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Electronics and Music

Part IX—Circuits of the Thyratone, a solo-type electronic instrument

By
RICHARD H. DORF*

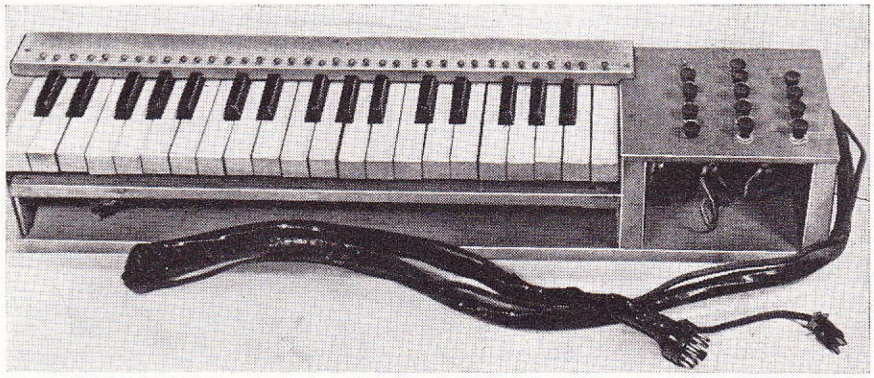

Photo A—Thirty-seven keys control the 5-octave range of the Thyratone. Buttons at right are used to select the tone color combinations.

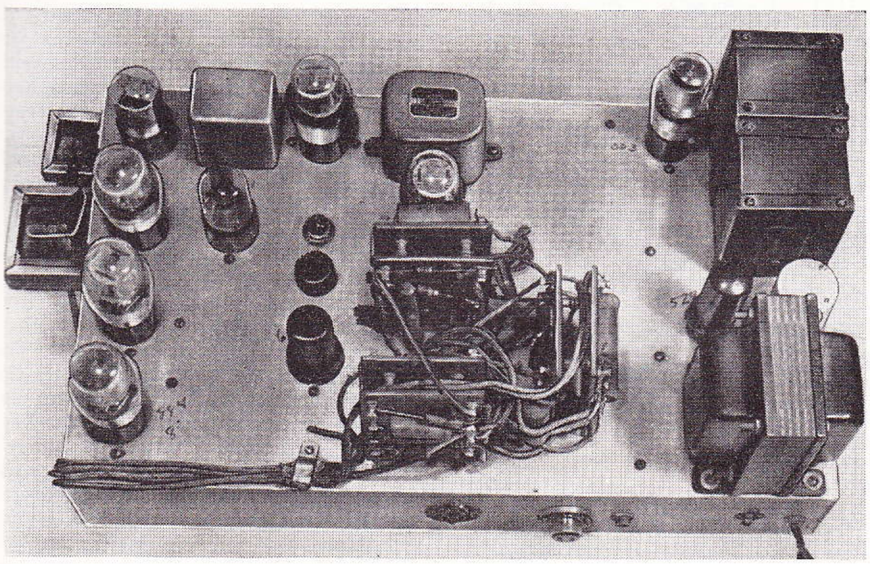

Photo B—Entire electronic circuit is on this 10 x 17 chassis. This unit is normally mounted inside the cabinet which houses the speaker.

IN THIS and the next article of our series we shall describe the Thyratone, an electronic musical instrument designed and constructed by the writer. The Thyratone is purely an experimental instrument, first designed on paper, then built and modified as various weak points showed up. It still has weak points, but each of these will be discussed as the description progresses and solutions to the problems will be suggested for the benefit of other experimenters.

The primary virtue of the Thyratone is that it is more truly a *musical* instrument than most of those which have been offered before to the individual constructor in the technical press. It not only provides a series of tones of the correct pitches but—more important—it includes genuine tone-shaping circuits to make the tones sound musical and to give a variety of tone colors both singly and in combination. The theory and background of tone-shaping methods is much too large a subject to discuss in a construction article, so the circuits will be described here only for construction purposes. Several articles later in the series will be devoted to tone-coloring.

What is the Thyratone?

The Thyratone is a monophonic or solo-type instrument, appearing, at first glance, to be much like the Hammond Solovox. It is similar in that its three-octave keyboard of foreshortened keys (Photo A) may be fastened to the front of a piano and the instrument can be played at the same time as the piano. Another likeness is that only a single key may be played at a time. But there the resemblance ends.

The block diagram of Fig. 1 gives an over-all view of the instrument. There are three tone generators operating at octave separation. The 8-foot generator produces three octaves of tones ranging from C_{40} (middle C—261.7 cycles—see frequency chart on page 42 of the August, 1950, issue) to C_{76} (2,093 cycles). The 16-foot generator produces a three-octave range from C_{28} (130.8 cycles) to C_{64} (1,047 cycles). The 32-foot generator produces pitches from C_{16} (65.41 cycles) to C_{52} (523.3 cycles). The nomenclature for the ranges is taken from organ practice for convenience.

When the Thyratone keyboard is fastened to the front of a piano the lowest key coincides with the position of middle C on the piano. Therefore, in the 8-foot range, sounding this note will produce an actual pitch of middle C. (For those not familiar with organs, the 8-, 16-, and 32-foot measurements refer to the lengths of organ pipes.) Pressing the same key but using the 16-foot range, the tone heard is one octave below what one would normally expect from that key. The 32-foot pitch is an octave below that. The Thyratone therefore has a total range of five octaves (plus one note—the top C).

The generators are all keyed simultaneously so that pressing any one key produces three notes an octave apart.

