁₁ which is controlled by a swell pedal on the instrument. This controls the volume of the entire instrument. The voltage across resistor R₁₁ is supplied to a conventional amplifier C. A. which feeds into one or more loud speakers L. S. as illustrated.

In those oscillators which are utilized to give a string tone as described hereinafter, it is desirable to provide a frequency tremolo effect. In the specific embodiment illustrated, the tremolo voltage is derived from a suitable source or generator G and is applied to the control grids of the oscillator tubes. The tremolo voltage source may comprise a conventional oscillator having suitable provision for varying the frequency and amplitude of the voltage. If desired, an oscillator of the general type employed in groups A and B may be utilized as the tremolo voltage source.

In those oscillators from which a flute tone only is derived, one of which is shown in group A, there is provided a grid resistor R₇, as described fully hereinafter.

Having described the organ generally, I shall now describe in detail the various features thereof. Referring to the oscillators, I employ an individual vacuum type oscillator of a modified Hartley type for each note on the manual of the instrument. It is possible also to have a separate individual oscillator for each note on the pedal board of the organ, but I prefer to key the pedal board in a manner in which the pedal board switch is directly in parallel with its corresponding switch on a given note on the manual. This is not a new practice, as it has been done in the past for years on small pipe organs. Each individual oscillator consists of a pentode or tetrode type vacuum tube, a variable inductance, a tank tuning condenser, a grid blocking condenser, a screen grid keying by-pass condenser, a grid leak, a screen series keying resistor, and an output potentiometer. In some of the oscillators, I prefer to use in addition to the above-mentioned components a series grid resistor. Where a tetrode tube is used, I have also found it very desirable to employ a negative bias resistor in this particular connection.

Referring to any one of the illustrated oscil-

lators, the plate of the tube is returned to one of the inside leads of the primary of the variable inductance. The other inside lead of the other primary coil is connected to one side of the tuning condenser and blocking condenser. The two outside leads of the primary coil are joined together and connected to B+. The other side of the tank tuning condenser goes to the other inside lead of the primary coil. In other words, the tank tuning condenser is shunted across the primary winding and is primarily in the circuit to roughly set the frequency of each individual note. The grid-blocking condenser is in a circuit to block the D. C. in the primary coil from the grid and also to complete the A. C. path of the oscillator circuit. The grid leak is in the circuit to return the D. C. to ground. On the secondary side of the variable inductance, there is a potentiometer in parallel to regulate the output of the primary circuit, which I prefer to call the flute tone, of each individual oscillator.

In initially adjusting the organ at the time that it is built, there are a number of variables that have to be taken into consideration, as follows:

1. Frequency or pitch
2. Wave form or tone character
3. Amplitude or loudness
4. Attack and decay conditions
5. Tremolo or vibrato

Now I have found that with the proper selection of the components that go to make up each individual oscillator, the above conditions can be controlled in a manner to insure that the organ will have the proper musical characteristics.

I have found that the tank tuning condenser mostly affects frequency. In other words, I use this condenser for crudely setting the frequency of the oscillator to its approximate pitch on the tempered scale. The grid-blocking condenser has very little affect on frequency, but it does have a large affect on the character or wave form of the oscillator and also some affect on the strength of oscillation or loudness and, in addition, an affect on the tremolo condition at least to some degree. However, in changing this grid-blocking condenser to change one individual function, for example wave form, there are other means provided in the circuit to offset any change in the tremolo condition, etc. which might be upset by change in the condenser.

The screen or keying by-pass condenser, I have found, has affect on two conditions: the keying with respect to attack and decay, and also clicks and plops, and the tremolo condition of the oscillators. This condenser, however, is not critical and it is not necessary to change its value very often. However, when a condenser is initially changed to effect a more favorable keying condition, it is an easy matter to vary the other components to compensate for any undesirable change in the tremolo condition. I have found that it is desirable to keep the capacity of this condenser as small as possible with consistent results. The grid leak is not critical except in the low frequency and where series resistors are used, and there I have found it is necessary to change values occasionally.

