Tremolo

For years some commercial electronic organs have used mechanical rotating speakers to produce a tremolo effect; recently, this offbeat approach has gained popularity with musicians in general because the sound produced is totally unlike most electronic forms of tremolo.

The problem with mechanical speakers is that they are bulky and much too heavy to be conveniently carried; and their high cost puts them beyond the means of many amateur and semiprofessional musicians. The tremolo circuit described in this section is a low-cost portable electronic device that simulates the rotating speaker effect. The manufacturer of the commercial version (see board, Fig. 2-61) calls it *Synthespin.*

Other than the rotating-speaker sound, the Synthespin can produce numerous effects ranging from very slow phasing type sounds to a bubbling pseudo-reverb. Electrical inputs provide for foot-pedal control of both speed and range of the rotating effect and allow instantaneous foot-switch cancellation and bypass functions.

Operation. The Synthespin is designed for low-level signal processing, so peak-to-peak signal amplitudes should in general be kept below 0.5V. When the unit is being used to process the signals from electrified musical instruments such as guitar, accordian, saxophone, etc. there is no problem as the signal levels from these instruments are typically considerably below this limit. When using the Synthespin with an electronic organ, however, the insertion point must be carefully chosen. An organ with an *expression* pedal offers the

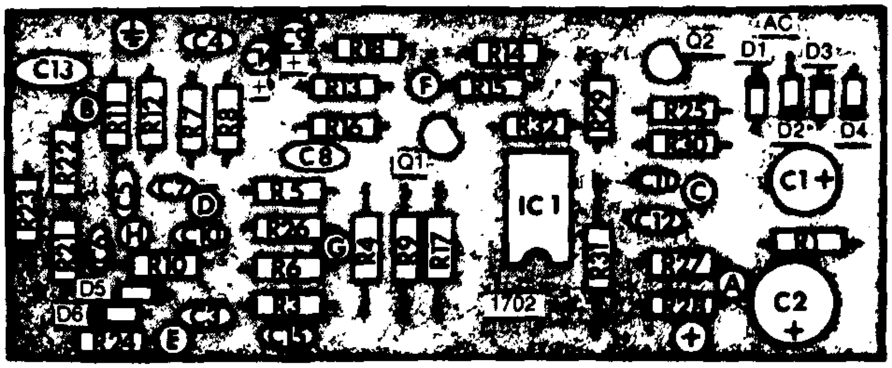


Fig. 2-61. Synthespin circuit board layout.

easiest possible installation because the connections to this pedal are often made with RCA-type phono connectors. It is a simple matter to unplug the input to the expression pedal and extend the lead by a sufficient amount to reach the location of the Synthespin unit. On organs that do not have expression pedals, the Synthespin may be inserted between the organ's preamplifier and power amplifier. This may require that small modifications be made inside the organ (to gain access to the preamp output).

You may find that you do not need to advance the volume controls of the instrument or amplifier quite as far when using the Synthespin. This is normal and is caused by a slight power boost designed into the Synthespin.

Operation of the controls as labeled on the schematic of Fig. 2-62 is as follows:

The apparent speed of the "rotating speaker" is variable from one cycle every three seconds to 15 per second using the SPEED control. Rotating the knob in a clockwise direction increases the speed.