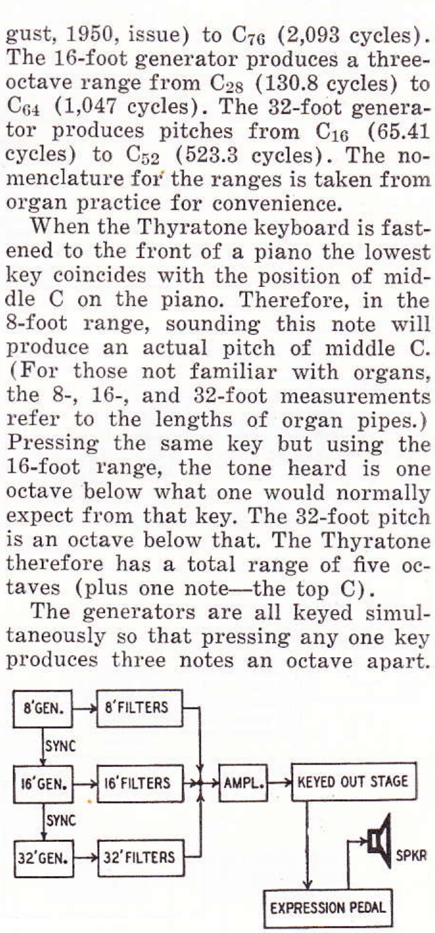

Fig. 1—Block diagram gives an over-all picture of how the Thyratone functions.

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The tones from each generator are fed to a series of L-R-C filters which alter the waves in such a way as to give a more or less close approximation of a standard organ tone. The three ranges are filtered separately, as Fig. 1 indicates, so that a bourdon tone, for example, is produced only in the 32-foot range, and an oboe is available only in the 16-foot register. There are four 8-foot tone stops, six 16-foot stops, and two 32-foot stops, a total of 12 tone qualities or stops in all. One or several may be in use simultaneously to give any type of mixture desired, just as in an organ. The tone colors will be described later in the discussion of playing.

The tones from the outputs of all the filters are mixed and amplified, then fed to a push-pull output stage. This stage is normally biased to cutoff. The cutoff bias is removed each time a key is pressed and an R-C time-constant network provides keying delay to eliminate clicks and thumps and give a good musical attack and decay. An expression pedal, consisting of a foot-operated 8-ohm T-pad, is placed between the output transformer secondary and the speaker. A preset volume control in the amplifier section allows the player to set maximum desired level so that the pedal can be operated over its entire range.

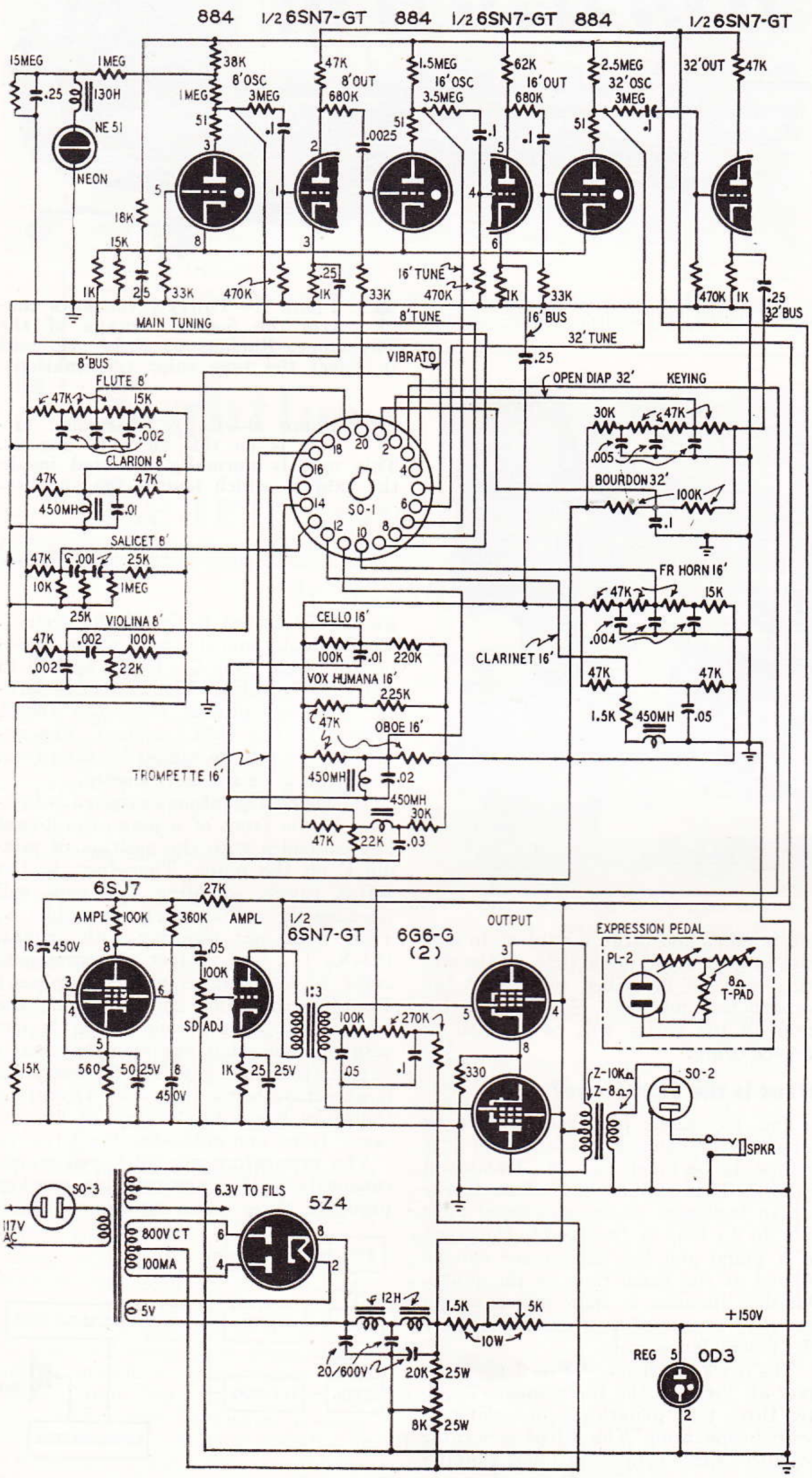


Fig. 2—Main circuit of the Thyratone, including amplifier and power supply.

