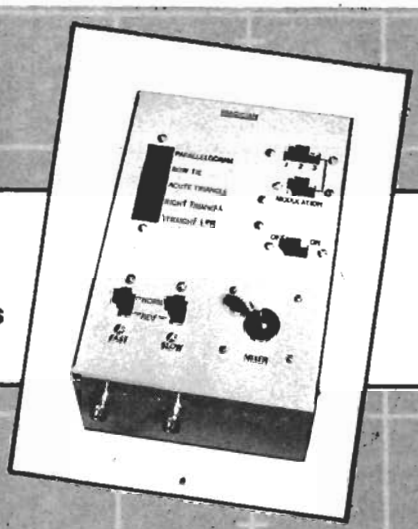
ELECTRONICS HOBBYIST
1980 EDITION

With a little help, your scope becomes an electronic canvas

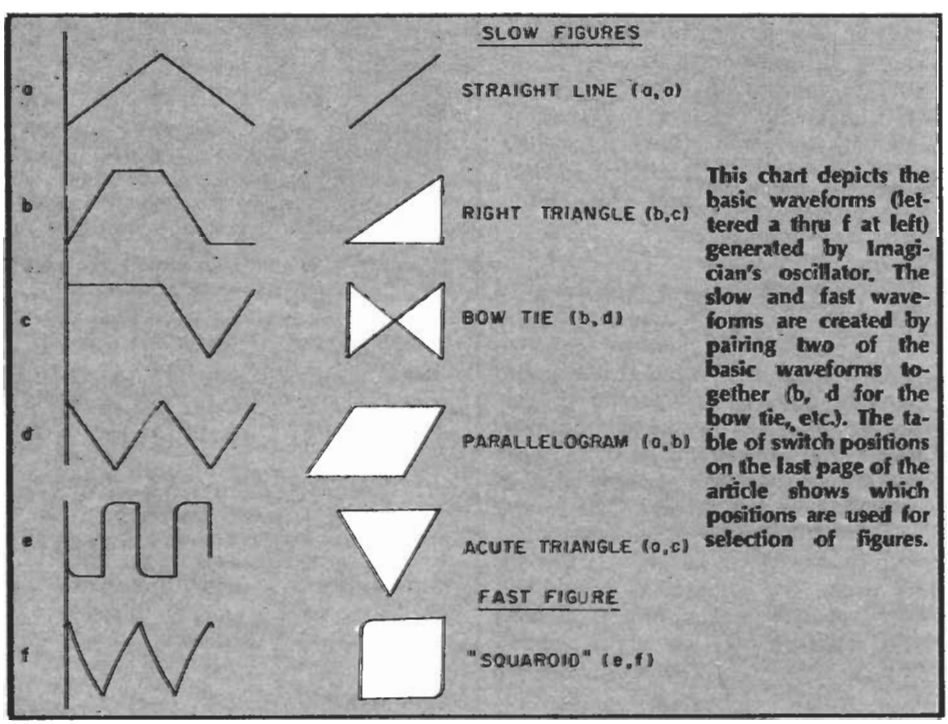


IMAGICIAN

HOW WOULD YOU LIKE TO be able to generate beautiful geometric line drawings electronically? And what if these figures could be made to look 3-dimensional, with forms that expand, rotate, and flow under the command of a joystick? Sounds expensive and complicated, doesn't it? If you've seen some of the graphics produced by hobby-type digital computers, you're probably skeptical and rightfully so. Small digital computers generate simplistic graphics with a chunky appearance. Generating smooth lines and complex figures with a digital computer requires much more memory than most computer hobbyists can afford.

But if a few ideas are borrowed from the *analog* computer, a device rarely mentioned anymore, it's possible to generate dazzling graphics with simple, inexpensive circuitry. That's the principle of the Imagician, a simple, two-IC project that transforms your oscilloscope's screen into a window on a magic land of animated geometric figures.

The Lissajous Figure. Before delving into the workings of the Imagician's circuit, let's talk about Lissajous figures. If you own a scope, no doubt you are familiar with them. A Lissajous figure is a closed curve that results when two harmonically related signals are applied to a scope—one signal to the vertical input, the other to the horizontal input. The most familiar figure occurs when a sine wave is applied to one input, and a phase-shifted sine of the same magnitude and frequency is fed to the other input. On the scope's screen there appears either an elliptical or circular trace, depending upon the phase relationship between the two signals. With non-sinusoidal waveforms driving the X and Y inputs, other geometrical displays can be created.



