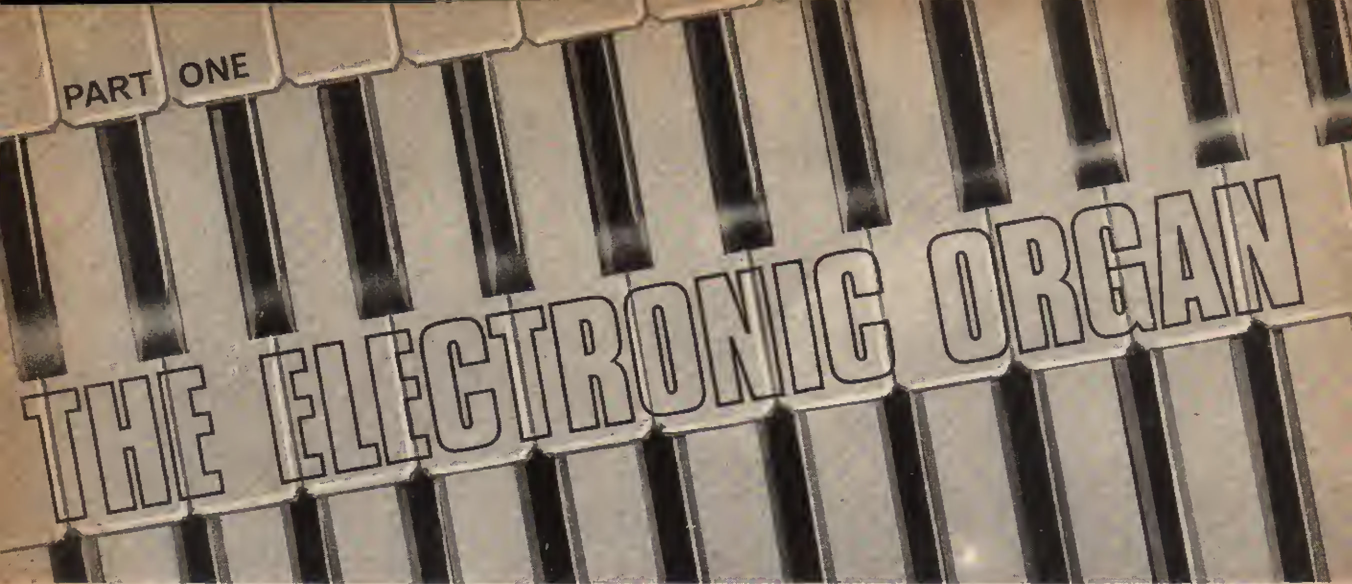

THE ELECTRONIC ORGAN

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A great deal has been written about electronic organs, but they still remain, to most people, something of a mystery. Why are there so many types of organs, using all kinds of generating systems to produce what appear to be the same kinds of sounds? What has one make got that is better than another make? Above all, why do they cost so much?

In this series of articles we will try and explain these things, and to do this we must go back to fundamentals and see how early investigators viewed the art and why some methods were bound to fail. Firstly, however, we must remember that one cannot define an organ of any kind more exactly than to say it is a sustained tone instrument capable of producing a variety of tonal qualities which can be used singly or in combination. What these tonal qualities are, and what other effects may or may not be desirable, depend on whether the instrument is intended for the serious musician, for church or liturgical work; or for home entertainment, where the romantic and popular qualities are predominant. In other words, we find the same situation which has existed for so many years in the pipe organ world; the division between the church organ and the theatre organ.

This first article will give the reader an insight into some of the experiments and devices which led up to the present state of the art; for all readers of this journal are experimentally-minded and it must always be remembered that many of the early workers knew exactly what they wanted, but the materials and processes simply did not exist to interpret their ideas.