What it looks like

The physical appearance of the Thyratone is illustrated by the photographs. Photo A shows the keyboard unit. There are three octaves of keys and, at the right, a control board. On the control board there are 14 push-button switches to control the stop combinations and the vibrato. At the upper left is the a.c. power switch. In this experimental model the front has been left open for access; in the finished product, of course, it will be closed. The wood will also be finished and the hole at the upper right will probably be filled with another push button. The entire keyboard unit may be fastened to the front of a piano with metal brackets in the same way as the Solovox is mounted. Because of the nonavailability of compactly built keyboards the writer did not bother to keep the keyboard unit especially small. Other constructors should try to do better in that respect, as long-legged players may find that there is not enough room underneath.

The chassis appears in Photo B. The entire electronic equipment, with the exception of the generator-tuning capacitors, is mounted on it, and the keyboard unit serves only for control. Normally the chassis is mounted within an ordinary loudspeaker enclosure along with the speaker. Photo C shows the expression pedal in position on the floor. A cable from it plugs into the chassis. The keyboard unit connects to the chassis through a 20-conductor cable terminating in a standard Amphenol 20-pin plug. An additional 2-wire line serves for the a.c. power switch.

The tone generators

Because of the type of tone-color filters used in the Thyratone, sawtooth waves are required from the tone generators. An additional requirement is three generators which will synchronize easily in exact octave relationships without having any of the synchronizing frequency appear in the output. In an experimental mood, 884 thyratrons (from which the instrument gets its name) were chosen. Gas-filled tubes are not the most stable oscillators, as they vary in characteristics with temperature and various tubes of the same type differ. A main tuning control was included, however, and operation is satisfactory as long as the tubes are not interchanged among the three generators. Replacements for burned-out 884's must be selected on a trial basis from a stock of them.

The diagram of the main chassis is given in Fig. 2. Each of the three 884's is used in much the same way as it would be for the sweep oscillator of an oscilloscope. A lead from the plate of each is brought to the keyboard unit, diagrammed in Fig. 3, where it is connected to one end of a string of capacitors. Pressing a key grounds the string at some point, giving a certain net capacitance between plate and ground to tune the oscillator.

The 8-foot oscillator is the "master." Its string has one capacitor for each note. When the junction between the leftmost capacitor and the next one (Fig. 3) is grounded, there is maximum capacitance between plate and ground, and the lowest 8-foot tone (middle C) is produced. When the next key is pressed, there are two capacitors in series between plate and ground, resulting in a lower net capacitance and raising the pitch. When no keys are pressed, the capacitance is the series net of all the units in the string, giving the highest tone. This system avoids off-color tones caused by accidentally pressing two keys at a time. With the string arrangement, only the lowest note of any several that might happen to be keyed at one time will sound.

There are four small contact springs under each key. A piece of flat metal is attached to the key bottoms and is grounded by contact with a square metal bar at the rear of the keyboard, on which the keys are mounted. When the key is pressed, this metal strip contacts all the springs, grounding each. Three of the springs under each key are connected to junctions between capacitors for tuning the 8-, 16-, and 32-foot generators. The fourth keys the output stage.

Since it is very difficult to represent this exact arrangement in a schematic diagram, the system of representation as in Fig. 3 is used. The four arrows for each key connected with a dashed line represent the single grounded metal strip. The small circles connected to the capacitors represent contact springs.

The output from the plate of the 8-foot 884 generator (Fig. 2) is connected to the grid of one triode of a 6SN7-GT amplifier through a 3-megohm attenuating resistor and a 0.1-μf blocking capacitor. Output is taken from the unbypassed cathode of the 6SN7-GT triode to form the 8-foot bus carrying 8-foot tones to the 8-foot filters. Output from the plate of the 6SN7-GT triode is fed through a 680,000-ohm attenuating resistor to the grid of the 16-foot 884 to provide synchronizing voltage. The plate of the 16-foot 884 is carried to the keyboard and a string of capacitors for tuning.

Referring again to Fig. 3, note that in the 16-foot string there is not a capacitor for every note but only one for every six or seven notes. This saving in capacitors is allowed by the fact that the 16-foot generator is synchronized. For each group of six or seven notes, the natural frequency of the oscillator is made slightly higher than the highest note; when the synchronizing voltage is fed to the 884 grid from the 6SN7-GT the frequency is brought to exactly one octave below the 8-foot tone. For greater stability, constructors may find it wise to use a few more capacitors, say one for every four notes.

The plate output from the 16-foot 884 is fed to the other triode section of the first 6SN7-GT. The cathode output of the triode is fed to the 16-foot filters and the plate output is applied as sync voltage to the 32-foot 884. The latter is tuned exactly as is the 16-foot gen-

