Electrochune

By John Clarke

A 23-note organ—two full octaves including sharps and flats—with special effects, the Electrochune is capable of a surprising variety of harmonious sounds.

☐WHY THE NAME *ELECTROCHUNE*? BECAUSE IT'S MEANT TO be a fun name for a fun project. We think that readers will really enjoy it, both in the building and in making music. Electrochune is easy to put together, with no expensive hardware, and is capable of a surprising variety of harmonious sounds. Electrochune has a range of almost two octaves, together with sharps and flats, and has six controls for varying its sound output.

Electrochune* is a complete self-contained keyless organ with all components mounted on a medium-size printed-circuit board measuring 8-in. × 10-in. It can be built in the bare-bones form shown in the photographs or dressed up with a cabinet, if you wish.

Electrochune can be played with your finger. Merely touching the *key* areas on the printed-circuit board brings each note into action.

Much of the circuitry in the Electrochune is similar to that used in modern synthesizers and so it has some features similar to those popular instruments. For example, like most synthesizers, Electrochune is monophonic. That means that it cannot play chords and is meant to be played one-handed or, really, in that case, one-fingered.

Electrochune is also similar to many synthesizers in that it uses voltage-controlled amplifiers, a sample-and-hold circuit and a voltage-controlled oscillator. As a result, it has such features as adjustable attack and decay for envelope control and tremolo. It also has voice mixing and its own built-in amplifier and loudspeaker.

Unlike earlier keyless instruments, the Electrochune can be tuned very precisely over its almost two-octave range, because each key can be tuned exactly and individually, without affecting any other key. That means that if you want to use the Electrochune seriously, in spite of our remarks at the beginning of this article, you can do so and set up each key so that it is exactly on pitch. It is also possible to tune the Electrochune to match other instruments. The mind boggles at the possible ramifications of that—you could even have "Electrochune in Concert".

Even though the Electrochune can be tuned very precisely, it is not necessary to go to any special bother if you are just building the unit for casual use. Just install the resistor values we have specified.

Electrochune is powered by an AC plugpack. While that will make it initially a little more expensive, it will soon pay for itself by eliminating the cost of batteries.

How It Works

While the complete circuit is fairly complicated, the Electrochune is easy to understand if the circuit is broken down into sections which can be examined one at a time.

Look at Fig. 1 which explains the broad principles of the circuit. The heart of the circuit is a voltage-controlled oscillator (VCO). As the name implies, that has a frequency output which is proportional to a voltage applied to its input. The input voltage for each note is fed to the VCO from its indivual voltage divider via an individual switch. Since there are 23 notes, there are 23 separate voltage dividers and 23 switches, each of which is actually a switch element in a CMOS quad bilateral switch package.

Following the VCO are the envelope-shaping and tremolo

*Original project appeared in *Electronics Australia*, July, 1981, and appears here by permission.

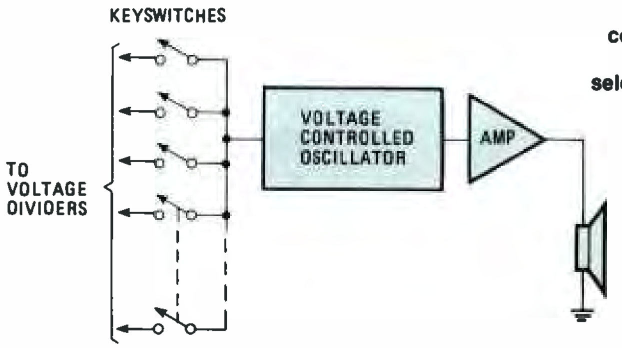


FIG. 1—THE HEART of the Electrochune is a voltage-controlled oscillator (VCO) that provides a cycled output proportional to the voltage applied to its input. By selecting proper voltages in sequence, a tune can be heard.

circuits and the audio amplifier and loudspeaker. Now if it were not for the fact that we wish to provide envelope shaping, the simple principle embodied in Fig. 1 would be adequate and the complete circuit diagram would be quite a lot simpler than it is.

By *envelope shaping* we mean giving a precise and defined value to the attack and decay of each note. Thus, for a given setting of the controls for attack and decay, each note will sound roughly the same in initial intensity, in duration and in the way it fades into silence. Thus, the envelope of each note will be same regardless of whether the player hits the notes in staccato or slower fashion. That is quite a refinement compared to previous keyless organs which provided very little facility for expression.

Okay. Now remember that the VCO requires a defined input voltage to produce a given frequency and that it is only while the particular keyswitches are closed that they connect the particular note voltage divider to the VCO. So what happens when the player takes his big greasy finger off the particular key and expects the note to fade away? It doesn't. Because when the input voltage is removed from the VCO its frequency immediately rises to a very high value, which is its free-running frequency. Since that would lead to a very unmusical and totally unsatisfactory instrument, we need to provide some means for the circuit to *remember* the VCO input voltage after the key is pressed. That is done with a sample-and-hold circuit and that is incorporated as shown in Fig. 2.

That diagram shows an array of switches for the various notes, each with its own voltage divider. When a key is touched, the appropriate CMOS switch (U11-U16) is closed, feeding the note voltage through to a FET-input op amp, (U10) which operates as a buffer stage. The output from that buffer is fed to a conventional op amp (U8) functioning as a Schmitt trigger and to a sample-and-hold circuit. The Schmitt trigger controls the sample-and-hold circuit as well as the envelope-shaping circuitry (for attack and decay) following the VCO. After the envelope shaper, a similar circuit provides further signal processing in the form of tremolo (amplitude modulation). Finally, the signal is amplified and fed to a loudspeaker.

Fig. 3 shows the different functions possible with the envelope shaping and tremolo circuits.

