Electronic Organ in Kit Form For Home Construction

RICHARD H. DORF*

Description of the filters which create the pipelike tone qualities and the new type of phase-shift vibrato in the Schober Organ Kits.

In three parts — Part 3

As explained in last month's article, each of the nineteen stop filters in the Schober Organ is fed tone of the correct pitch register or registers by one or two preliminary-amplifier triodes. Several of these filters are presented in detail in *Fig.* 19. Discussing one or two examples will show the scheme of operation.

The pipe organ has normally four types of tones—flute, string, reed, and diapason: there is of course, considerable variety available within each class. All these tone types are reproduced in the Schober.

The Great 8' Flute is typical of the first class. Here the incoming 8-foot sawtooth is passed through a three-section low-pass filter designed to roll off the upper harmonics so as to give a smooth, round tone which is not quite a sine wave. As with all the filters there is a blocking capacitor at the input to prevent d.c. from the tube plate from passing into the filter and following circuits. There is also a resistor at the output to set the comparative volume level of the stop. Stop switching is done by shorting the filter input (after the blocking capacitor) to ground.

A typical string filter is the Swell 8' Salicional. String tone is characterized by comparatively little fundamental and large high-harmonic content: it is very "buzzy." In this filter there is little filtering action other than slight differentiation due to the small blocking capacitor, and the sawtooth comes through unchanged except for some flattening of the sweep with consequent transformation of the flybacks into near-spikes.

Reeds are used in pipe organs not only as imitation of orchestral reed instruments but also to simulate brasses. A typical true reed is the Swell 8' Oboe, with its thin, nasal, penetrating tone. In this filter the input wave is first slightly differentiated by the blocking capacitor and the 47,000-ohm resistor and tuned circuit to ground. Then it is shunted by the tuned circuit which greatly emphasizes a portion of the spectrum in the neighborhood of 1600 cps. All reeds are characterized by a definite formant of this type.

Diapason tone is peculiar to pipe organs and is not imitative of any orchestral instrument. Typical is the Great 8' Open Diapason which employs both 8- and 4-foot tone to give it a somewhat accentuated second harmonic at all frequencies. The tones are passed through a low-pass circuit which has a fairly high cutoff. In this way the tone retains the vitality of a good organ diapason while retaining the necessary full body imparted by the fundamental.

All the filters work in this same manner to yield synthesized pipe and orchestral tones reasonably close to the originals. All the filter outputs for each manual and the pedals are connected together permanently. Because the stop-switching ground shunt is at the input of each filter, there is no change in the loading on the output bus when additional filters are switched on. For this reason, the tone of each filter retains its integrity and can be picked out separately in an ensemble of several, just as in a pipe organ. They can be used in ensembles of many kinds, and the pitch register systems of the Schober is especially useful here; a solid 8-foot tone can be brightened by a touch of 4-foot tone from a 4-foot filter, a 4-foot ensemble can be given a little more body by an 8-foot filter, and so on *ad infinitum*. The couplers add greatly to this flexibility in making it possible to mix stops from both manuals or add them to the pedals, as well as to add the octave on either or both manuals.

Each of the nineteen filters and six couplers is mounted on a 2×4-inch etched-circuit panel, some of which are shown in *Fig.* 20. While there are too many connections on these panels to allow marking component placement, each connection point is lettered and the instructions contain charts showing which components go into which lettered holes, making construction easy and unmistakable.

All the filters are mounted on the Fil-

Fig. 20. All stop filters are constructed on uniform-sized printed circuit panels.

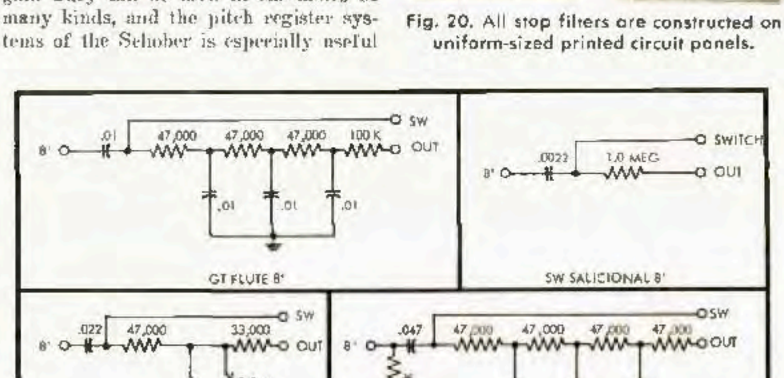

Fig. 19. Schematics of four typical filters used in the organ and described in the text.