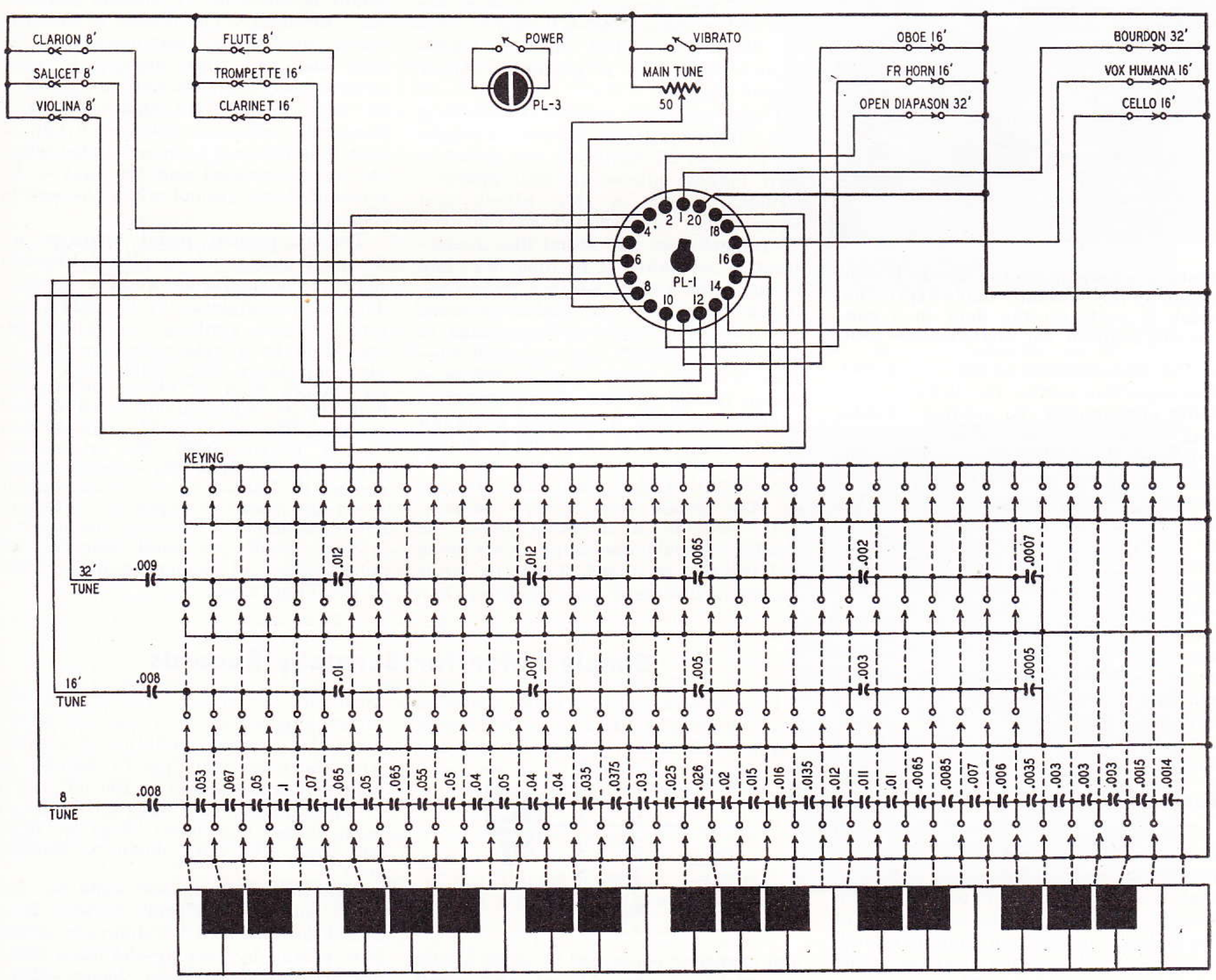


Fig. 3—The keyboard unit tunes the tone generators and controls the tone colors. A cable connects it to main chassis.

erator. It feeds one triode of a second 6SN7-GT, the cathode of which provides 32-foot tone for the 32-foot filters.

The cathodes of all three 884's are common and are placed a few volts above ground by a voltage divider between the B-supply and ground. The lower portion of the divider (15,000 ohms in parallel with 25 μf) is paralleled by a 1,000-ohm resistor, the lower end of which goes to a 50-ohm wire-wound rheostat on the keyboard unit. Varying the resistance of the rheostat varies the grid-bias voltage of all the thyratrons and changes their pitch. It is used as a main tuning control to compensate for aging and heating. Its range is a little over a half-tone; if it were more it would materially upset the frequency spacing between notes.

The vibrato is provided by a variation of the standard neon-lamp oscillator, which includes a high-value inductance as well as the usual resistor and capacitor. B-voltage for the neon oscillator is taken from the junction of the 38,000-ohm and 1-megohm resistors

Photo C—Volume of the music is controlled by this specially made expression pedal. It rests on the floor in a convenient position for the player's foot.

in the plate circuit of the 8-foot 884. The capacitor across the lamp is normally ungrounded. To produce vibrato, that capacitor is grounded through a switch on the keyboard unit. The oscillations produced are nearly sine waves because of the storage action of the inductor. They vary the plate voltage of the 8-foot generator slightly at the oscillation rate, which is about 7 cycles; since gas-tube oscillators change pitch with a change in supply voltage, a frequency vibrato is produced. The 15-megohm resistor across the 0.25-μf capacitor discharges it after the bottom end is ungrounded (when the vibrato switch is turned off). Without the discharge the neon will not oscillate again when the switch is closed.

Tone filters

The theory of *formant filters*, as these are called, will be discussed in future articles. Suffice it to say here that they are due principally to Winston E. Kock, the principal designer of the Baldwin organ, and that they analogize electronically the acoustic action of an ordinary musical instrument. Their capabilities are not realized fully in the Thyratone because of the desire to avoid unnecessary complexities, but even here they do produce uncannily realistic imitations of many of the tones of a pipe organ. Briefly, they provide electrical resonances and rolloffs equivalent to the body resonances and acoustic absorption properties of ordinary instruments. For details see U.S. Patent No. 2,233,948.

The inputs of all the filters in each register are obtained from the corresponding bus and all filter outputs are paralleled. Because of the long lines involved in the Thyratone as it now exists, switching filter outputs to select tone colors or stops was found impractical. The stop buttons therefore are normally closed switches which short out the filters. Punching a button removes the short on the corresponding filter and allows the tone color to come through. The short circuit is made in the "middle" of the filter so that it will not appreciably affect input or output busses.

Amplifier

The outputs of all filters go to the grid of a 6SJ7. The amplified tones go to a volume control which is preset for the desired maximum level. From here the tone goes to the second triode section of the same 6SN7-GT used to feed the 32-foot bus. The plate is transformer-coupled to a push-pull 6G6-G output stage.

There are two reasons for keying this output stage. First, when no keys are pressed, all oscillators are tuned to their highest pitches by the capacitor strings. Second, a slow attack and decay must be provided so that the instrument does not sound like a code-practice oscillator. It is difficult to key a single-ended stage because, unless the attack is too slow for musical comfort, the rush of electrons from cathode to plate when cutoff bias is removed—even with a delay circuit—makes a thump in the speaker. This hazard is removed by using a balanced push-pull stage; the rush of electrons is in the same direction in both tubes and the two cancel in the output transformer (if the tubes are fairly similar).