With Fig. 1 and Fig. 2 in mind, we can consider the complete circuit diagram as seen in Fig. 4. The heart of the circuit, the VCO, is U4, which is an Exar XR2206 function-generator integrated circuit. That is connected to provide simultaneous sinewave and squarewave outputs, which are mixed across a 5000-ohm potentiometer, R33, providing the necessary range of sinewave and squarewave.

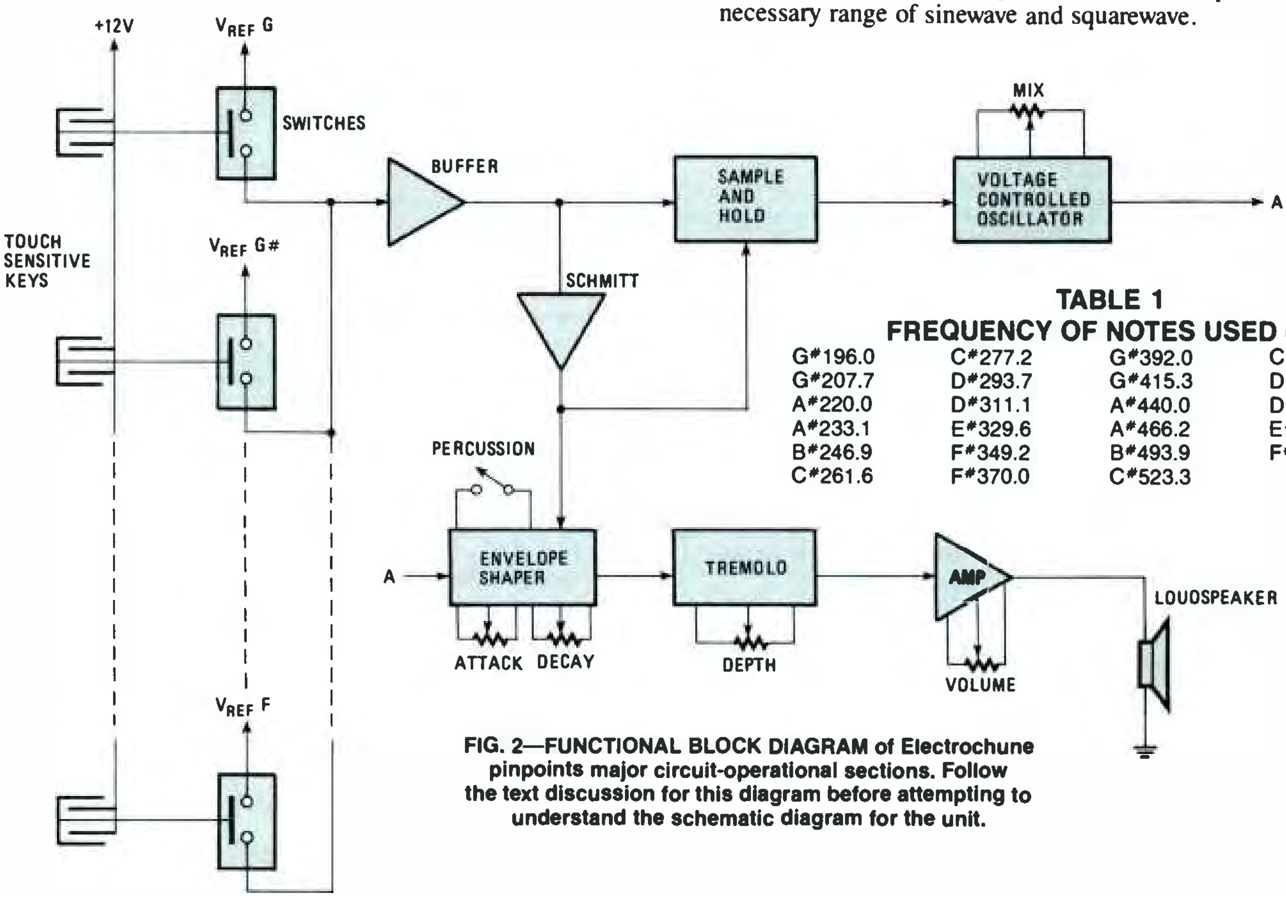


TABLE 1
FREQUENCY OF NOTES USED (Hz)

G#196.0	C#277.2	G#392.0	C#554.4
G#207.7	D#293.7	G#415.3	D#587.3
A#220.0	D#311.1	A#440.0	D#622.3
A#233.1	E#329.6	A#466.2	E#659.3
B#246.9	F#349.2	B#493.9	F#698.5
C#261.6	F#370.0	C#523.3	

FIG. 2—FUNCTIONAL BLOCK DIAGRAM of Electrochune pinpoints major circuit-operational sections. Follow the text discussion for this diagram before attempting to understand the schematic diagram for the unit.

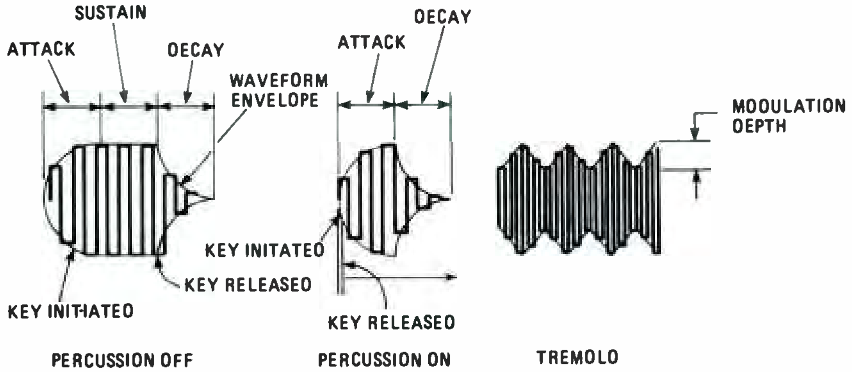


FIG. 3—A PICTURE IS WORTH a thousand words, and a diagrammed waveform is worth even more! Here, the attack, sustain, and decay effects on a waveform are seen in the two waveforms at left and center. Percussion on/off pertains to the setting of switch S1. The right diagram of a waveform illustrates the tremolo effect superimposed on a continuous wave; however, the effect will function on random-frequency waveforms (like music) as well.