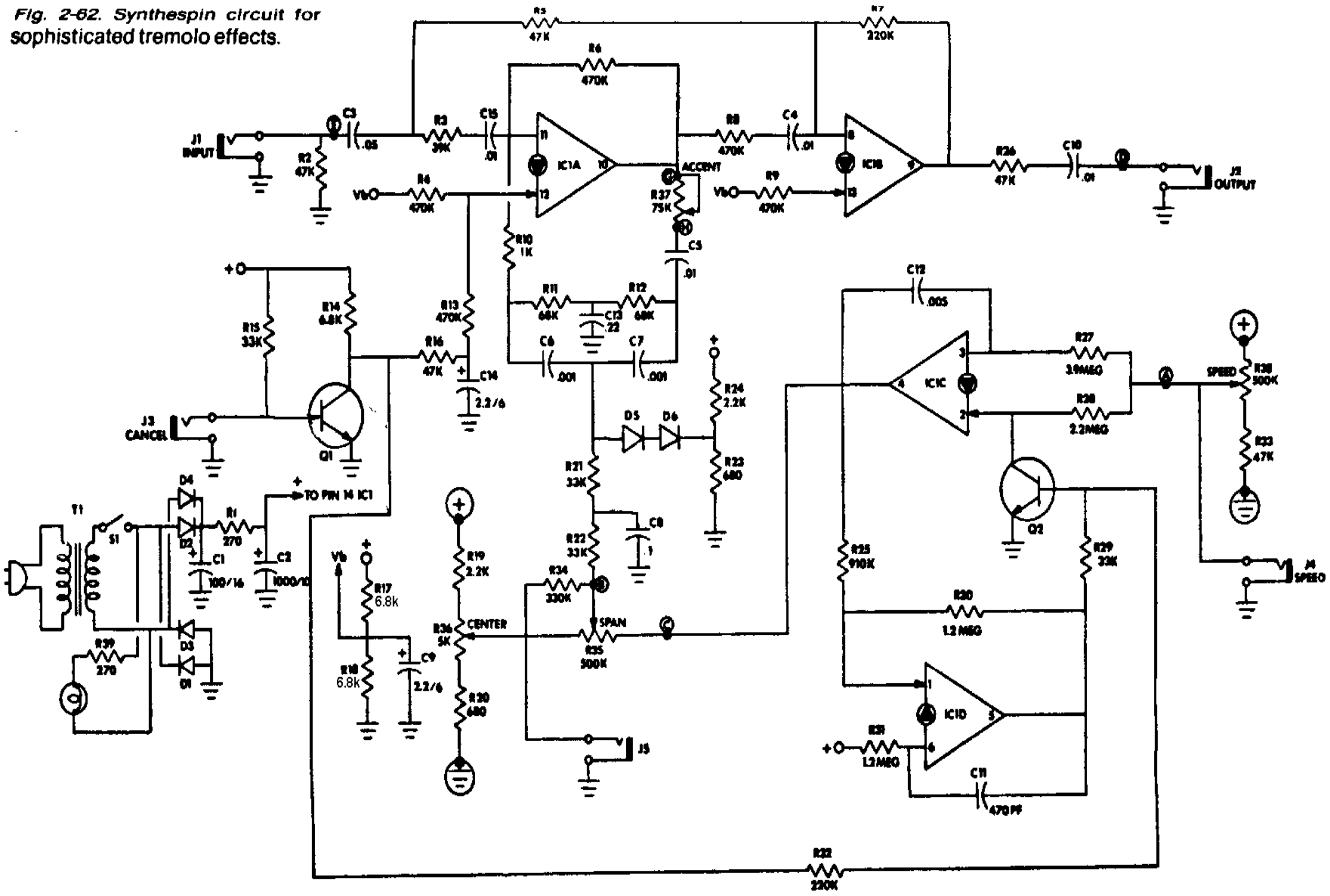
The ACCENT control allows the performer to alter the presence of the Synthespin effect. As the control is rotated in a clockwise direction the effect becomes more pronounced. After some experimenting with the Synthespin you may notice that as the SPEED control is advanced the effect becomes more noticeable and a lower setting of ACCENT will produce an equivalent sound. This phenomenon is purely subjective; there is no interaction between these controls.

The SPAN control is also connected to the power switch; rotating the control fully counterclockwise turns the power off.

With the SPAN control at its fully clockwise setting, the CENTER control has no effect; but as SPAN is turned back, the CENTER control has a greater effect on the portion of the instrument's tonal range that is modified. When the SPAN control is fully off, the CENTER control can be used to manually phase the signal.