The series grid resistor accomplishes a number of things. In a number of organs which I have built, I have utilized this resistor in the first eighteen notes or so primarily to smooth out the wave form of the flute tone. In using this resistor for that purpose, it is necessary to gradually taper the resistance value off towards the higher

frequency until it practically becomes negligible in the circuit. I have found, however, from experiment that it is possible with the use of a series resistor to produce a very effective wood-wind tone practically devoid of even harmonics, which in some instances would be a very desirable tone.

The series screen resistor accomplishes primarily a favorable attack and decay condition and, in conjunction with the by-pass condenser, will give a suitable attack and decay condition, practically devoid of thumps and clicks. It might be well to mention at this point that a series screen resistor, such as indicated at R₂₀ in Fig. 1A, also plays a very important part in the strength of oscillation, and the output derived from the oscillators can be governed to some degree by the value of this resistor. Of course, when the resistor is changed, it is necessary to make other minor changes in the circuit so that the oscillators will operate correctly.

Where a tetrode is used, and in some instances this may be desirable, I have found that it is very essential that a negative bias be applied to the tube when the key is open and there is no screen voltage applied to the tube. This is accomplished by a resistor connected directly from the keying lead to a D. C. negative bias source such as S₁ in Fig. 1A. Of course, this resistor has to be large enough that when a number of oscillators are connected together, there will be no cross modulation between oscillators from this point. This resistor and the negative bias applied through the resistor will tend to avoid a spurious oscillation, due to capacity coupling in the elements of the tube and similar conditions. It also tends to minimize leakage reactions in the switching mechanism and associated keying cables. Even where a pentode is used, if there should be leakage in the keying cables, it might be desirable to utilize this negative bias arrangement.

The variable tank inductance may comprise a core about one-half inch square in cross section and formed of a stack of super-dynamo steel laminations each approximately .026 inch in thickness. Preferably the inductance comprises E-pieces and I-pieces with provision for moving the I-pieces relative to the E-pieces by means of a suitable screw. The inductance of the transformer, and hence the frequency of the individual oscillator, can be very accurately set by the turning of this screw. I have found that each individual oscillator can be controlled through an approximate range of five notes, plus or minus, and, in some instances, as high as three-fourths of an octave, plus or minus. This variable tuning means also eliminates a change in the other tuning components of the circuit for every note. In fact, I have found that it is only necessary to change the other tuning elements of the circuit about every three to five notes. The point where I prefer to set the I-pieces with relation to the E-pieces is such that when the screw is turned to effect a change of say plus or minus four notes, the only actual change in the oscillation condition is frequency. All of the transformers from the lowest frequency (32 cycles) up to eighty notes above this point, which usually is as high as it is necessary to go in a small one-manual organ, may be physically the same with the exception of the size of the wire and the number of turns of the primary and secondary of the coils. I have found that it is necessary to vary the coils themselves only four times in a whole instrument.

I have found that it is possible to so adjust the components in each individual oscillator that

there can be derived from the secondary of each oscillator a wave form that substantially approximates a flute tone. It is also possible to derive a very desirable reed-type of tone from the cathode of the oscillator, and a number of intermediate tones can be derived from the control grid, screen grid, and suppressor. In the one-manual instrument illustrated only the two tones are derived. The flute tone is derived from the secondary of each individual oscillator and its amplitude is controlled preferably by a low resistance potentiometer. I have found that it is very desirable that the impedance of the secondary winding be low, and that a suitable turns ratio between primary and secondary is 40 to 1 step-down. Of course, the potential across the secondary coil to regulate the flute output of the oscillator should be just low enough so that it does not effectively load down the primary of the oscillator. I have found that it is very desirable to connect all the oscillators in series, as this method is characterized by low inherent loss in signal and lends itself very readily to impedance matching requirements, even in the case where eighty oscillators are connected in series. It will be readily understood that if a parallel arrangement were used, the secondary coils would have to be high in impedance and the amount of loss with eighty coils connected in parallel would be tremendous.

The string or reed tone is taken directly from the cathode of the oscillator and I have found that, in view of the fact that the cathode of each individual oscillator is near ground potential, each one of the outputs from the cathodes can be terminated on a 50 ohm resistance and the average of each cathode may be approximately only 15 to 20 ohms above ground. It will be readily understood that a low impedance parallel arrangement of this character practically eliminates any possibility of cross modulation from this point and, in view of the fact that a substantial signal is realized at each cathode point and also in view of the fact that this signal due to its higher harmonic content appears to the ear about four times louder than a given amount of flute voltage, the amount of loss incurred by a parallel mixing arrangement of the cathodes can very readily be gained by a suitable step-up transformer which also takes care of proper impedance matching into the control grid of the first audio stage.