** Electronics Consultant, 255 West 84th St., New York 24, N. Y.*

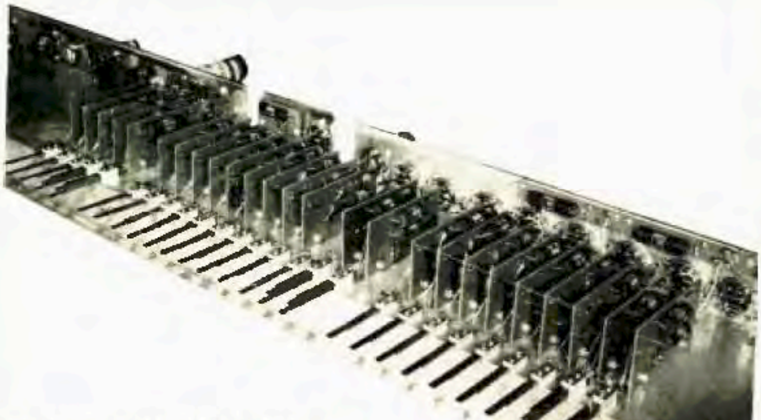

Fig. 21. A portion of the filterboard, showing mounting of the stop filters. Switches at the front are engaged by the stop tabs.

terboard, a long metal channel which runs the length of the organ, as shown in *Fig.* 21. On the front of the filterboard are the stop switches; they are actuated by the toggle-type organ tablets mounted on the wooden nameboard of the console. On the rear edge of the filterboard are mounted the chassis of the preliminary amplifier, woodwind circuit, and preamplifier-vibrato unit. All connections are made by wires "swept under the rug" to eliminate cabling by passing them through holes and running them under the filterboard.

Preamplifier-Vibrato Unit

The Preamplifier-Vibrato Unit is the final electrical assembly through which all signals go before reaching the power amplifier; the unit is diagrammed in *Fig.* 22.

Each set of stop filters—great, swell, and pedal—has a common output bus. These busses are terminated by R_4, R_5, and R_6 and from each bus one of the resistors R_1, R_2, and R_3 goes to the grid of the 6SQ7 first preamplifier tube. These isolating resistors are included to avoid the necessity of commoning all busses, which would increase the loading on the output with reactive components. Although such a common would not cause the switching in of any filter to affect the tones of filters already in use (this is due to the shunt-type stop switching), the output of almost every filter is partly reactive and commoning all of them would slightly complicate the voicing problem.

R_{33} and C_{14} to ground constitute a variable low-pass filter which is adjustable from the stop panel (or *nameboard*, as it is called) to add flexibility by giving control of over-all brilliance. Tone colors are normal with the potentiometer arm in center position.

Two 6SL7's are used in the novel phase-shift vibrato which is unique in the Schober Organ. It is common practice in electronic organs to vary the voltage of some electrode of all the master oscillators for vibrato; this varies the frequency of oscillation (at a rate somewhere between 5 and 8 cps) and produces the familiar and necessary vibrato or "tremulant" effect. It is axiomatic that an oscillator whose frequency can be varied in this manner is inherently not entirely stable, and its center frequency may be prone to vary from time to time so that the instrument does not stay in tune over long periods. While it would be presumptuous to say that all organs using this type of vibrato get out of tune easily, it is possible in a kit instrument to forego certain economies in order to achieve the ultimate in operation. This philosophy was responsible for the 14-tube Preliminary-Amplifier, a unit whose benefits kit constructors can enjoy at small cost but which would be much too expensive for most commercial factory-assembled instruments.