Looking back to the key inputs, U11, U12, U13, U14, U15, and U16 are quad CMOS bilateral switches which provide the input from the note-voltage dividers. The CMOS switches are switched by skin resistance of the finger placed across the appropriate key pattern.

The selected note voltage is fed to a FET-input operational amplifier, U10, operating as a buffer stage. The input of U10 is normally held high by a 10-Megohm resistor, R24, when all CMOS switches are closed. Resistor R24 has a negligible loading effect on the note voltage.

The output of U10 is fed to U8, the Schmitt trigger, and also to the sample-and-hold circuitry. That consists of a single CMOS switch (U14d) and U3, another FET-input operational amplifier connected as a voltage-follower which monitors the voltage across a .047-µF capacitor, C27.

Sample and Hold

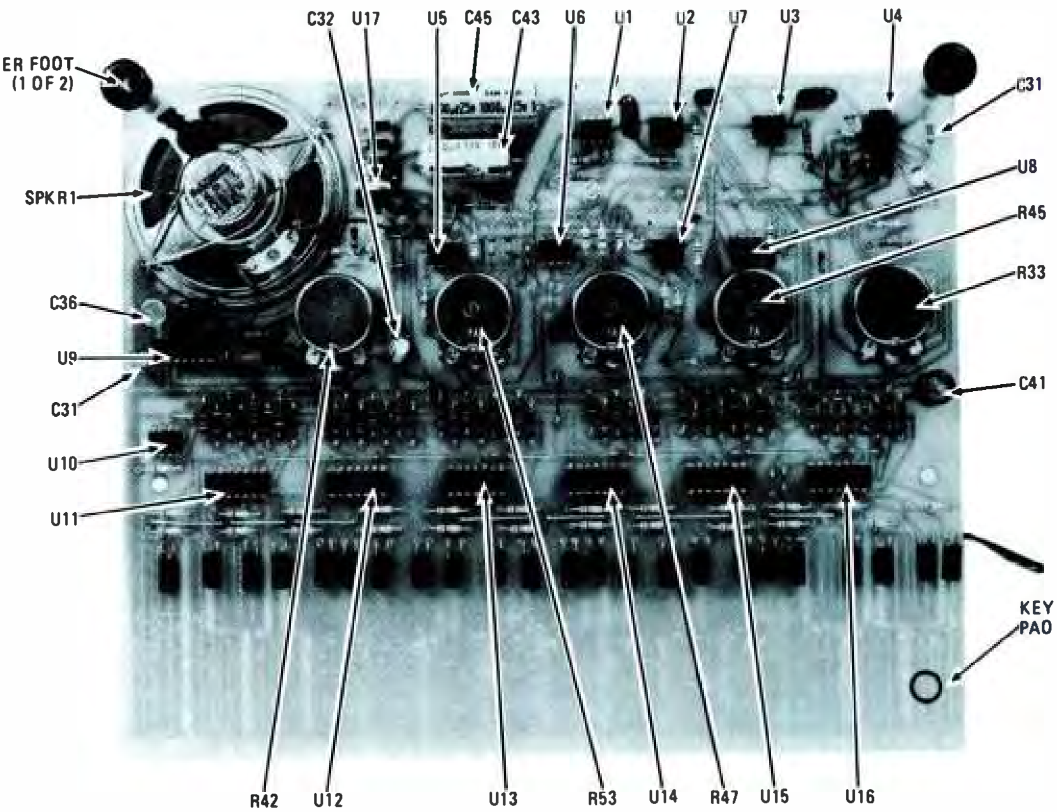
As soon as a selected voltage appears at the output of buffer U10, it drives the output of Schmitt trigger U8 low, initiating the 555 monostable timer, U2, which delivers a short turn-on pulse to U14d in the sample-and-hold circuit. That allows the .047-µF capacitor, C27, to charge to the full value of the note voltage—a value which it will hold, by virtue of being in a very-high impedance circuit, until the next note is struck. Voltage-follower U3 then feeds the capacitor voltage value to the VCO to determine the frequency.