To provide a negative bias, the bleeder of the power supply is tapped and the tap grounded. Thus the lower end of the bleeder is more negative than ground. In the model shown the power transformer produced insufficient d.c. voltage at the filter output (about 250 volts). Other constructors should use transformers with at least 400 volts each side of center-tap. This allows the tap on the bleeder to be moved up higher, giving more bias for good cut-off of the final stage, while still providing enough B-voltage for reliable operation of the 0D3 (which provides regulated voltage for the thyratron tone generators).

The negative end of the bleeder is wired to the center-tap of the driver transformer through an R-C network. A lead from the network goes to the keying contact springs on the keyboard unit. When a key is pressed the junction of the 100,000-ohm and 270,000-ohm resistors in the delay network is grounded. This removes negative bias from the output tubes. It takes a certain time, however, for the .05-μf capacitor to discharge the bias voltage, and the tubes do not conduct fully at once. When all keys are released the bias voltage is applied again, but delay of the sound decay is caused by the 0.1-μf capacitor, across which the bias voltage must build up.

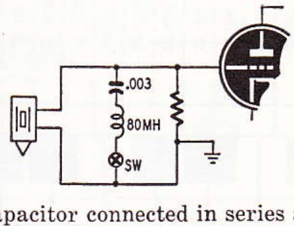
The delays are a little shorter than would be musically optimum, particularly the decay. The reason is that the sound must have disappeared by the time the key rises enough to take ground away from the tuning-capacitor contacts. The keying contact spring is purposely adjusted under each key so that it is the last to be grounded when the key is pressed and the first to be removed from ground when the key is released.

The expression pedal operates an 8-ohm T-pad which is placed between the output transformer and the speaker. This is the simplest way to control volume without running a high-impedance line to a grid potentiometer. A high-impedance line could easily pick up enough hum or other undesirable noise to be objectionable, even if well shielded. The pedal itself is simply two hinged boards with the attenuator sandwiched in between. A cable strung around its knob rotates the attenuator when the pedal is depressed. Pushing down on the pedal increases the volume.

Next month we shall describe the construction, adjustment, and operation of the Thyratone.

Simple Filter for Scratchy Records

It is easy to construct and install a filter which will make scratchy records sound much better. It consists of a coil



and capacitor connected in series across the pickup leads. Almost any small choke will do—a shielded r.f. choke is excellent. Try small capacitors of different values until you find one which gives the greatest reduction in scratch with the least reduction in volume. If your coil is around 80 to 100 mh, try a .003-μf capacitor and work up and down from there. Use large steps at first, and gradually work down to smaller ones.

The filter attenuates some of the highs, so it is advisable to wire in a switch as shown in the diagram. Avoid hum pickup by keeping the leads short and well away from a.c. leads.—*R. C. Sandison*

Electronics and Music

Part X—Construction details and tuning procedure of the Thyratone

By RICHARD H. DORF*

IN LAST month's article we described the principles on which the Thyratone operates. In that article the complete schematic diagram and some photographs appeared. This month we shall discuss construction, adjustment, operation, and modifications. It is therefore a good idea to have the March article on hand for reference while this is being read.

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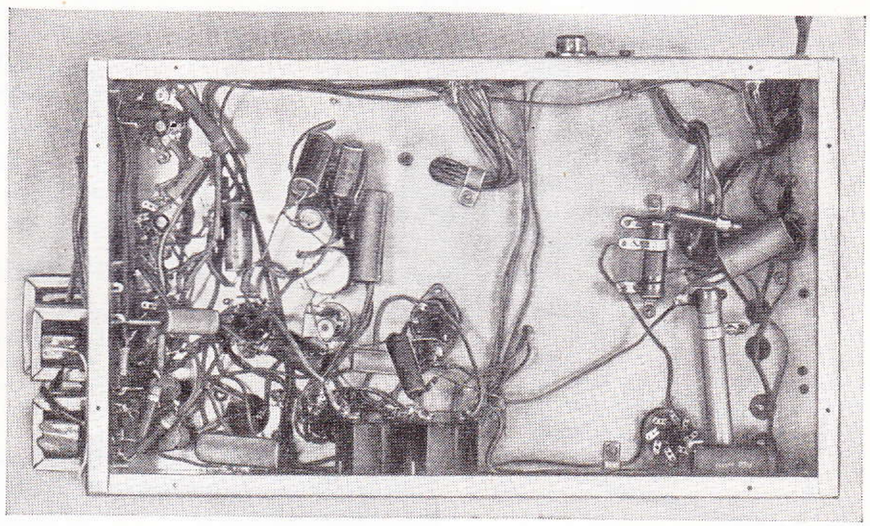

Photo A—Underside of the Thyratone's chassis. Other constructors may find that a somewhat different layout will make the wiring considerably easier.

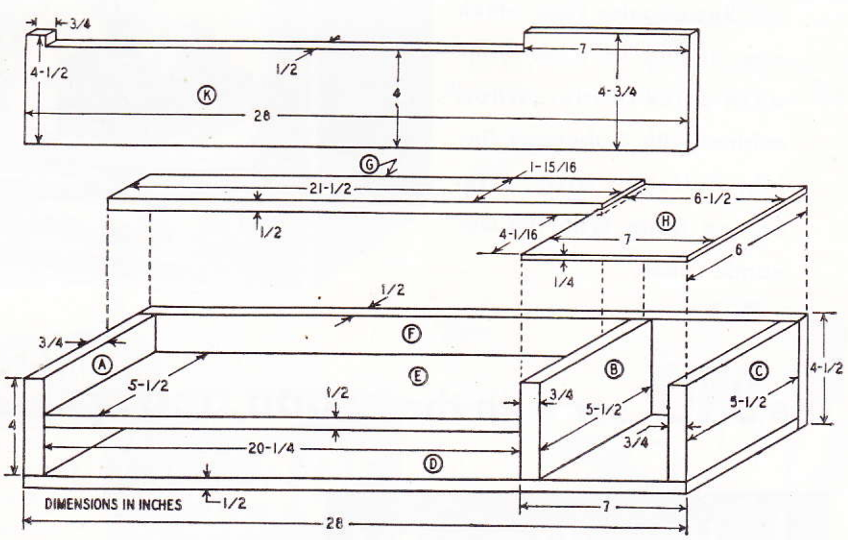

Fig. 1—Exploded diagram of the keyboard housing showing assembly details.