The Schober vibrato system, therefore, does not operate on the tone generators at all. As a result, the master oscillators could be—and have been—so designed that, for instance, a 50-volt plate-supply change has negligible effect on tuning, truly an unusually high degree of stability. The vibrato operates on the tones after they emerge from the 6SQ7 stage in *Fig.* 22 by varying the relative phase of the signal over a wide range at a vibrato rate. Such phase variation is to the ear the equivalent of frequency modulation (which is what vibrato is) just as many FM broadcast transmitters generate FM by phase modulation.

Phase modulation of the necessary type is not such an easy trick and the circuit employed was developed by the writer especially for the purpose. *Figure* 23 shows a phase-shift circuit of the usual type in which the capacitive reactance is equal to or greater than the resistance. If either element is varied the relative phase of the output signal changes. The two faults of this circuit for vibrato use are:

1. Change of phase in this way also causes change of amplitude, and amplitude changes are different at every frequency.

2. The amount of phase shift differs at every frequency, the maximum attainable at the best frequency being somewhat less than 90 deg.

Figure 24 shows a circuit of more practical value, first published for use in phase-angle measurements.[1] The input signal is in push-pull form—two signals of equal amplitude and opposite phase.

[1] Robert C. Moses, "Phase-angle measurements at a.f.," *Radio & TV News*, Radio-Electronic Engineering Section, July 1953.

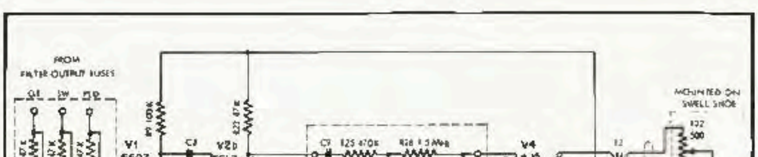

Fig. 22. Schematic of preamplifier-vibrato unit.

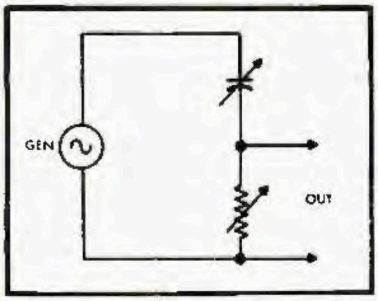

Fig. 23. Basic equivalent circuit of the phase-shifting operation of the preamp-vibrato unit.

With connections as shown, variation of either impedance component will cause changes in relative output phase over a maximum possible angle of about 175 deg. While the phases of outputs of different frequencies with respect to either half of the input signal are different, varying a component shifts the phase of a signal of any frequency within a wide band over a considerable range with respect to its resting phase.

The action of the circuit can be seen superficially with the aid of the theory of extremes. If the resistor value is reduced to zero, the output is directly across *GEN 2*, and it has the phase of that half of the input. If the capacitor is at zero reactance, the output has the phase of *GEN 1*. It follows that at intermediate values of resistance and reactance the phase of the output is somewhere between these two 180-deg. extremes. The crowning—and a most important—point is signal output amplitude does not change during phase shift, nor is the input-to-output path frequency discriminating under any conditions.

To translate this to an actual vibrato circuit several things are necessary. It is obvious that either output lead could be grounded in *Fig.* 24; that shown is deliberately chosen for our purpose. The input signal must be translated from single-ended (as it emerges from the 6SQ7) to push-pull; this is easily done by feeding it through V_{2A} to T_1, which has a centertapped secondary. Next, either the resistance or capacitance must be replaced by an element with the same characteristics but which can be varied electronically. The solution to this is to replace the resistor with the plate resistance of a tube—V_{3A} in *Fig.* 22. With the grid of V_{3A} driven by signals from the phase-shift oscillator V_{3B}, which operates at a vibrato frequency of around 6 cps, the plate resistance of V_{3A} varies at a vibrato rate and the signal output between the transformer centertap and ground is phase-modulated. The capacitance of *Fig.* 24 is the series value of C_4 and C_5.