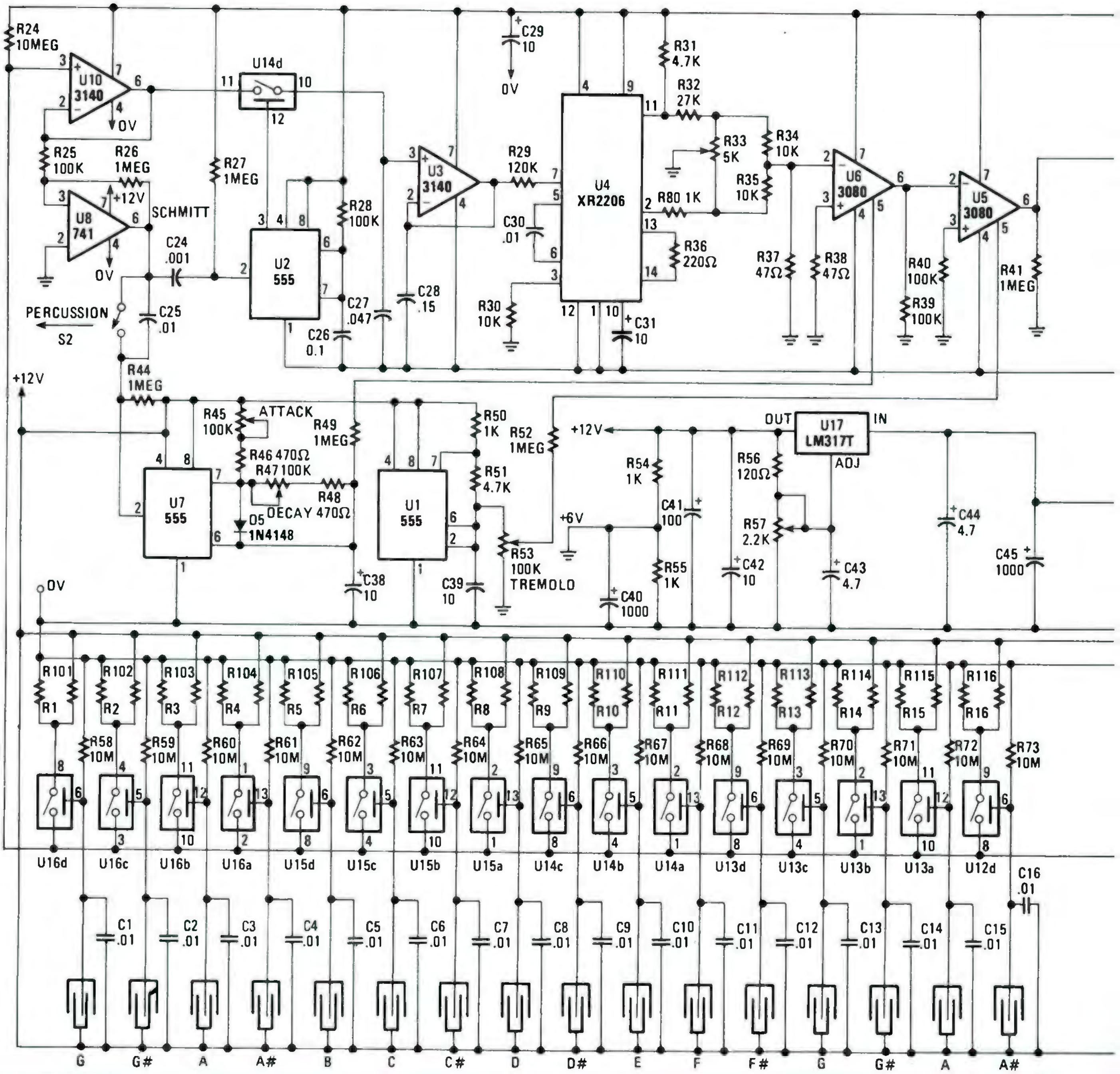
At the same time as the Schmitt trigger initiates the monostable to operate the sample-and-hold, it also initiates the envelope-shaping circuitry. Thus, at the same time as the note frequency is determined, its envelope is also controlled. Logical, isn't it?

So the Schmitt trigger also initiates 555 monostable timer U7 for a set period. Here, the ramp voltage at pin 6 is used to control a CA3080 transconductance amplifier (read: variable-gain amplifier) U6. The ramp voltage goes up for attack and down for decay, and is separately controlled for those two parameters by 100,000-ohm potentiometers, R45 and R47.

The percussion switch associated with U7 works in the following way: A 1-Megohm resistor, R44, normally holds the trigger input, pin 2, high and triggering is either done through the .01-µF capacitor, C25, or directly, via the percussion switch contact, S2. When the percussion switch is in the

PARTS LOCATION for key components located on the printed-circuit board. This project requires an etched circuit board. Using other wiring techniques will only prove to make the project more difficult to assemble and operate.





PARTS LIST FOR ELECTROCHUNE KEYLESS ORGAN

SEMICONDUCTORS

D1-D4—1N4002 1A rectifier diode
D5—1N4148 small-signal switching diode
U1, U2, U7—555 timer integrated circuit
U3, U10—CA3140 BiMOS operational amplifier
U4—XR2206 monolithic function generator integrated circuit
U5, U6—CA3080 operational amplifier
U8—741 operational amplifier
U9—LM380 audio power amplifier (14 pin DIP) integrated circuit
U11-U16—4066 CMOS quad bilateral switches integrated circuit
U17—LM317 three-terminal regulator

RESISTORS

(All fixed units are 5% tolerance, ¼-watt. Refer to Table 2 for additional information)
R1-R4—22,000-ohm
R5-R7—20,000-ohm
R8-R10—18,000-ohm
R11-R12—16,000-ohm
R13—15,000-ohm
R14-R15—13,000-ohm
R16—12,000-ohm
R17—11,000-ohm
R18-R21, R30, R34, R35—10,000-ohm
R22-R23—9100-ohm
R24, R58-R79—10-Megohm
R25, R28, R39, R40, R104—100,000-ohm
R26, R27, R41, R44, R49, R52—1-Megohm
R29—120,000-ohm
R31, R51—4700-ohm
R32—27,000-ohm