A, B, C—sides and partition—4 x 5½ x ¾
D—bottom—28 x 5½ x ½
E—contact board—20¼ x 5½ x ½
F—back—28 x 4½ x ½
G—key mask—21½ x 1 15/16 x ½
H—switchboard—6 x 7 x ¼ (note slot)
K—front—28 x 4¾ x ½ (note shape)
All dimensions in inches

Housings

The instrument is in two principal parts, the electronic chassis and the keyboard unit. The chassis is a 10 x 17 x 3-inch aluminum unit which, after completion of all the construction and adjustment, can be mounted in a suitable wooden cabinet used for the speaker.

The keyboard unit was especially constructed of wood. While it serves the purpose well, it is a trifle large and heavy; that could probably be cured by using lighter wood.

A three-dimensional drawing of the keyboard unit appears in Fig. 1. This sketch, handed to a cabinetmaker, will result in a satisfactory unit. If the reader builds his own, the list of wood pieces in the figure should be helpful. Comparing the drawing with the keyboard unit photograph in last month's story should make the scheme clear.

Referring to the photo of the chassis top in last month's issue, the power supply—transformer, can capacitor, rectifier, two chokes, and voltage-regulator tube—are at the right end of the chassis. At the left end, from front to rear, are the three tone generator 884's, 8-, 16-, and 32-foot, and the 6SN7-GT which amplifies the outputs of the 8- and 16-foot generators. To the right of the latter is the vibrato choke, and in front of it the second 6SN7-GT. Next to the right, from front to rear, are the 6SJ7, the present volume control, the neon lamp, and one 6G6-G. The output transformer is at rear center, with the other 6G6-G in front of it. All the tone filter components (except for the inductors) are mounted on the three double terminal boards atop the chassis. The inductors had to be kept far from the power supply, so are mounted on the left side of the chassis.

On the front chassis apron are four connectors. The leftmost is a 20-pin female for the cable running to the keyboard unit. Next is a 2-prong (and grounded shell) connector for the expression pedal. An ordinary phone jack follows for the speaker, and at the right is a 2-prong female for the a.c. switch on the keyboard unit.

Photo A shows the underside of the chassis. The wiring under the tone-generator side is rather complex and crowded, which is one reason a change in placement of some components (as discussed later) may be advisable.

Construction steps

The first order of business is to prepare the keyboard unit so that as each portion of the chassis circuit is completed it can be tested and made final.

After obtaining the wood specified in Fig. 1 and cutting it all to shape and to fit, assemble the rear and the two sides and partition, pieces A, B, C, and F. The keys used in the original model were obtained from an old reed organ which was scrapped after being removed from a church to make way for a Baldwin electronic. The individual keys were removed and cut down as in

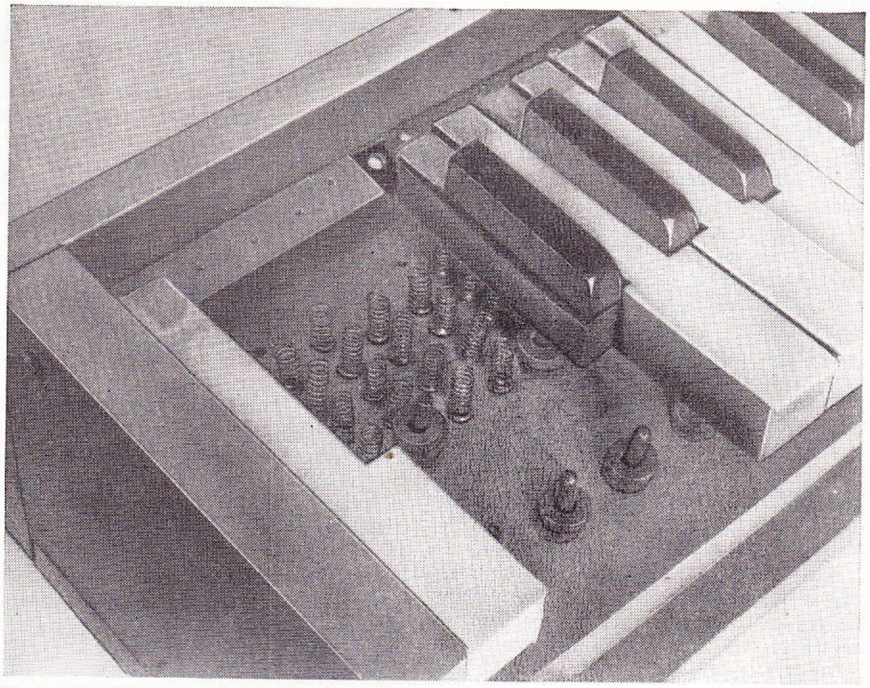

Photo B—Closeup of the keyboard assembly showing the keys and contacts.

Photo B, so that each was about 4¾ inches long. The raised portions of the black keys also must be cut down about another ¾ inch, so that when the black keys are in place with the white ones, the raised portions stop 4 inches back from the tips of the white keys. This allows the key mask (piece G in Fig. 1) to be put in place eventually, holding all keys at the same height.