Some further refinements are necessary. First, the vibrato rate and amplitude are made variable and controlled by S_1 on the organ nameboard. This is simply a matter of controlling the frequency of the oscillator and the signal input to the grid of V_{3A}. Both are done simultaneously by the switch, so that in the first position vibrato is slow and narrow, in the second position slow and wide, and in the third position fast and wide. Position 2 is used normally; position 1 gives an unobtrusive vibrato suitable for serious music, while position 3 is used for some popular music or where a rather ethereal and novel effect is desired.

Because it is not convenient for the player to use a three-position switch for control of vibrato in the middle of a selection, on-off control of vibrato is assigned to a tab similar to those used for stops and marked in red. With this tab in the up position, the connection marked vib sw in Fig. 22 is grounded and the vibrato oscillator stops. When the tab is flicked down, the ground is removed and the vibrato begins quickly but smoothly due to the finite time required for oscillation to build up.

One problem with this system is that if used without further modification the vibrato-frequency signal applied to the grid of V_{3A} will come through to the output as a series of thumps. This is easily cured, however, and the cure solves another requirement—that for good musicality the bass tones should have much less vibrato than others. Output from the transformer centertap passes through a high-pass filter C_{10}-R_{24}-R_{27}-C_{11} on its way to the final preamplifier stage V_4; this reduces the thumps to inaudibility and also greatly reduces the level of bass tone from the vibrato circuit. The missing bass, unvibrated, is then supplied to the final tube by V_{2B} through the low-pass filter R_{25}-C_{12}-R_{26} in its output circuit. The two networks are complementary, so that the final tube receives all input frequencies in correct proportion but with bass obtained mostly from V_{2B} and therefore low in vibrato.

Although the vibrato circuit in the Schober Kit is furnished as shown in *Fig.* 22, it is obvious that enterprising individuals could use separate vibratos for the two manuals to achieve additional musical flexibility as well as a chorus effect.

R_{18} is a potentiometer with a short or screwdriver shaft located on the Preamplifier-Vibrato Unit chassis. It is preset at the time of installation to limit the maximum output volume to that desirable in the room, so that the expression pedal can be used fully. V_4 is an ordinary transformer-output voltage amplifier which furnishes a maximum of 2 volts in 600 ohms to the high-quality carbon potentiometer R_{32} which is mechanically coupled to the expression pedal or swell shoe. C_{13} adds additional impedance at low frequencies so that when the volume is made low the overall tonal balance between bass and treble does not alter appreciably—a sort of loudness control.

Output taken from J_1 is fed by a cable to any power amplifier the constructor wishes to use: none is furnished in kit form. Any of the good modern "high-fidelity" amplifiers is satisfactory, though it is recommended that the amplifier be rated at a minimum of 20 watts to take care of the high-level 30-cps tone of the pedal division. Common practice in homes is to use the same amplifier employed for the home music system, with the organ line coming up on the same switch in the regular control unit which selects phonograph and tuner.

The same loudspeaker as in the home music system is usually used, but it must be a good one, particularly from the bass standpoint. Tweeters are not really necessary, though they add some brilliance, the important point being one—and preferably more than one—good bass speaker in a solid enclosure and able to withstand large cone excursions.

A few years ago, most people would have laughed at the idea of constructing a full-scale concert electronic organ at home. The Schober Organ Kits are evidence that the phenomenal advance of electronics has not stopped at the fine reproduction of sound typified by the modern high-fidelity era, but has gone on to make possible the synthesis of traditional music by electronics entirely practical and artistically satisfactory.

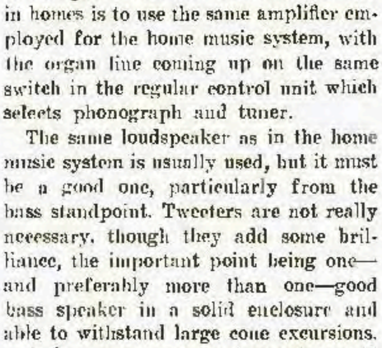

Fig. 24. Simplified circuit of the phase-changer which introduces an effect resulting in vibrato. GEN 1 and GEN 2 are actually the same tone, but with a 180-deg. phase difference.