THE first recorded experiments were by C. E. J. Delezenne in 1837. He used a toothed iron wheel turned by hand in front of an electromagnet, as in Fig. 1.1. By varying the speed he found he could vary the frequency of the e.m.f. induced in the coil, and hence the pitch of the note. The sound was heard in a crude telephone receiver. This idea was put into Delezenne's head by the earlier experiments of Savart, who held a piece of card against the rotating teeth when the pitch of the note could be heard audibly.

Then we come to the monumental concept of Thaddeus Cahill, who in 1895 devised and made a complete series of alternators all driven by belts from pulleys of the correct diameters to give the intervals of the equally tempered scale. But not only did Cahill

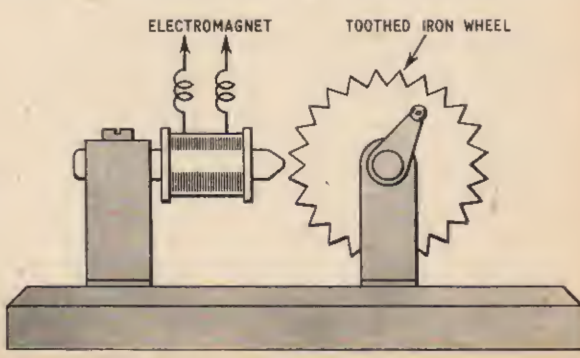

Fig. 1.1. Delezenne's tone wheel

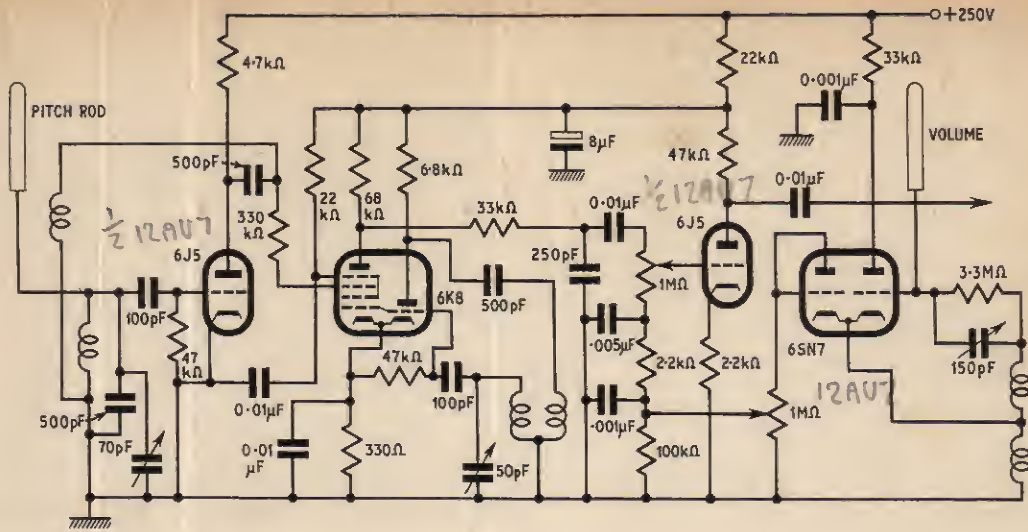

Fig. 1.2. Circuit diagram of the original theremin

provide 73 odd generators, he knew that if some of these frequencies were added together as harmonics of the fundamental note, complex sounds like trumpets and violins could be formed.

Helmholz, Fourier and Rayleigh had already found and analysed the number and strength of these harmonics, so Cahill devised a formidable array of switches and relays to introduce resistors controlling the amplitude of these harmonics. The whole of the arrangement is too complex to draw here, but it can be seen in British patents nos.: 8725, 1897; 3666A, B, C, 1903. Distribution and financial difficulties caused the abandonment of this project, and the reader will have no difficulty in recognising in this invention the fundamentals of the Hammond organ.

Next we move on to 1910, when W. Duddell discovered that an oscillatory circuit connected across an arc lamp could be used to produce musical tones. At that time, the arc was in widespread use for high power radio telegraph transmitters. Obviously this was not a basis for a serious design.