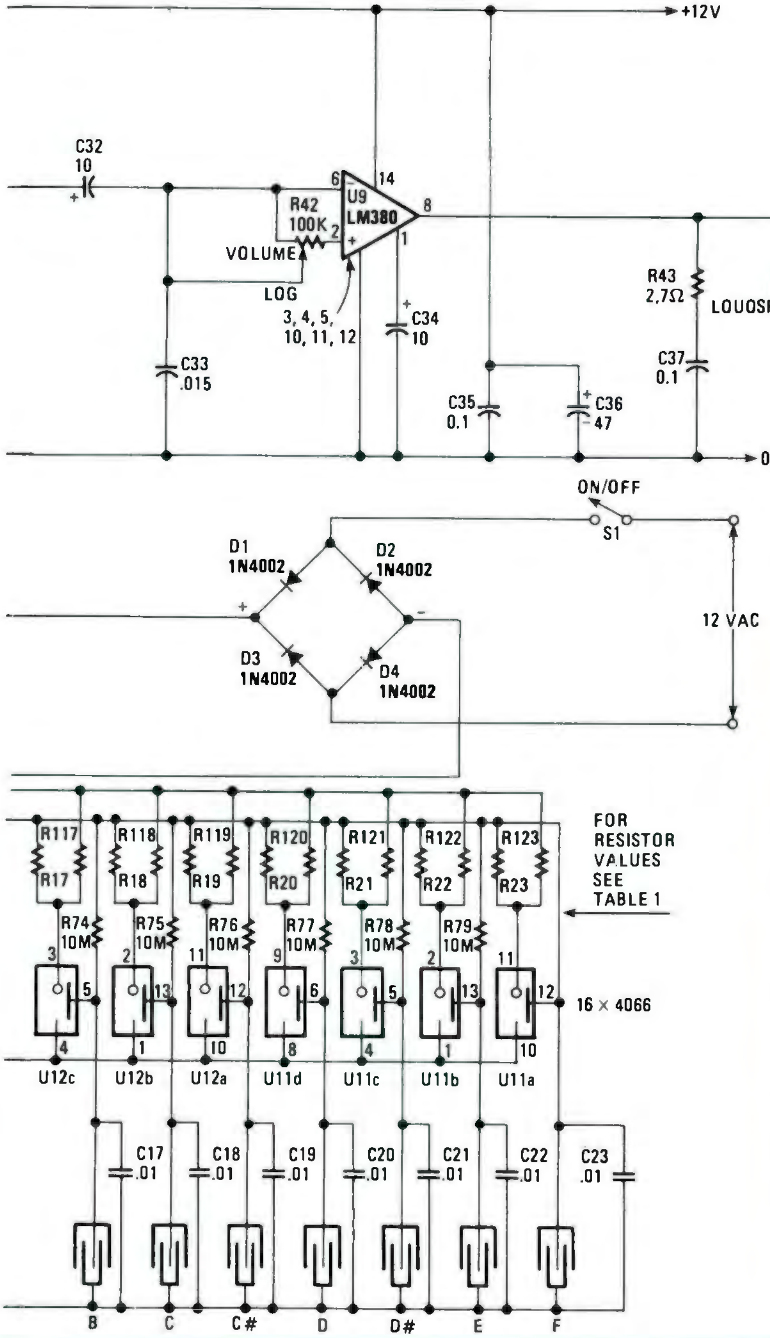
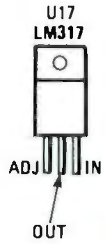


FIG. 4—COMPLETE SCHEMATIC DIAGRAM for the Electrochune is given on this page. Power supply is a 12-volt DC plug pack.



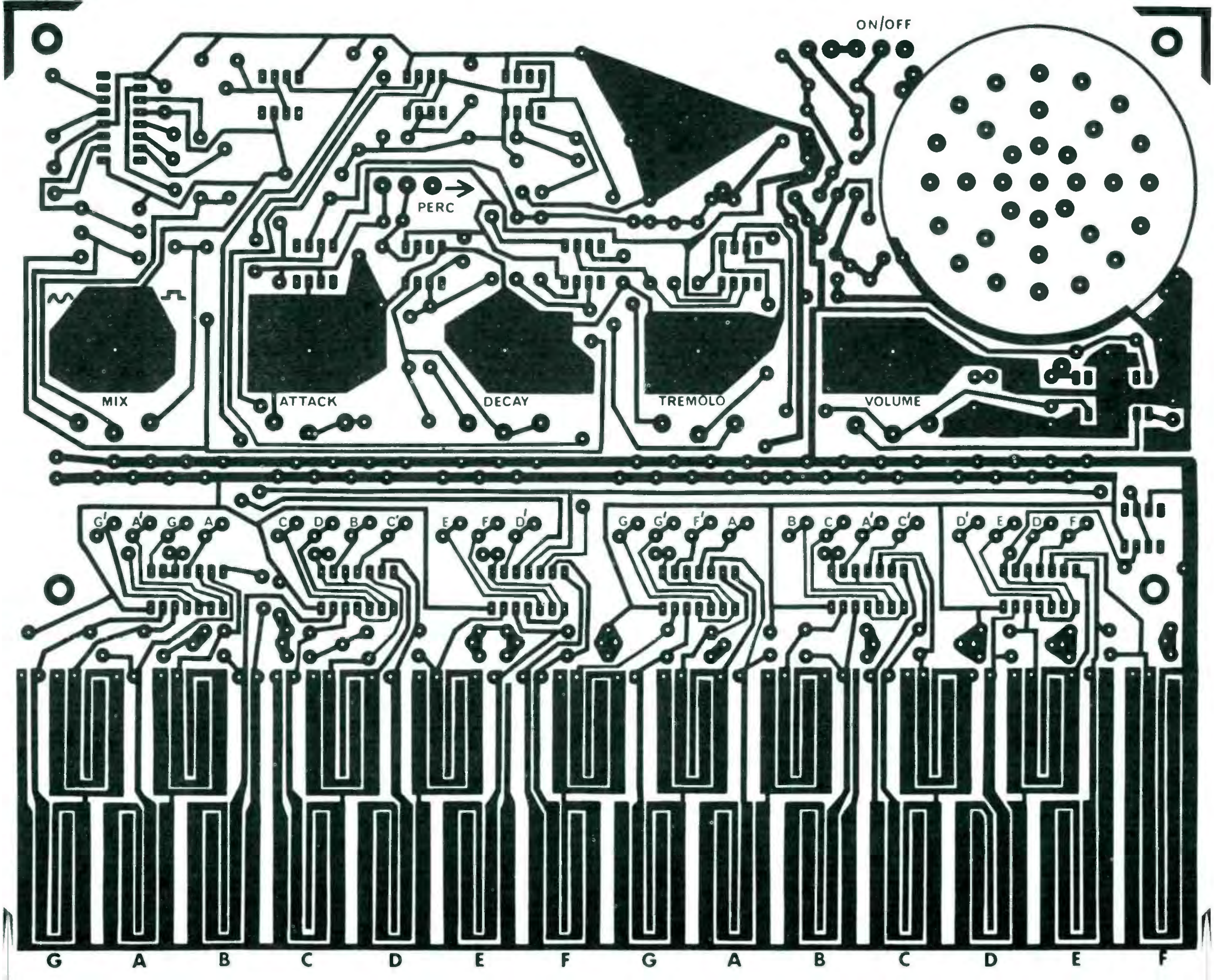
R33—5000-ohm, linear-taper potentiometer
R36—220-ohm
R37, R38—47-ohm
R42—100,000-ohm, logarithmic-taper potentiometer
R43—2.7-ohm
R45, R47, R53—100,000-ohm, linear-taper potentiometer
R46, R48—470-ohm
R50, R54, R55, R80—1000-ohm
R56—120-ohm
R57—2200-ohm, miniature, vertical trimpot
R101—91,000-ohm
R102, R105, R114—110,000- and 680,000-ohm in parallel
R103, R111—110,000- and 750,000-ohm in parallel
R106—110,000- and 820,000-ohm in parallel
R107—120,000- and 620,000-ohms in parallel
R108—110,000- and 620,000-ohm in parallel
R109—110,000- and 910,000-ohm in parallel
R110—120,000- and 750,000-ohm in parallel
R112, R113, R115—120,000- and 680,000-ohm in parallel
R116—120,000- and 820,000-ohm in parallel
R117—130,000- and 560,000-ohm in parallel
R118—130,000- and 620,000-ohm in parallel
R119—150,000- and 750,000-ohm in parallel
R120—180,000- and 820,000-ohm in parallel
R121—240,000- and 680,000-ohm in parallel
R122—360,000- and 560,000-ohm in parallel
R123—330,000-ohm