The following voltages seem to give optimum results with respect to oscillation stability, wave form, amplitude, and particularly keying conditions with respect to thumps and clicks:

B+ plate voltage..... 75 to 90 volts
Screen keying voltage..... 75 to 90 volts
Filament voltage.... As called for by tube rating

It is very important that the 75 to 90 volts utilized for plate and keying conditions be well regulated, and the B supply utilized should have as low internal impedance as possible to avoid cross modulation at this point since the plates and screens of all of the oscillators are common to the B supply. I have found that both the plate supply voltage and the screen keying supply voltage can both be derived from one well regulated power supply unit.

Preferably, in the one-manual organ illustrated the oscillators are divided into two equally numbered groups A and B of 40 each. One purpose of this is to divide the keyboard into two

sections. Another reason is that, where the components of the oscillators are mounted on a conventional steel chassis similar to a radio set, physical conditions are much more favorable where two chassis with 40 oscillators on each are used rather than one long chassis with 80 oscillators thereon. From each chassis, the high potential end of the series output terminates on one section of a dual potentiometer R_1 — R_2 . The bottom sides of both sections of the dual potentiometer, or flute fader as I prefer to call it, are connected to ground. The sliders of both sections have a suitable high impedance resistor in series, the other sides of these two resistors being tied together and connected to the control grid of the first audio stage V_1 of the mixer. Across the input of this stage, I prefer to interpose a suitable by-pass condenser C_2 and a switch S_2 , or a combination of a by-pass condenser and a potentiometer, to provide a filter for attenuating higher harmonics of the flute tone. The dual potentiometer is so connected in the circuit that when one slider approaches ground the other slider approaches the high potential end of its resistor. This arrangement makes it possible for one-half of the organ to be either strengthened or diminished, while the other half is being varied in the opposite direction. This is very desirable on a one-manual organ.

I prefer to use two parallel string tone mixing dividers R_{21} of 50 ohms each, one for each chassis. One end of each of these resistors is grounded and the other ends are connected to a dual potentiometer R_4 — R_5 similar to the one already described.

The operation of the string fader is identical with the flute fader. Since the two operate independently, it is possible to obtain different and varied effects, for example it is possible to obtain a strong flute and weak string effect at the low end of the console, or any other combination that can be obtained. The only difference between the string mixer arrangement and the flute mixer is that a step-up transformer T_1 is employed in the string mixer so that the proper voltage can be impressed upon the grid of the first audio stage of the string mixer and also the impedances may be properly matched at this point.

The outputs of the mixer stages are connected to individual conventional volume controls R_3 and R_6 which make it possible to set the volume of the flute independent of the string character. From these volume controls, the signal is mixed together through two high impedance resistors and then goes to the control grid of a common mixing tube V_3 . Across the input of the common mixing tube, I have found it desirable to interpose a condenser and variable resistor filter combination to effect attenuation of the higher harmonics of the entire instrument. The output of this stage is connected to a voltage divider R_{11} which is attached to the swell pedal of the organ for controlling the volume of the entire instrument in the conventional manner, which is usually with the right foot. I prefer to so adjust this potentiometer that it is possible to fade out the entire organ when the pedal is all the way back and, of course, the amount of signal that will get in through the system will depend entirely upon the setting of the two fader controls and the two main volume controls as well as the setting of the foot-operated swell pedal.

From the final mixer stage, the signal goes into a power amplifier P. A., which should not ex-

ceed 2% total harmonic distortion, and thence to the loud speaker. It is very desirable naturally to use a speaker and baffle combination that is capable of covering the fundamental and harmonic range of the tones generated. The natural frequency of the loud speaker should be definitely lower than the lowest frequency to be reproduced which, in the case of the one-manual organ, is 32 cycles. The speaker should be capable of reproducing 8000 cycles at the high frequency end. I have found, from actual experience, that it is not necessary to go any higher in frequency than 8000. In fact, in some organs that I have built where tweeters were used, the consensus of musical expert opinion has been that these extremely high frequencies tend to spoil the over-all tone qualities rather than enhance them.