Closing a switch plugged into the CANCEL jack turns off the effect. Best results are obtained using a push-on/push-off switch such as that in the PAIA 4720 foot switch. (Throughout this book I refer to PAIA modules, special components, and systems. PAIA is the name of the synthesizer manufacturer that supplied not only the majority of working circuits published herein but much of the operating information, design analysis, and performance data. Specifically

Fig. 2-62. Synthespin circuit for sophisticated tremolo effects.



referenced components, foot switches, keyboards, and completely wired and tested circuit modules may be obtained by mail from PAIA Electronics, Oklahoma City 73144.)

With the CANCEL switch closed, only the rotating effect is turned off; the unit should still pass the signal at the same relative level as when the effect was on.

The jack on the rear of the case marked SPEED accepts an external 0–9V control voltage and sets the speed of the effect proportional to the positive external voltage. Typical of the devices used to supply this voltage is the PAIA 2730 foot control. Other voltage sources may be used for remote control as long as the positive side of the supply goes to the tip of the jack used to make the connection. When using a remote control voltage, the SPEED control must be turned fully counterclockwise.

The CENTER jack allows remote foot-pedal control of the *center* function. Like the SPEED jack, this input accepts a 0–9V control signal. As the control voltage increases it has the effect of turning the CENTER knob in a clockwise direction. Polarity of the control voltage at the phone jack is the same as for the auxiliary SPEED input, so the same voltage source may be used for either of these functions. When using an external control voltage source the CENTER control should be rotated fully counterclockwise.

Design Analysis. At the heart of the Synthespin is a new integrated circuit package, the LM 3900 quad Norton amplifier. This device consists of four separate differential input amplifier sections, each of which is somewhat similar to the more familiar operational amplifier. It is different in two subtle but very important respects: First, unlike standard opamps, the Norton amplifier is designed as a current differencing rather than a voltage differencing device. Second, the Norton amplifier is meant to work from a single voltage supply rather than the split supply typically used for opamps.

The fact that the inputs of the Norton amplifier are intended as current sinks is implied by the schematic symbol for the device shown in Fig. 2-63. The arrowhead on the noninverting (+) input denotes a current flow into this input, and the circled arrowhead between the inverting (–) and noninverting inputs is meant to imply that there is a constant current sink at this input which is controlled by the signal at the noninverting input.

Because of this current differencing configuration, the Norton amplifier is capable of performing some functions that

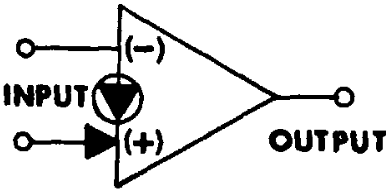


Fig. 2-63. Norton amplifier symbol.

are beyond the capabilities of a standard opamp. Typical of this versatility is the voltage-controlled oscillator composed of amplifiers 1C and 1D. (Note that in schematic diagram the four separate sections of the IC have been labeled as 1A through 1D for clarity.) Experimenters used to working with operational amplifiers will recognize the circuitry surrounding the IC as some sort of strange integrator.

Assume for a moment that Q2 is off. With this condition, there is a current flow into each of the inputs of the amplifier and the amplifier works to make these currents identical. If C12 were not present this would of course be impossible because the value of the resistor at the positive input (R28) is almost half the value of R27 at the inverting input. With C12 in the picture, however, the situation is different; and by constantly and linearly increasing the voltage at its output, the amplifier can cause a current to flow through C12 that, when added to the current through R27, causes the two input currents to be identical. The result is a linearly increasing voltage ramp at the output of stage 1C that would continue to rise almost to the supply voltage if it were not for the Schmitt trigger built around stage 1D.