CAPACITORS

C1-C23, C25, C30—.01-µF, metallized polyester
C24—.001-µF, metallized polyester
C26, C35, C37—0.1-µF, metallized polyester
C27—.047-µF, metallized polyester
C28—0.15-µF, metallized polyester
C29, C31, C32, C34, C38, C39—10-µF, 16-WVDC, electrolytic
C33—.015-µF, metallized polyester
C36—47-µF, 16-WVDC, printed-circuit mount, electrolytic
C40—1000-µF, 16-WVDC, axial-lead, electrolytic
C41—100-µF, 16-WVDC, printed-circuit mount, electrolytic
C42—10-µF, 16-WVDC, tantalum
C43—4.7-µF, 16-WVDC, tantalum
C44—4.7-µF, 25-WVDC, tantalum
C45—1000-µF, 25-WVDC, axial-lead, electrolytic

ADDITIONAL PARTS AND MATERIALS

S1, S2—SPDT slide switch
SPKR1—2-1/2-in., PM loudspeaker
AC plug pack 12-Volts AC at 500 mA, IC sockets optional, decals, cabinet material, printed-circuit material, knobs, tinned copper wire, solder, hook-up wire, etc.



ON/OFF
PERC
MIX
ATTACK
DECAY
TREMOLO
VOLUME
G' A' G A
C D B C'
E F D'
G G' F' A
B C A' C'
D' E D F
G A B C D E F G A B C D E F