In addition to the above-described apparatus, it is necessary to have a suitable switching mechanism that operates in conjunction with the playing keys. In view of the fact that the keying mechanism is a one-wire system for each individual oscillator throughout, a conventional pipe organ type of coupler arrangement can be utilized. As the present invention is not concerned with the coupler, it has been deemed unnecessary to illustrate or describe this known device. When a key is struck and a suitable coupler or stop is depressed, screen voltage is impressed on the oscillator and it starts functioning. The keying constants of the oscillator circuit, viz. the series resistor and by-pass condenser, are so adjusted as to give a smooth attack and decay.

A very important function in connection with a suitable organ is the tremolo. I prefer to employ as the tremolo generator G a low frequency keyed oscillator or a resistance-coupled oscillator with a frequency-controlling network. The output of this tremolo oscillator is preferably passed through a cathode-load resistance-coupled stage and impressed on the grid leak of each tone oscillator that is to be tremoloed. Of course, in the oscillators that are not to be tremoloed, the grid leak is returned directly to ground. Also, in the case where a pentode tube is used as an oscillator tube, the suppressor grid is also grounded. The grounding of the suppressor grid tends to shield the tube inside in such a fashion as to accomplish the same net result as a negative bias, already mentioned, to suppress the spurious oscillation in the oscillators during the time in which no screen voltage is applied to the tube. The tremolo voltage that is applied to the grid leak actually tends to shift the frequency of each note enough so that a very desirable frequency tremolo condition can be effected. The phenomenon in connection with this condition is not quite clear but it is believed that the tremolo voltage applied to the control grid of the oscillator has the same effect as changing the grid resistance of the oscillator itself, and that the effect is one that actually takes place within the tube itself and is not an external condition, such as a change in inductance in the transformer due to a partial saturation of the iron of the transformer. Of course, means are provided in the tremolo oscillator and subsequent cathode-load stage to control the frequency and amplitude of the tremolo.

It is possible to effect a tremolo condition by impressing the tremolo voltage on the screen of the tube, but it is preferred to apply the tremolo voltage to the control grid because it requires

less swing for a given amount of tremolo frequency shift.

With the various components that go to make up each individual oscillator plus the associated apparatus, it is possible to set the frequency initially for each note, adjust the wave form of the various tone colors derived from each oscillator, adjust the attack and decay condition, take care of the plop and click condition of the keying, adjust the oscillators for optimum tremolo condition, set the amplitude of the tone colors derived from each oscillator independent of one another, etc., so that a wide range of desirable tone conditions can be controlled. Moreover, the individual components that control these conditions have very little effect on one another and, in any instance where there is an overlapping of functions, it is a simple matter to adjust the other components in such a way to accomplish the desired result.

In a one-manual organ, the playing condition is entirely different than in a multiple manual organ. Accompaniment and solo conditions naturally have to be all played from this one manual. It is a well-known fact that for a solo part, assuming for example the extreme condition where this solo is a one-note-at-a-time affair and the accompaniment to be effective is three or more notes, the solo has to be considerably louder than the accompaniment to stand out. I have found that it is very desirable to carefully adjust the volume of each note in such a way to make this possible. Really the keyboard, as far as volume is concerned, is divided into three sections; one, for extreme bass which is strong; two, the middle section which is weak; and three, the upper section which is stronger than either of the other two. Now the adjustment of each individual note for loudness has to be done initially by ear, because naturally the ratio of voltage to actual signal heard depends upon the wave form of the tone that is being listened to. After each key is set with respect to volume, it is very desirable that the wave form of each individual note be so adjusted that from one end

of the instrument to the other is a constant change. Of course, the change in wave form and volume both are very gradual between any two notes. After each oscillator is accurately tuned to its place in a tempered scale, there is a slight drift in frequency one way or the other almost immediately, and over a period of time the frequency of each individual oscillator might change slightly. I have found from actual experience, however, that this shift in frequency is really an advantage rather than a disadvantage.