For the moment disregard C11 and notice that there is positive feedback from the output of stage 1D to the + input. The amplifier compares the two input currents and acts in such a way as to try to make them equal. There is a constant current supply into the inverting input of this amplifier through R31 which is compared to the sum of the current supplied to the noninverting input through R25 and R30. When the circuit is first turned on, the output of stage 1D is at ground (as is the output of stage 1C) so that the current into the noninverting input of stage 1C is very low compared to the current flow through R31. Because of this the output of stage 1D is held low. As the integrator begins to ramp up, the current flow through R25 increases until it exceeds the current flow through R31. At this point stage 1D switches and the output changes from near ground to close to $+V_{CC}$. The sum of the currents through R25 and R30 now far exceed the current flow through R31 so that the amplifier stays in this high output state.

When the output of stage 1D goes high, it turns on Q2, which now acts as a current sink to prevent any current from being supplied through the noninverting input of stage 1C. The only current now being supplied to the inputs of stage 1C is through the inverting input, so the amplifier must act in such a way as to make this current equal to the current at the noninverting input. The only way it can do this is to constantly and linearly decrease the voltage at its output so that a current flows through C12 that is equal and opposite to the current through R27. This causes the voltage at the output of stage 1C to decrease until at some point the current flow through R31 is greater than the combined current flow through R25 and R30. At this time stage 1D switches back to its low state, thereby turning off Q2 and causing the integrator to begin ramping up again. The result is a triangular wave at the output of stage 1C as it integrates up and down, and a square wave at the output of stage 1D as it switches between its high and low states. The rate at which the voltage rises and falls is a function of the voltage input at point A. The SPEED varies the voltage at this point and therefore the frequency of this oscillator within the limits of 3 Hz, equivalent to over 5 octaves.

Stage 1A in the IC is arranged as a voltage-controlled bandpass filter. R11, R12, C6, C7, C12, and the equivalent impedance of diodes D5 and D6 form a notch filter which is in the negative feedback loop of this amplifier stage. Frequencies outside the notch of this filter pass through the feedback loop with little attenuation and tend to cancel the original input signal of that frequency at the amplifier's input. Signals that are attenuated by the notch are not fed back to the input and therefore do not cancel but are allowed to pass through the amplifier without attenuation. The Q of the active filter is controlled by attenuator R37 in the feedback loop; the time constants of the notch filter section are selected for maximum variability and flattest response over the frequency range from 350 to 1200 Hz. As the voltage across D5 and D6 increases, its equivalent impedance decreases; this causes the center frequency of the notch filter to shift up.

There are three biasing and control voltage sources for diodes D5 and D6. The first, R23 and R24, places the cathode of D6 at about 100 mV above ground. The second is a biasing source consisting of R19, R20, and potentiometer R36. This combination is capable of voltages between 1 and 8V at the wiper of R36. The third supply is the triangle output of the voltage-controlled oscillator, which appears across potentiometer R35. The wiper of R35 picks off a voltage that is a combination of the oscillator output and the voltage at the wiper of R36. When the wiper of R35 is at the end of the pot closest to point C, the voltage from R36 is isolated by the parallel combinations of R35 and R34 and therefore has little effect on the voltage at point B. But as the wiper of R35 is moved away from point C, the contribution of the oscillator becomes progressively less while the influence of the voltage at the wiper of R36 becomes progressively greater. This arrangement allows the voltage at point B to be anywhere between 1 and 8V, with any percentage of that voltage coming from either the oscillator or the constant supply. The voltage at point B is applied to the anode of diode D5 through the low-pass filter section composed of R21, R22, and C8, which converts the triangular output of the control oscillator to roughly a sine wave by filtering out the higher-order harmonic content.

Transistor Q1 provides a means of turning active bandpass filter section 1A on and off. As long as there is no connection between the base of Q1 and ground, it is held on by R15. With Q1's collector at ground, the total biasing current to stage 1A's noninverting input must come from R4.

When the base of Q1 is grounded—as it would be by closing a switch plugged into J3—the voltage at the collector jumps to near $+V_{CC}$, causing C13 to charge through R16. This causes an increased current flow into the noninverting input through R13, and will eventually result in the saturation of stage 1A. With 1A saturated and therefore not functioning, the only element in the signal path is stage 1B, which is arranged for a slight gain into a moderate load at output jack J2.