Now refer to Photo C, showing the undersides of some of the keys. Along the bottom of each key is a piece of spring metal extending about ¾ inch out from the rear. This is a springy metal and serves two purposes. It acts as the contact which electrically connects all the contact springs under each key to ground when the key is pressed, and it is the method by which each key is mounted to the ⅝-inch square hollow bar of brass which extends the length of the keyboard (20¼ inches). The bar can be seen in Photo B. It is drilled and tapped at each key location (or self-tapping screws can be used) and the metal extension under each key is fastened to it. When the key is pressed, the metal contacts the four springs; when it is released, the springiness of the metal brings it up again. The writer used transformer laminations for the job.

Now assemble the lowest and highest keys, with their metal strips, and fasten them to the ends of the brass bar. Hold the assembly so that with the keys perfectly horizontal the key tops are even with the top edges of the sides (pieces A and B in Fig. 1). Set in place the contact board (piece E) so that it will hold the bar in this position. Then remove the bar and keys.

The next job is to place the guide pins at the front of each key so that when the key is in place the guide slot underneath it (see Photo C) will engage the pin to prevent any sideways motion of the key. The pins will be found in the original keyboard assembly and can usually be pulled right out with a pair of strong pipe pliers. Each key must be held in place, the hole in the brass bar drilled and threaded, the key fastened to that, then the guide pin position marked. Drill a hole for each guide pin, then push it in place. When the keys are mounted permanently, a pair of small rubber grommets are slipped over each pin so the keys will hit bottom without a thud and will not go down too far.

After all the keys are mounted and working mechanically, detach them one by one and mark the contact board to show the area covered by the metal strip under each key where the contact springs will be located.

The contact springs used in the original model were cut down from copper motor brush springs obtainable at motor repair shops. A hole was drilled through the contact board at each spring location and the spring held down with a round-head machine screw. Small solder lugs were placed between the nut and the board underneath. Quarters are close, so careful measurement is necessary.

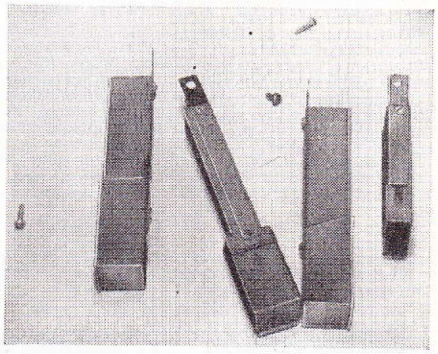

Photo C—Springy metal strips fitted to the keys return them to rest position and make electrical contact to the four metal springs mounted below them.

The keys must be remounted next, and the contact springs adjusted by bending, pulling, and cutting them off, so that an ohmmeter shows positive contact when the key is pressed and no contact when it is released. The key mask (piece K in Fig. 1) should be mounted before the final ohmmeter check is ended.

One very important point is to adjust the springs so that with each key the rearmost spring is not contacted until the key hits almost the very bottom. This spring controls the keying of the output stage; that stage should remain inoperative until all the tuning contacts have been made and should cut off again before any tuning contacts are broken.

Before going back to the chassis, the stop buttons may be mounted on a thin board (piece H in Fig. 1). The cable leading to the chassis should be made up. It consists of 20 shielded wires bound together with Scotch electrical tape and terminated in a 20-prong male Amphenol connector. Numbered connections are indicated in last month's Fig. 3. The keying (pin 3) and ground (pin 20) leads may be connected to the terminal lugs under the springs as indicated in that diagram. For that purpose, all rear contact springs are connected together. The cable comes out of the keyboard unit through a hole in the rear in the right-hand compartment, as shown in Photo D.

Chassis assembly

The construction of the chassis assembly as indicated in last month's photos and diagrams and in this month's Photo A is next on the agenda. Begin by wiring all the filaments. Then complete the 8-foot generator and its amplifier (but *not* the synchronizing connection from the plate of the amplifier to the grid of the 16-foot 884), the 8-foot flute stop filter, the 6SJ7 and ½ 6SN7-GT voltage amplifiers, and the 6G6-G output stage. Short out the expression pedal receptacle SO-2, and plug a speaker into the phone jack.

In the keyboard unit, wire temporarily the first 8-foot tuning capacitor, using the .008-μf value shown in last month's Fig. 3. Now, when the lowest key is pressed, some tone should be heard in the speaker. Wire up the vibrato circuit and test it. Press the key several times to see that there are no clicks or pops. If there are, or if there is too much delay in tone buildup, experiment with the tap on the 8,000-ohm, 25-watt section of the power supply bleeder, but do not place this so far up that the 0D3 does not glow. The 5,000-ohm, 10-watt series regulator resistor also requires adjustment for this purpose; if the supply voltage is low, it will probably have to be shorted out entirely. If attack characteristics are not perfect, experimenting with all the resistors and capacitors of the delay network at the center-tap of the interstage transformer will supply the answer. The arm of the present 100,000-ohm potentiometer may have to be moved down to prevent the audio tone from overriding the cutoff bias on the final stage with the key up.

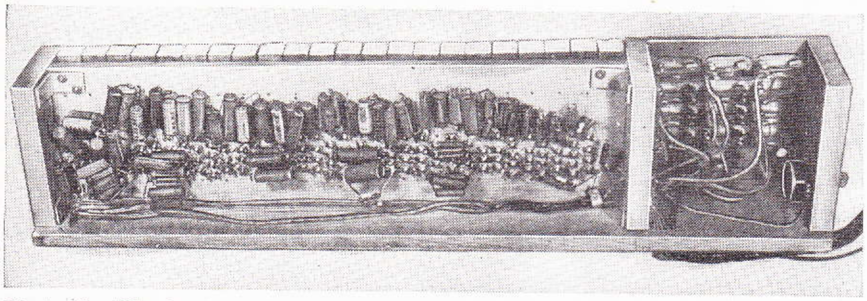

Photo D—The keyboard unit with bottom cover removed. The compartment at right contains the stop buttons; the capacitors at left tune the three ranges.

Next wire the rest of the generators and amplifiers, but do not connect amplifier plates to 884 grids for synchronization. One each of the 16- and 32-foot filters also may be wired.