Thus there is provided a complete organ, first, in which each individual note of the instrument is slightly different in tone from its predecessor on each tone that the organ is capable of playing; second, there is a slight change in volume between each individual note; and, third, there is a very slight mistuning of each note. Now it is well-known that the only reason one actually hears twenty-five violins is the fact that each one and each individual string of each one is slightly out of tune to start with and is played very slightly out of tune by the violinist. Exactly the same condition exists in the present organ and, in view of the three above-mentioned conditions, there is absolutely no question about an ensemble, or a combination of tones, being heard when the organ is played with two hands. It is possible to play five notes with each hand and in some cases six with each hand. Therefore, if each note is slightly different from its predecessor, and from one end of the instrument to the other there is a marked difference, naturally an ensemble effect can be accomplished. Also, the three above-mentioned conditions also make it possible for the solo to stand out against an accompaniment condition, and this condition is also still further enhanced by the use of the individual fader controls already mentioned.

In a particular single manual organ, which was constructed according to the invention and which had eighty notes, the oscillator components had structural characteristics and values as set forth in the following table, which is given as a specific example.

Notes	Transformers	Condensers (μfd's)			Resistors		
		Tank	Grid	Screen	Grid leak	Grid series	Screen or keying
1.....	Nos. 1 to 36—each primary 4500 turns of #39 wire, secondary 225 turns of #39 wire.	.5	.25	.5	1/4 meg.	1 meg.	25M
2.....		.5	.25	.25	1/4 meg.	1 meg.	50M
3.....		.4	.25	.25	1/4 meg.	1 meg.	70M
4.....		.4	.25	.25	1/4 meg.	1 meg.	70M
5.....		.4	.25	.25	1/4 meg.	500M	75M
6.....		.4	.25	.25	1/4 meg.	500M	75M
7.....		.3	.2	.25	1/4 meg.	500M	80M
8.....		.3	.2	.25	1/4 meg.	500M	80M
9.....		.3	.2	.25	1/4 meg.	500M	125M
10.....		.3	.2	.25	1/4 meg.	250M	125M
11.....		.25	.2	.25	1/4 meg.	250M	125M
12.....		.25	.2	.25	1/4 meg.	250M	125M
13.....		.25	.2	.25	1/4 meg.	250M	125M
14.....		.2	.08	.08	1/4 meg.	100M	250M
15.....		.2	.08	.08	1/4 meg.	100M	250M
16.....		.17	.08	.08	1/4 meg.	35M	250M
17.....		.15	.08	.08	1/4 meg.	25M	500M
18.....		.15	.1	.08	1/4 meg.	10M	500M
19.....		.1	.1	.08	1/4 meg.	10M	500M
20.....		.1	.1	.08	1/4 meg.	10M	500M
21.....		.1	.1	.08	1/4 meg.	5M	500M
22.....		.1	.1	.08	1/4 meg.	4M	500M
23.....		.1	.1	.08	1/4 meg.	4M	500M
24.....		.1	.1	.08	1/4 meg.	4M	500M
25.....		.08	.07	.06	1/4 meg.	4M	500M
26.....		.08	.07	.06	1/4 meg.	4M	500M
27.....		.08	.07	.06	1/4 meg.	3M	500M
28.....		.06	.05	.06	1/4 meg.	2M	500M
29.....		.06	.05	.06	1/4 meg.	None	500M
30.....		.04	.04	.06	1/4 meg.	do	500M
31.....		.04	.04	.06	1/4 meg.	do	500M
32.....		.04	.04	.06	1/4 meg.	do	500M
33.....		.03	.03	.06	1/4 meg.	do	500M
34.....		.03	.03	.06	1/4 meg.	do	500M
35.....		.03	.03	.06	1/4 meg.	do	500M
36.....		.03	.03	.06	1/4 meg.	do	500M