FIRST VALVE ORGAN

With the advent of the three electrode valve and the consequent ability to amplify, coupled with the rapid development of circuits in the 1914–18 war, it was now getting more feasible to reduce the bulk of the apparatus and we find the indefatigable Lee de Forest producing a valve "organ" in 1915. No need for an illuminated console then, as all valves used a tungsten filament with a light output equal to about 6 candlepower!

However, the old bogey of instability was still not conquered, so after a lapse of some years we find the Russian Leo Theremin working on the simple instrument in which the tuning capacitance for the b.f.o. employed was a metal rod like a car aerial. By bringing the hand near to this rod, the pitch could be altered and gliding tones produced. Another rod altered the volume by hand capacity, whilst a foot switch was used to cut off the note (Fig. 1.2). First made in 1924, the "Theremin" has been used until quite recently for solo work with an orchestra.

By this time the stage was set for great expansion in the art, but the first multi-note instrument came from Oskar Vierling in Germany in 1927. He made a two manual and pedal organ using gas tubes as relaxation oscillators, and this seemed to have stimulated other experiments. Coupleux & Givelet in France installed a two manual valve oscillator organ in the broadcast studios of Poste Parisienne.

THE TRAUTONIUM

So far, it is very doubtful if any of the investigators understood how to form musical tone colours from the various waveforms which they produced, and it is fairly certain that it was the novelty of the devices which attracted attention. But in Germany, a great

The two manual organ designed by O. Vierling. This instrument uses neon tubes to generate sawtooth waveforms