The next step is to tune the 8-foot range. The capacitor values suggested in last month's Fig. 3 are not exact and will vary with different 884's. It is simply a matter of having a good stock of capacitors on hand and substituting for each note until the right value is found.

Begin with the lowest note. It is essential to have a piano or a well-tuned organ for this job, and not the least of the required equipment is a good ear. As the correct capacitor is found for each pitch, wire it in place and proceed to the next note. Every few minutes, recheck the pitches of the preceding ones, readjusting the main tuning control if necessary. There will not be significant drift while the Thyratone is in operation, but the initial tuning should be very exact, which is why any drift at all should be corrected.

After tuning the 8-foot generator throughout the range, tune the 16-foot generator. Pull the 16-foot stop which has been wired and select the capacitor value which, when the lowest key is pressed, will tune the 16-foot generator to a shade *lower* than an octave below middle C. Then connect temporarily a 1-megohm potentiometer (in series with a .0025-μf capacitor) between the plate of the 8-foot amplifier and the grid of the 16-foot generator. Pressing the lowest key, reduce the resistance until the tone just pops into synchronism and hits the C exactly. Now press the next keys up through F, each time reducing the resistance until the 16- and 8-foot tones synchronize an octave apart. In each case, recheck the lower tones to see that they are still where they should be.

It may or may not be possible, depending on the tubes and the wiring, to go as far as F with one resistance value keeping all tones in sync. If not, stop at a lower note. Insert a fixed resistor and go on to the next group of notes in the same way. Tuning the 32-foot range duplicates the same process. When it is finished, pushing any key should produce three octavely related notes. The one or ones heard will depend on the stop buttons pulled.

The rest of the filters may now be wired up. There is an opportunity for the individual to express himself here, for by experimenting with values the tone quality of each stop can be altered to suit a whim. The ones shown in last month's Fig. 2 use values found in W. E. Kock's Patent No. 2,233,948 and are fairly well imitative of the organ stop qualities with which they are labelled. The woodwind stops really should be fed square waves, as is provided in the patent, but we have not bothered with that in the Thyratone. The inductors in the filters were made by removing cores and windings from old audio chokes and transformers and checking values with a bridge. For less exact results, the same thing can be done by ear.

In the keyboard unit, the hollow brass bar acts as the common ground connection so that when a key is pressed the strip of metal under it grounds all four contact springs.

Expression pedal

Photo E is a side view of the expression pedal. It consists principally of two pieces of wood 4 x 10 inches and ½ inch thick. A pair of angles attached to the center outside of each and a threaded ¼-inch bar going through all four pivot it. A wire-wound, 8-ohm T-pad is mounted on an angle on the bottom piece and is turned by a string-pulley arrangement with screw-eyes. Three turns of the string around the knob is sufficient, but one end of the string arrangement should be terminated in a spring to keep tension fairly constant. A pair of angles at the ends of the bottom board provide stops to prevent the pedal from being pushed too far in either direction.

Though this arrangement can be made to turn the pad through its full rotation, that is not ideal, since the pedal should not be allowed to cut volume down to zero. Selecting a knob with the correct diameter is the easiest way to control the amount of total rotation.

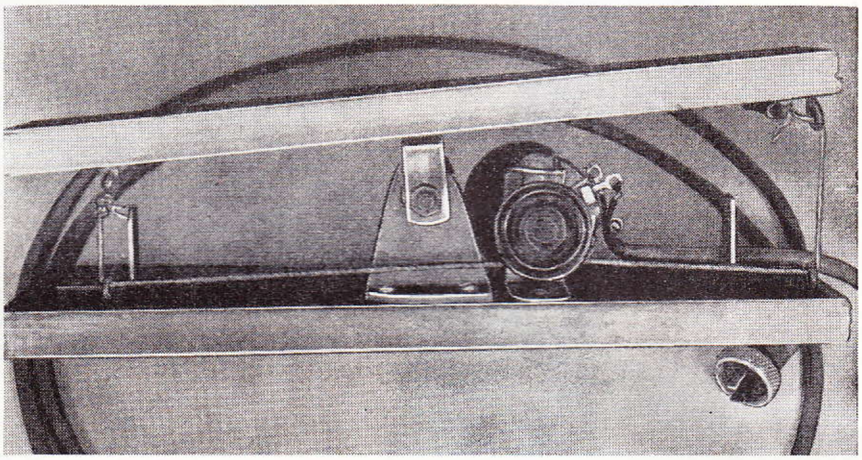

Photo E—View of the expression pedal. A cable connects it to the main chassis.

Modifications

The Thyratone, as described in these two articles, is an experimental instrument. While it was first designed on paper, many changes were made during the course of construction and there is no doubt that ingenious constructors will have many more excellent ideas to contribute to their own versions.

One good idea, for example, might be to alter the keyboard unit so as to place in it the tone generators. This would eliminate a healthy amount of wire and make for less cross-talk.

Addition of the "woodwind device" explained in the Kock patent would add to the realism of the woodwind tones.

There is a slight amount of gliding when a key is pressed; that is, the tone is not sounded squarely but slides up to pitch. That is caused by the use of a thyratron as a master oscillator, and it could be eliminated (and stability improved) by using some other kind of oscillator for at least the 8-foot range. For good tone shaping with the Kock system, however, the oscillator should provide a sawtooth waveform.

A separate tube for the triode amplifier which follows the 6SJ7 probably would help to eliminate cross-talk.

The present design, in any case, does give the electronic music designer a few interesting ideas and certainly provides a satisfying solo musical instrument. Since the stops are imitative of existing acoustic instruments and can be used individually or in any desired combination, a very large range of tone qualities is available to prevent the listener and player from tiring of the sound. It does, of course, sound rather "electronic" because each pitch is so steady, without the minute, random waverings caused in acoustic instruments by variations of air pressure and swelling of sound cavities. Later in this series methods of overcoming the "electronic-ness" of many such instruments will be discussed. —END—