This chart depicts the basic waveforms (lettered a thru f at left) generated by Imagician's oscillator. The slow and fast waveforms are created by pairing two of the basic waveforms together (b, d for the bow tie, etc.). The table of switch positions on the last page of the article shows which positions are used for selection of figures.

Let's examine the various waveforms synthesized within the Imagician (Figure 2). From just these six signals, thousands of fascinating displays can be produced. Waveforms *a, b* and *c* all oscillate at 60 Hz; signal *a* is a triangle wave, *b* is a symmetrically clipped triangle, and *c* is trapezoidal. Signal *d* is another triangular waveform, but with a frequency of 120 Hz. For reasons that will be apparent later, let's call figures *a* thru *d* "slow" figures.

It stands to reason that there must be some fast signals, too. Waveforms *e* and *f* are the fast ones, with a frequency equal to 3840 Hz (64 times faster than 60 Hz). Signal *e* might be called a "soft-shouldered square wave," while *f* just begs to be called a "shark-fin wave."

What are the simplest Lissajous figures that can be generated by selected pairs of the above six waveforms? Figure 3 shows these fundamental figures along with the X and Y components necessary for their generation. It is assumed that the X and Y components are of equal magnitude; if such is not the case, the shapes will be distorted to new forms. Note that these fundamental Lissajous figures are segregated into slow and fast classes. The slow figures have slow waveforms (*a* through *d*) as components, while the fast figure has fast components (*e* and *f*). The slow figures include familiar geometric shapes: a straight line, a right triangle, a parallelogram, an acute triangle and the perhaps not-so-

familiar bow tie. Were it not for a slight slope to the sides and a pair of rounded corners, the fast figure would almost appear to be a square. In recognition of the similarity, let's call the fast figure a "squaroid."

New complex Lissajous figures, some of which will appear to be 3-dimensional, can be synthesized by adding together one of the slow figures and the squaroid. This is accomplished by summing the X- and Y-component waveforms of the two figures independently. Furthermore, it's not necessary to mix signals in a one-to-one ratio. Different mixing ratios yield new and fascinating displays in a manner that's often hard to predict. As a final touch, the components of the fast figure (squaroid) can be amplitude-modulated. The type of modulation used here was specifically chosen to enhance the illusion of perspective in those displays that appear 3-dimensional.

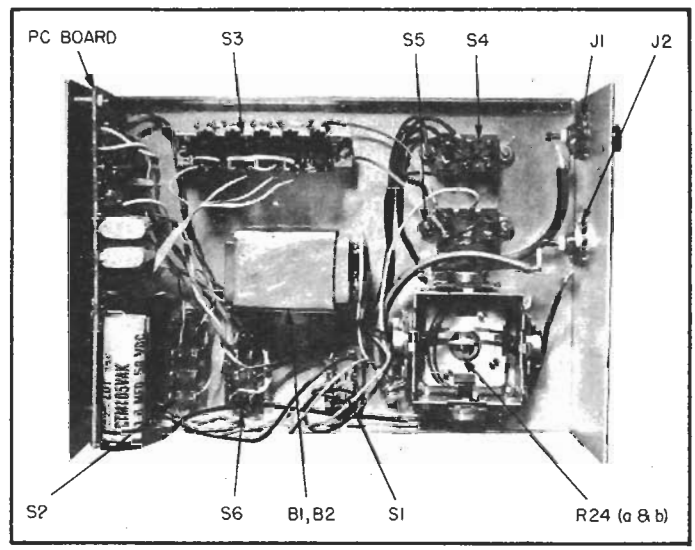
The Circuit. Let's consider the Imagician's circuit in detail. Two batteries, B1 and B2, provide +9V and −9V supply potentials for the circuit when power switch S1 is closed. Diodes D1 and D2 protect the ICs from incorrect battery installation and also drop the supply potential slightly, which is desirable here. Capacitors C1 through C4 provide supply bypassing.

Q1, a programmable unijunction transistor (PUT), works together with R1, R2, R3 and C5 to form an oscillator that feeds pulses to the clock input (pin 1) of U1, a 4024B seven-stage binary frequency divider. U1 divides the input frequency by 2, seven times in succession to yield seven harmonically related square-wave outputs. We need harmonics in order to generate Lissajous patterns, but square waveforms do not yield interesting displays. Consequently, the greater portion of the Imagician's circuitry is devoted to the shaping of square waveforms into other more useful signals.