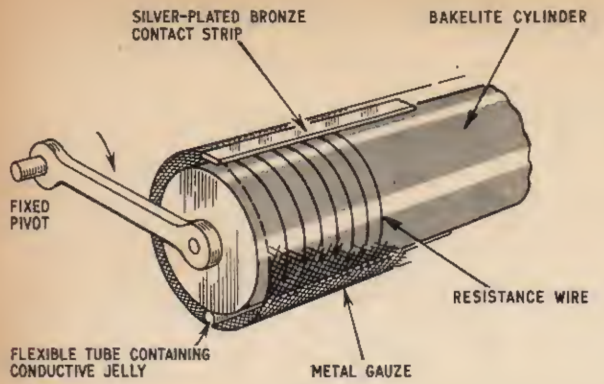

Fig. 1.3. Elements of trautonium frequency control

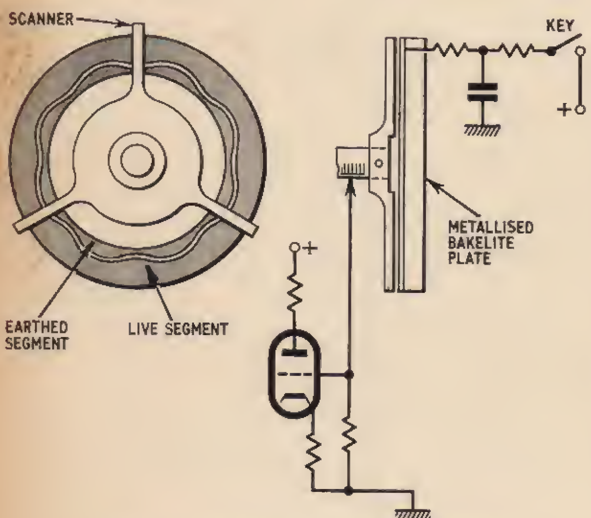

Fig. 1.4. Principle of the electrostatic organ

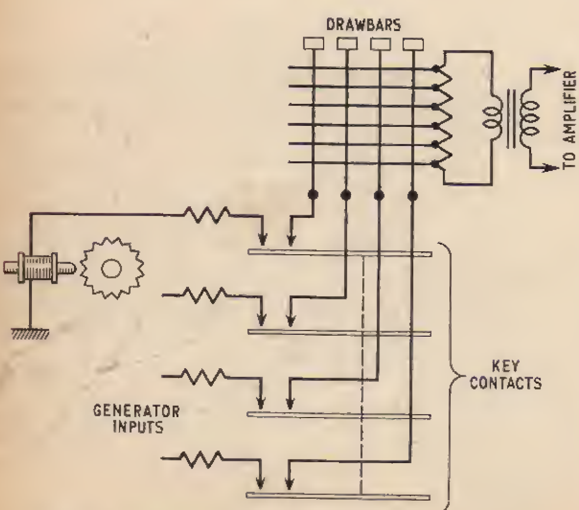

Fig. 1.5. Principle of the electromagnetic organ

deal of work was going on on tonal research in connection with orchestral instruments, and to assist in this Professor F. Trautwein devised the ingenious apparatus which he called the Trautonium (true tone). So advanced was he in his ideas that the instrument is still in use and in fact, seems unlikely to be superseded.

In Fig. 1.3 we can see the elements of the idea. An elliptical rod of bakelite has a spiral groove cut around it, and in this is wound a high resistance wire in coiled form. Above the rod is a metal strip which cannot touch the wire because it is inside a springy metal gauze surrounding the coiled wire. If, however, the outside of the gauze envelope is depressed at any point, the strip contacts the wire and this is used to vary the grid bias of a thyratron relaxation oscillator which—in turn—alters the pitch. Each rod (there are two, one above the other) has a compass of about 2½ octaves. The waveform is a sawtooth. But this is not all; under the rod is a rubber tube like a bicycle inner tube. This contains a jelly-like conductive substance, and since the touch rod and gauze are mounted on springs, it is possible to depress the whole lot further and squeeze the rubber tube; this alters the resistance of the liquid and allows the signal to pass to the amplifier.

Dr Trautwein devised a great many tone forming circuits including percussion and sustain circuits, and the results made every other investigator sit up and take notice. The original patents are dated 1928 but the "Trautonium" is used (with later modifications) for concert work to this day.

The trautonium, it will be noticed again, used gas tubes; this was because at that time, Germany had brought these to a great state of perfection. Now M. Martenot in France appeared with some ingenious ideas. He went back to the melodic instrument, that is, one on which only a single note at a time can be played. His playing keys could move slightly sideways and advantage of this was taken to alter the frequency of a b.f.o. so that some gliding tones could be produced. Then as the keys were depressed further, a resistance was reduced in value, so that the loudness was proportionate to depth of touch. By using the finger to rock a key, rather in the way a 'cellist does with his string, a similar kind of vibrato was produced. Some of these instruments are still in existence.

ELECTROSTATIC GENERATOR

So far as valves were concerned, there was still trouble with instability of pitch and regulation of power supplies, so this type of organ receded into the background.

The greatest advance was that due to the John Compton Organ Co. when in 1932 they devised the electrostatic generator which they still use. By engraving a groove in a metallised disc in the form of a sine or other wave, and rotating a web-like metal electrode just above it, the cyclic changes in capacitance when a potential is applied to the disc can be transferred to a valve and amplified as in Fig. 1.4.

If a series of such scanners is driven by a belt running over properly proportioned pulleys, then we have a musical scale. If there are enough multiples of one particular groove on a disc, then we have octaves of the scale. By adding some of these together, we can have complex tones. There are many practical advantages of this system, apart from the permanence of tuning, and this was the first successful departure from valves—although a few rotating photoelectric generators had seen a brief existence in the interim.

MAGNETIC TONE WHEEL

Continuing the search for stability, Laurens Hammond launched his magnetic tone wheel organ now so well known—and fundamentally unchanged after more than 30 years. The rotating iron discs have a tooth formation giving the nearest possible approximation to a sine wave, and the signals from the pickup coils are fed to contacts under the keys which transfer them to a selector switch mechanism for mixing in a transformer in any desired manner. See Fig. 1.5.