Notes	Transformers	Condensers (μds)			Resistors		
		Tank	Grid	Screen	Grid leak	Grid series	Screen or keying
37	Nos. 37 to 48—each primary 3000 turns of #37 wire, secondary 150 turns of #37 wire.	.03	.03	.02	¼ meg.	do.	500M
38		.02	.02	.02	¼ meg.	do.	500M
39		.02	.02	.02	¼ meg.	do.	500M
40		.02	.02	.02	¼ meg.	do.	500M
41		.0175	.02	.02	¼ meg.	do.	500M
42		.0175	.02	.02	¼ meg.	do.	500M
43		.0175	.02	.02	¼ meg.	do.	500M
44		.0175	.02	.02	¼ meg.	do.	500M
45		.015	.0175	.02	¼ meg.	do.	500M
46		.015	.0175	.02	¼ meg.	do.	500M
47		.015	.0175	.02	¼ meg.	do.	500M
48		.015	.0175	.02	¼ meg.	do.	500M
49		.0125	.015	.02	¼ meg.	do.	500M
50		.0125	.015	.02	¼ meg.	do.	500M
51		.0125	.015	.02	¼ meg.	do.	500M
52		.0125	.015	.02	¼ meg.	do.	500M
53	Nos. 49 to 60—each primary 2250 turns of #37 wire, secondary 120 turns of #37 wire.	.01	.0125	.02	¼ meg.	do.	500M
54		.01	.0125	.02	¼ meg.	do.	500M
55		.01	.0125	.02	¼ meg.	do.	500M
56		.01	.0125	.02	¼ meg.	do.	500M
57		.008	.009	.02	¼ meg.	do.	500M
58		.008	.009	.02	¼ meg.	do.	500M
59		.008	.009	.02	¼ meg.	do.	500M
60		.008	.009	.02	¼ meg.	do.	500M
61		.008	.008	.01	¼ meg.	do.	500M
62		.008	.008	.01	¼ meg.	do.	500M
63		.008	.008	.01	¼ meg.	do.	500M
64		.008	.008	.01	¼ meg.	do.	500M
65		.007	.007	.01	¼ meg.	do.	500M
66		.006	.006	.01	¼ meg.	do.	500M
67		.005	.005	.01	¼ meg.	do.	500M
68		.004	.004	.01	¼ meg.	do.	500M
69		.004	.004	.01	¼ meg.	do.	500M
70		.004	.004	.01	¼ meg.	do.	500M
71		.004	.004	.01	¼ meg.	do.	500M
72		.004	.004	.01	¼ meg.	do.	500M
73		.004	.004	.01	¼ meg.	do.	500M
74		.004	.004	.01	¼ meg.	do.	500M
75		.004	.004	.01	¼ meg.	do.	500M
76	Nos. 72 to 80—each primary 1100 turns of #34 wire, secondary 55 turns of #34 wire. ;	.003	.003	.01	¼ meg.	do.	500M
77		.003	.003	.01	¼ meg.	do.	500M
78		.003	.003	.01	¼ meg.	do.	500M
79		.003	.003	.01	¼ meg.	do.	500M
80		.003	.003	.01	¼ meg.	do.	500M

In the same organ, the components were further characterized as follows:

Tubes V were 6SJ7 type
 Tubes V₁ to V₃ were 6C5 type
 Resistors R=50 ohms
 Resistors R₁ and R₂=250M
 Resistors R₄ and R₅=500 ohms
 Resistors R₃ and R₆=250M

Although a specific embodiment of the invention has been described in detail for the purpose of disclosure, it will be understood that the invention is not limited thereto but is capable of further embodiments within the scope of the appended claims.

I claim:

1. A source of tone frequency current including a space discharge device having at least a cathode, a control grid, an anode, and an auxiliary electrode, an oscillatory circuit including said device and manually operable means for controlling the potential applied to said auxiliary electrode, thereby to control the starting and stopping of oscillation of said space discharge device and series resistors and at least one shunt capacitor between said manually operable means and said auxiliary electrode for controlling the rate of increase and decay of potential on said auxiliary electrode to thereby control the rate of starting and stopping of oscillation of said space discharge device.

2. A source of tone frequency current including a space discharge device of the pentode type having a screen grid, an oscillatory circuit including said device and manually operable means for controlling the potential applied to said screen grid, thereby to control the starting and stopping oscillation of said space discharge device and series resistors and at least one shunt

capacitor between said manually operable means and said auxiliary electrode for controlling the rate of increase and decay of potential on said auxiliary electrode to thereby control the rate of starting and stopping of oscillation of said space discharge device.

3. A source of tone frequency current including an electron discharge device having at least a cathode, a control grid, an anode, and an auxiliary electrode, an oscillatory circuit including said device and a source of negative bias voltage connected to said auxiliary electrode, and manually operable means for applying a greater positive voltage to said auxiliary electrode, thereby to control the starting and stopping of oscillation of said space discharge device and series resistors and at least one shunt capacitor between said manually operable means and said auxiliary electrode for controlling the rate of increase and decay of potential on said auxiliary electrode to thereby control the rate of starting and stopping of oscillation of said space discharge device.