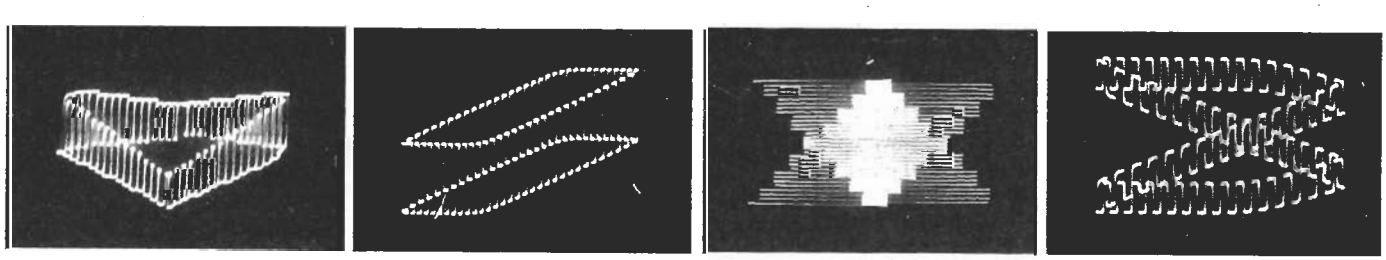
At pin 3 of U1, we find the lowest-frequency square wave (60 Hz), while pin 4 supplies the second harmonic (120 Hz). R15 and C6 integrate the 60 Hz signal to a triangular waveform (*a*). Diodes D3 and D4 together with integrating network R16/C7 produce the symmetrically-clipped 60 Hz triangle (*b*). Driven by both the 60 and 120 Hz signals, the D5/D6/R17/R18/C8 network yields a 60 Hz trapezoid (*c*). Finally, the last slow waveform, triangle wave *d*, is generated when R19 and C9 integrate the 120 Hz square-wave signal.

Fast waveforms *e* and *f* are formed with the aid of shaping networks R22/C10 and R23/C11, respectively. When S6 is flipped to the left, as indicated in the schematic, amplitude-modulated currents at 3840 Hz are fed to the shaping networks just discussed. As a result, waveforms *e* and *f* are also amplitude-modulated. The manner in which modulation is obtained here requires further explanation: U2, a 4070B quad EXCLUSIVE-OR gate, taps harmonically related signals from frequency divider U1. The gates within U2 are connected so as to yield a sort of digital multiplier when the various outputs are summed together (by R5/R9 and R10/R14). Switch S2 controls the shape of the modulation envelope, with three choices available. If S6 should now be flipped to the right, an unmodulated 3840 Hz square-wave current will be fed to each R/C shaping network. Consequently, signals *e* and *f* will be of constant amplitude.

The rest of the circuitry serves only to combine signals *a* through *f* in various ways. Switch S3 selects pairs of X and Y components for the 5 slow Lissajous figures. These signal pairs are routed to the vertical (R24a) and horizontal (R24b) mixers via reversing switch S4. (When a Lissajous figure's X and Y components are interchanged, it flips to a new orientation on the screen.) Switch S5 performs the same function as S4, but it operates on the components of the fast figure instead. Addition of the X components of the slow and fast figures occurs in the horizontal mixer; the vertical mixer sums their Y components. R24a and R24b are part of a joystick assembly; north-south movement of the stick controls R24a, while east-west motion affects R24b. Thus, a single control manipulates two pots independently of one another. If desired for reasons of economy, however, two separate potentiometers could be used for R24a and R24b. Jacks J1 and J2 send the mixer output signals to the appropriate high-impedance (1 Megohm) scope inputs.



This underside view of the chassis shows the positions of the panel switches and joystick control. As usual, this should only serve as an example of how you can go about building your own model. There are no critical component placements in Imagician.



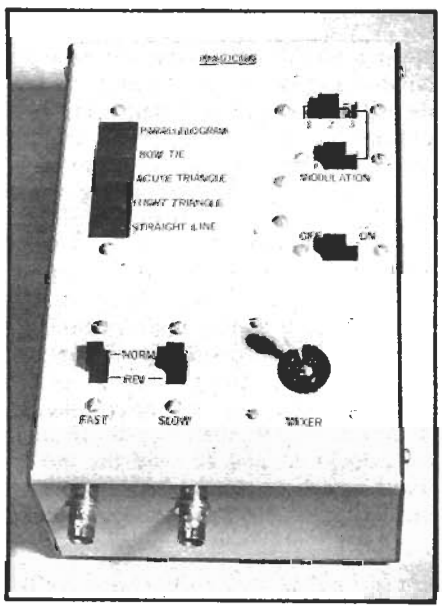
Here are a few examples of the designs which can be produced by mixing of the basic waveforms. What we can't show are the moving figures and the shifts which are possible. From left to right are: acute triangles, parallelograms, inverted acute triangles, and a double bow tie formed in a dot pattern instead of solid lines. With experimentation, you can come up with many more.