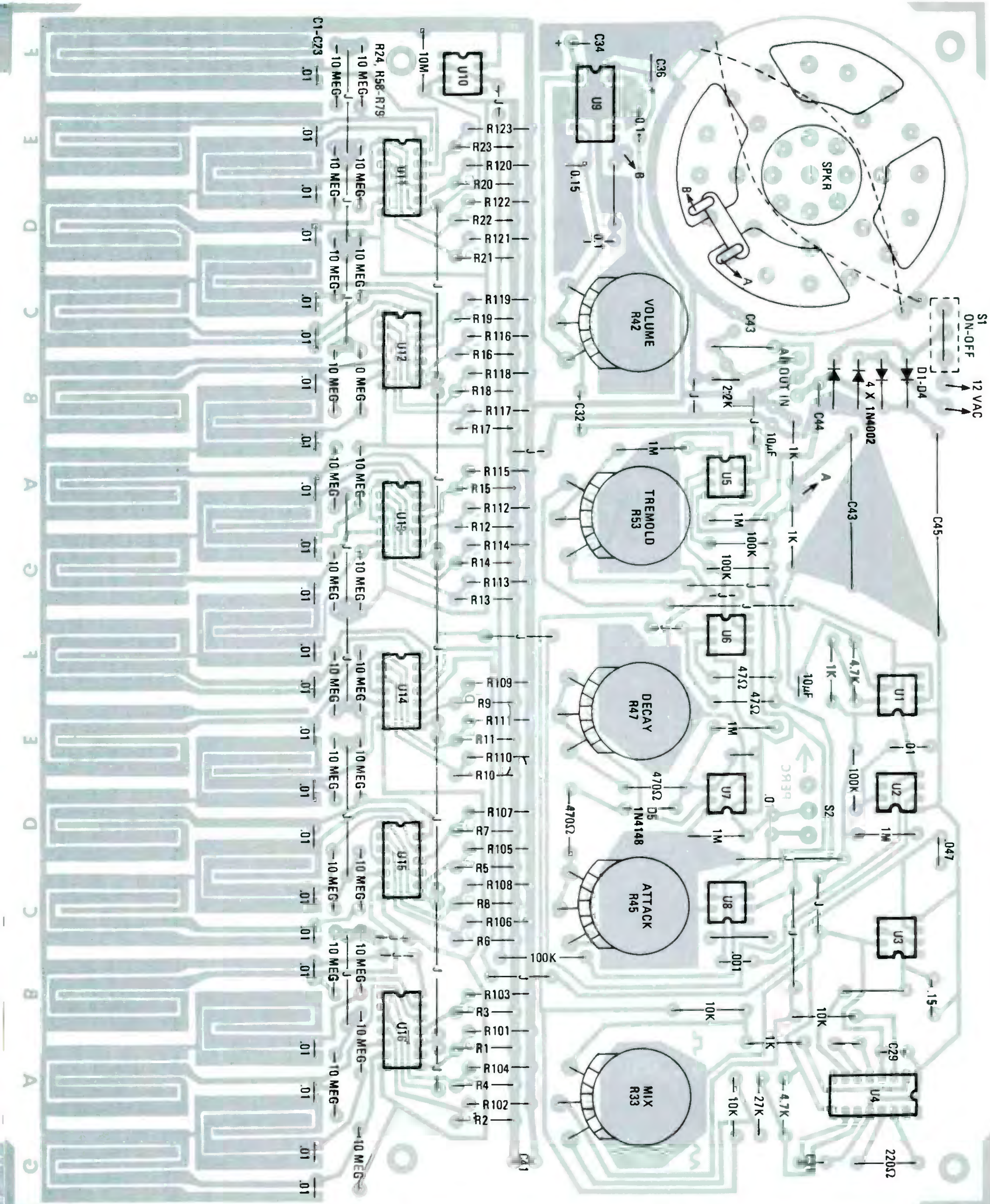
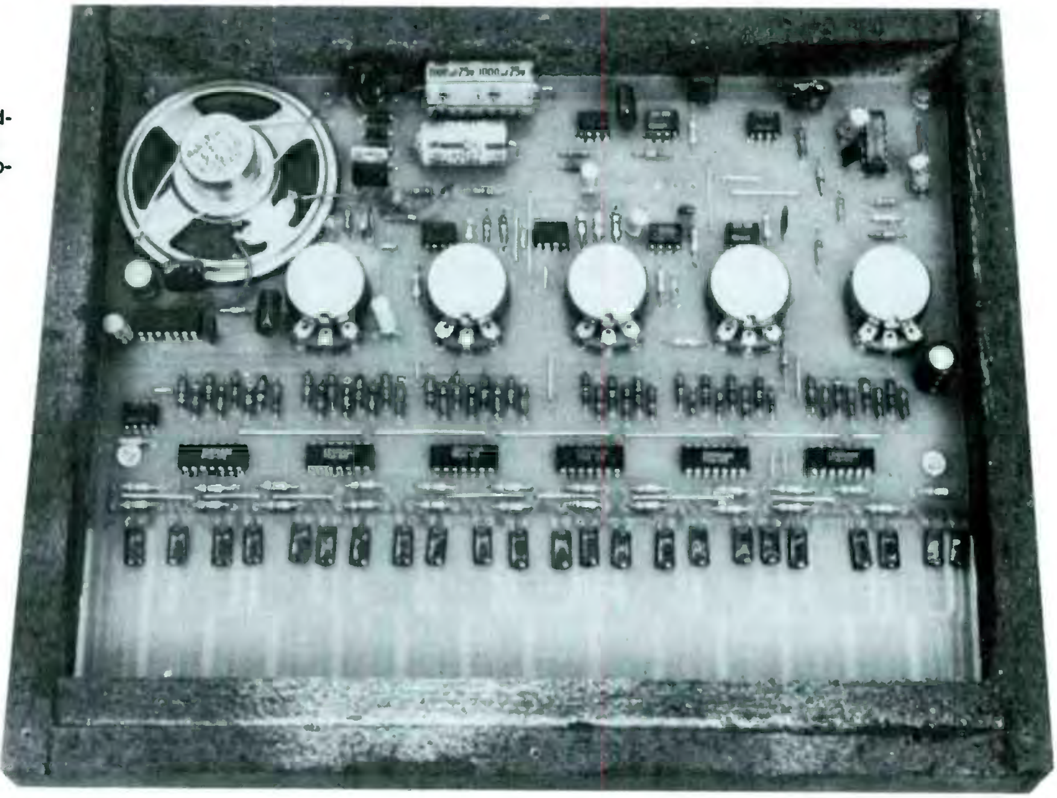


FIG. 6—PUTTING the Electrochune together is easy once you have made the printed-circuit board—just follow the wiring diagram above. Note that S1 and S2 slide switches are mounted on the copper-foil side of the board. Also, some of the paralleled resistors are located there. IC sockets may be used if desired.

FIG. 5—SAME-SIZE template of the printed circuit used to mount the parts on the original Electrochune.



YOU CAN SEE WHY a printed-circuit board is so important to the construction of Electrochune. The parts are lined up like soldiers on a parade field displaying their colors and markings clearly for inspection. Wood base surrounds the board providing some cosmetic effect and protection.

direct-coupled position, after the Schmitt goes low, the voltage at pin 6 rises at the attack-rate setting and is held at the maximum rise voltage until the Schmitt goes high. The voltage then falls at the decay rate setting. When the percussion switch is in the capacitive-coupled position, the voltage at pin 6 rises to the maximum level and then immediately falls regardless of the Schmitt output.

Following transconductance amplifier U6 is another of the same type, U5, which provides the tremolo function. That is controlled by the sawtooth output of the 555 timer, U1. U1 oscillates at about 7 Hz and it has a 100,000-ohm potentiometer, R53, across its sawtooth output to vary the tremolo effect between about 30-percent modulation and zero.

Incidentally, in case the IC numbers seem to have no particular order in this theory discussion, just take a quick look at the printed-circuit board overlay. There you will see that the numbering refers to a sequence on the PC board, making the particular IC easy to find.

Finally, the signal is capacitive-coupled to amplifier, U9, which provides about 1 watt of power—enough to give a substantial volume from the speaker. The volume control operates on the common-mode principle, whereby the input signal is applied to both inverting and non-inverting inputs. The greater resistance between the input at pin 6, and the non-inverting input, pin 2, the greater the volume. If both inputs were tied together, then the output volume would be zero.

To reduce the possibility of instability of the amplifier, the input signal is bypassed with a .015-µF capacitor, C33. A Zobel network at the output of the amplifier helps prevent instability caused by the loudspeaker load.