4. In combination a plurality of tone frequency current sources, each of said sources including a screen grid electron tube with the control grid thereof in a resonant circuit arranged to form an oscillator, said oscillators being individually pretuned to different frequencies in a tempered scale, the resonant circuit of each oscillator being tunable over a limited range about the frequency assigned to the oscillator, keying means arranged to control the screen grid potential of each oscillator tube thereby to control the starting and stopping of said oscillators, and means for selectively mixing tone frequency currents from said oscillators.

5. In combination, a plurality of tone frequency current sources, each of said sources in-

cluding a screen grid electron tube included in a resonant circuit arranged to form an oscillator, said oscillators being individually pre-tuned to different frequencies in a tempered scale, the resonant circuit of each oscillator being tunable over a limited range about the frequency assigned to the oscillator, keying means arranged to control the screen grid potential of each oscillator tube thereby to control the starting and stopping of said oscillators, a source of frequency tremolo voltage, means for applying said voltage to an electrode of at least some of the oscillator tubes, and means for selectively mixing tone frequency currents from said oscillators.

6. In combination, a plurality of tone frequency current sources, each of said sources including a screen grid electron tube included in a resonant circuit arranged to form an oscillator, said oscillators being individually pre-tuned to different frequencies in a tempered scale, the resonant circuit of each oscillator being tunable over a limited range about the frequency assigned to the oscillator, keying means arranged to control the screen grid potential of each oscillator tube thereby to control the starting and stopping of said oscillators, a dual fader control device, and means for selectively connecting different groups of said oscillators to said device to selectively mix tone frequency currents from said oscillators.

7. An electric organ including in combination a plurality of keys, a plurality of foot pedals, a plurality of unit couplers interconnecting said keys and said foot pedals, a series of controls for regulating volume, tremolo, and said unit couplers, a swell pedal for regulating the overall electrical volume of said organ, a plurality of electronic oscillators, each of said oscillators consisting of a screen grid tube having feedback means connected between its output and input, means for adjusting separately the oscillatory frequency thereof, means for starting and stopping each of said oscillators including additional means for preventing thumps and clicks, and means respectively connecting said starting and stopping means of each of said oscillators to said keys, an electro-acoustic transducer for said organ, means serially connecting said oscillators to said transducer, an electrical network for selectively mixing the outputs of said oscillators including means for regulating separately the amplitude of the oscillations applied to said

mixer, a source of low frequency oscillations including means for applying said low frequency oscillations to at least some of said plurality of oscillators, and means connecting said tremolo control to said source, and a power supply connected to said plurality of oscillators.

8. The combination of a plurality of groups of tone frequency current sources each including a space discharge device having a cathode, an anode, a control grid and a screen grid and each including a differently tuned network connected in its control grid circuit and provided with output terminals, a plurality of switches each connected in the screen grid circuit of a different one of said devices for selectively starting and stopping the operation of said sources, means connecting the output terminals of each group in series with one another, and means for selectively mixing the outputs of said groups.

9. The combination of a plurality of groups of tone frequency current sources each including a space discharge device having a cathode, an anode, a control grid and a screen grid and each including a differently tuned network connected in its control grid circuit and provided with output terminals, a plurality of switches each connected in the screen grid circuit of a different one of said devices for selectively starting and stopping the operation of said sources, means connecting the output terminals of each group in series with one another, and means for simultaneously increasing the output derived from one of said groups and decreasing the output derived from the other of said groups.

10. The combination of a plurality of groups of tone frequency current sources each including a space discharge device having a cathode, an anode, a control grid and a screen grid and each including a differently tuned network connected in its control grid circuit and provided with output terminals, a plurality of switches each connected in the screen grid circuit of a different one of said devices for selectively starting and stopping the operation of said sources, means connecting the output terminals of each group in series with one another, means for simultaneously increasing the output derived from one of said groups and decreasing the output derived from the other of said groups, and means for attenuating the higher frequencies of said derived outputs.

SPENCER W. MCKELLIP.