Since the generator is gear driven, tuning is permanent. It is interesting to note that it is not possible, by any economical combination of gear teeth, to produce the exact interval of a semitone. Each alternate note is fractionally sharp and then flat in pitch. It is partly this which gives the characteristic sound to a Hammond.

In later models, many ingenious additions have been made, but historically the foregoing represents the basic organ design.

The reed organ, using wind from foot bellows, was a great favourite in the United States from about 1850 onwards. The reeds used are also noted for constancy of tune, and this led the American F. Hoschke to use wind-driven reeds operating as variable capacitances as in Fig. 1.6. Although the sounds produced were limited in tonal variety, they were extremely pleasing and indeed even today this is a very fruitful field for experiment. Later the Hoschke organ became the Everett Orgatron, and later still, the Wurlitzer organ. This model has only been withdrawn a year or so ago.

Then we must not forget the German Welte photoelectric organ. The Hoschke patents date from 1934, the Welte from 1936. Large glass discs carrying photographically-reproduced copies of ready made waveforms were rotated in front of long photocells. Each playing key operated a small shutter which allowed light from a flashlight bulb to pass through a slit and so scan the waveform, as in Fig. 1.7. Again, constant speed pulleys ensured accuracy of pitch, and in fact this organ was a success.

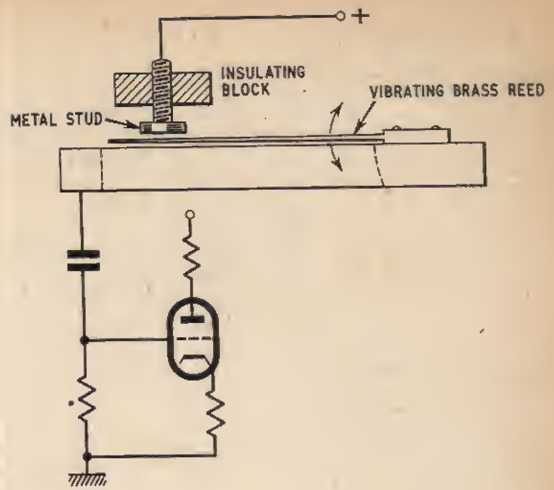

Fig. 1.6. Vibrating reed generator

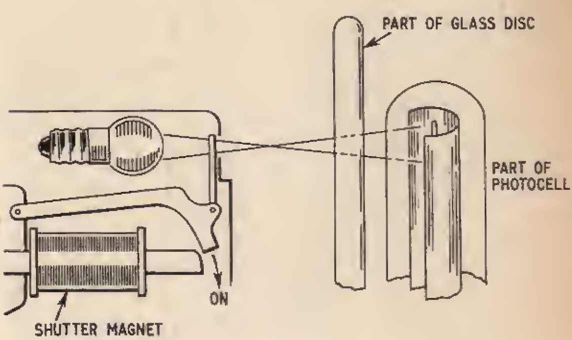

Fig. 1.7. Magnetic shutter for photoelectric organ

POST WAR ADVANCES

But then came the second war, and with it a tremendous advance in component and valve design. Intensive research regardless of cost produced all the parts required to restore the valve organ to the position it looked like losing for ever, and in addition, new magnetic materials, dielectrics and alloys enabled research into many new circuits to succeed. This brief historical survey could not include the many ingenious but hopeless ideas on which so many investigators worked, but we can conclude by mentioning the first successful post-war organs in order of appearance; Constant-Martin, Conn and Baldwin. It is to these companies that everyone owes a debt of gratitude because they laid the foundations of stability, good keying, and successful tone formation.

The present trend is to use transistors, or valves and transistors, although some makers prefer valves for large organs; they have certain advantages still.

In the next article we will try and explain what the basic musical requirements of an organ call for and what the various terms mean. This will lead us to examples of the most modern circuits and in due course to a design for a quite comprehensive organ which will have two manuals and pedals and be transistorised throughout.

The Everett Orgatron shown here uses vibrating reeds as variable capacitances in its tone generating system