The power supply is derived from a 12-volt AC plugpack which is full-wave rectified, filtered with a 1000-µF capacitor, C45, and regulated with an adjustable three-terminal regulator, U17, set to 12-volts DC. The supply is center-tapped by a resistive voltage divider (two 1000-ohm resistors, R54 and R55) to provide decoupled reference voltage for the various op amps. Decoupling is provided by a 1000-µF capacitor, C40, which also carries the loudspeaker return current.

Construction

All the components are accommodated on a large PC board. A same-size diagram of the printed-circuit board is provided in Fig. 5, and a top (foil-side) view of the printed-circuit board with components in place is shown in Fig. 6. We suggest that the printed-circuit board you use be tin-plated, providing the same corrosion protection and also making it easier to solder.

Start assembly by making sure that the holes are drilled to suit the potentiometers and slide switches used. Solder in all the links (use tinned, copper wire) keeping them straight and tight between the mounting holes. Next, all the resistors can be soldered in place. Note that R1/R101 to R23/R123, whose values are shown in Table 1, have some parallel resistor combinations. Those are mounted on both sides of the PC board. The resistors on the copper side are soldered directly over the opposing resistor and to the same mounting holes. Those specified resistors make possible the frequencies that make the musical notes from Electrochune.

Now the IC's can be soldered in place, making sure the orientation is correct. Note that not all the IC's are oriented in the same direction. The CMOS IC's should be soldered in place last. Be sure that the supply pins (pins 7 and 14) are soldered first; use a grounded soldering iron.

The capacitors can then be connected in place. The 23 .01-µF capacitors were soldered to the keyboard ¼-inch above the printed-circuit board so that they could be bent over flush to the board's surface. That prevents them from being broken off and gives a neater appearance.

The potentiometers are bolted to the printed-circuit board in their respective holes, and the terminals of those soldered directly to the board. The solder lug eyelet of each terminal will need to be cut off and the whole terminal bent through 180° in order for that to be achieved.

The loudspeaker is mounted face down on the fiberglass side of the printed-circuit board. Two lengths of stiff tinned copper wire are then soldered across the back of the loudspeaker from one side to the other and hold it tightly to the printed-circuit board.

Finally, the wires can be brought to the loudspeaker and the slide switches soldered to the printed-circuit board. Note that the switches are soldered on the copper side of the board—and not the fiberglass side, as would usually be the case. ¢We have attempted to make tuning as simple as possible. By using the values specified, the organ should be in reasonable tune. However, the overall tune would depend upon the voltage provided by the regulator being set close to 12 volts and the capacitor used for the oscillator on U2.

For critical tune applications, the organ can be adjusted with the aid of a frequency meter or organ-tuning standard. The frequencies for each note are given in the accompanying table for frequency meter use, but for the tuning reference method, beats can be listened for, or Lissajous figures set up on an oscilloscope. Various parallel resistors can be placed across the reference resistors, R1/R101 to R23/R123, until the instrument is in tune.

Note that the order of tuning resistors does not exactly follow the keyboard musical-note order, but the relevant resistors for each note are labelled on the printed-circuit board overlay diagram for easy identification.

If you wish to make the Electrochune tunable to match other instruments, it will be necessary to have a variable capacitor in parallel with C1, which is connected between pins 5 and 6 of U4, the VCO. The largest suitable variable capacitor we know of is the solid dielectric type used in most portable AM radios. Those normally have a range of several hundred picofarads, giving a useful tuning range.

To make use of that option, you will have to make sure that, when the variable capacitor is in circuit, the Electrochune can be brought to standard tune, i.e. A at 440 Hz. The same remark applies if you wish to tune the whole instrument precisely, as described above: First make sure that you have a precise 12 volts from the regulator and then set A440 by suitable adjustment (i.e., padding with small parallel capacitors if necessary) of C1.

TABLE 2
TABLE OF TUNING RESISTOR VALUES

R1	22K	R112	120K//680K
R101	91K	R13	15K
R2	22K	R113	120K//680K
R102	110K//680K	R14	13K
R3	22K	R114	110K//680K
R103	110K//750K	R15	13K
R4	22K	R115	120K//680K
R104	100K	R16	12K
R5	20K	R116	120K//820K
R105	110K//680K	R17	11K
R6	20K	R117	130K//560K
R106	110K//820K	R18	10K
R7	20K	R118	130K//620K
R107	120K//620K	R19	10K
R8	18K	R119	150K//750K
R108	110K//620K	R20	10K
R9	18K	R120	180K//820K
R109	110K//910K	R21	10K
R10	18K	R121	240K//680K
R110	120K//750K	R22	9.1K
R11	16K	R122	360K//560K
R111	110K//750K	R23	9.1K
R12	16K	R123	330K

Resistors are 5% units unless 2% or 1% units are available in the junkbox, or at a low cost.

Making Music

Playing the Electrochune involves the use of one finger only. If a second finger contacts another note while the first finger remains on a key the same note will still play. It is not until all fingers are released from the keyboard that another note can be played.

From time to time it will be necessary to clean off the keyboard (with a weak detergent solution) so that any build-up of grease and dirt does not prejudice operation by tending to turn on the CMOS keys. Do not use abrasive cleaners for that job.

The Attack and Decay controls are adjustable from about .005 second to about one second, giving rise and fall envelope times varying from almost instant to a slow-rise time. If the percussion is on with maximum attack and decay times, then just a "plop" will be heard. With the percussion off, the musical note will appear to respond only when the key is pressed.

The Electrochune is a bare-bones project without a cabinet. That construction aspect is left to the builder to work out to fit his needs. However, rather than let the matter drop cold, a photo of a dressed-up unit illustrates what can be done to make the unit eye-appealing. ■

DRESSING UP Electrochune adds spice to something that sounds nice and makes it look good, too! The printed-circuit board can do with some support. Wipe the key pads with a dry tissue from time to time, removing the accumulation of skin oils on the copper foil.