Part of the original musical input to the circuitry is coupled directly to the stage where it is summed with the output of the bandpass filter. Because of the gains of the bandpass filter and its natural 180° phase shift, the final output is actually a partial cancellation of the signal passed through the bandpass filter and a distortion of phase relationships of frequencies just outside this passband. As the passband sweeps back and forth under the influence of the oscillator, the effect is roughly the same as the frequency shifts generated by a rotating speaker.

In the commercial version, all controllable jacks and knob are accessible from the front panel. Figure 2-64 shows the circuit-board arrangement of these controls.

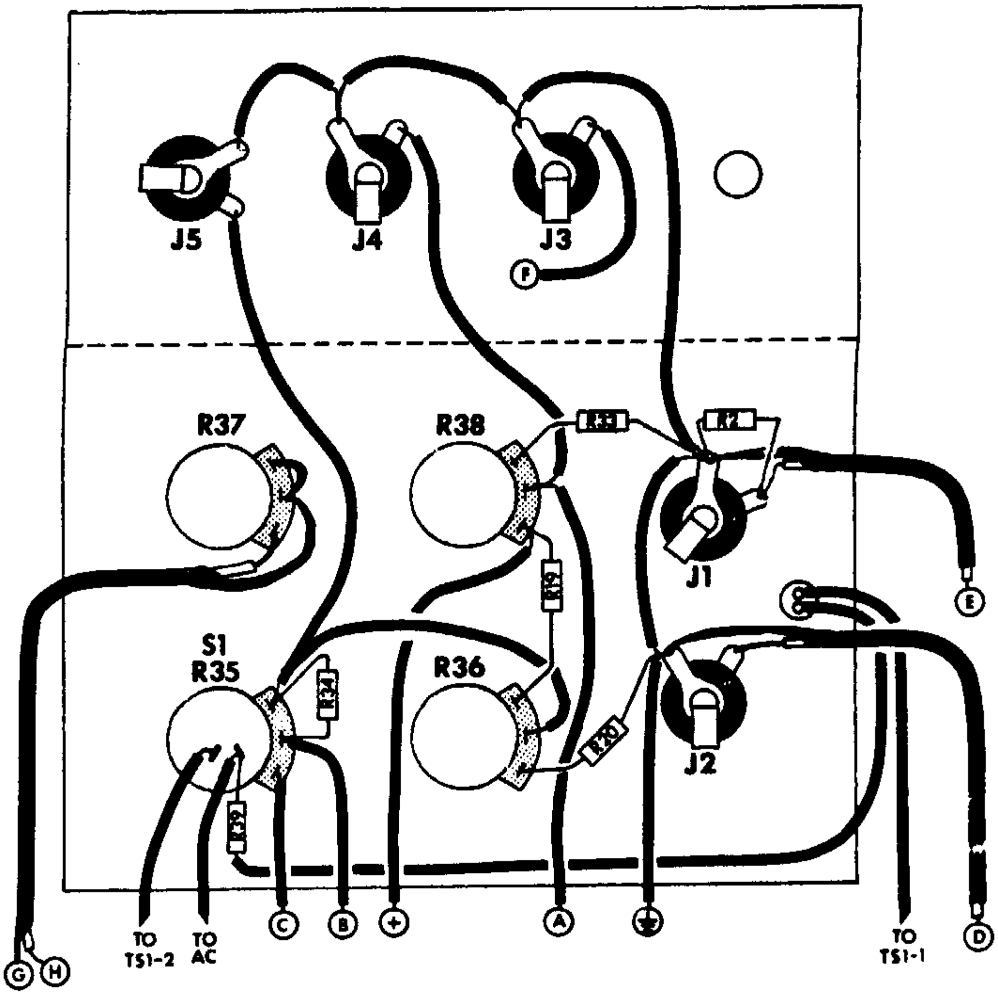


Fig. 2-64. Control layout of Synthespin circuit.