IMAGICIAN

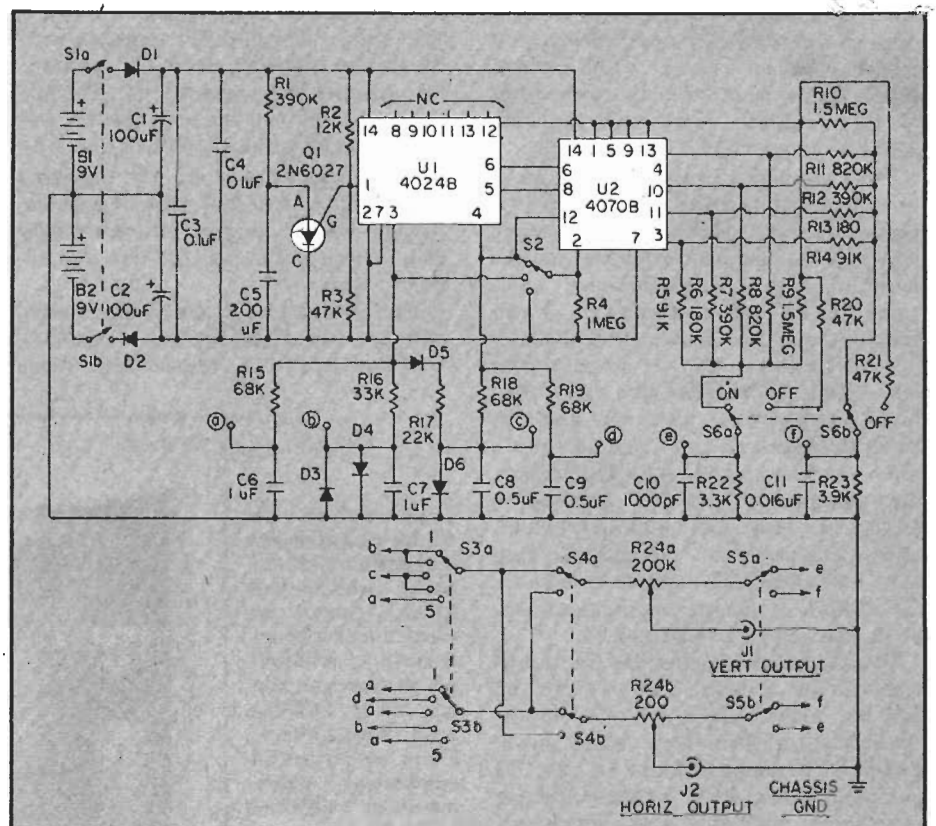
Construction. Printed-circuit construction of the Imagician is recommended, and complete details of the board can be found in Figures 4 and 5. For the sake of shielding, an aluminum cabinet should be used to house the circuit. Furthermore, the chassis should be connected to system ground at some point. Connections between the Imagician and your oscilloscope should be effected by means of relatively short, (18-inches or less) shielded cables.

As usual, solder joints should be made with a small, 25-watt iron and resin-core solder. Sockets are required for the two CMOS ICs, which should be installed only after all soldering is finished. Be certain that U1 and U2 both have the "B" suffix–devices with an "A" suffix will not work in this circuit.

Capacitor C5 must be a polystyrene (or mica) unit to ensure that your oscillator's frequency is close to that of the prototype. Be careful with those devices requiring proper orientation–electrolytic capacitors C1 and C2, Q1, the ICs, and the diodes. Although S3 is shown schematically as a rotary switch, it's obvious from the photos that a push-button unit was used in the prototype. You can use whatever is most convenient.



This front panel closeup shows the relative positions of all the controls, and the dry transfer lettering we utilized to achieve a more professional appearance for the prototype. We positioned the input and output coaxial jacks at the bottom front rather than at the top, so as to minimize the effects of body capacitance when one's hand is brought into proximity of the input and output cables. This feature also allows much more freedom of access to the controls as opposed to top mounting of the jacks.



PARTS LIST FOR IMAGICIAN

B1, B2—9-volt transistor battery
C1, C2—100-uF, 16-VDC electrolytic capacitor
C3, C4—0.1-uF ceramic disc capacitor, 100-VDC
C5—200-pf polystyrene capacitor 100-VDC
C6, C7—1.0-uF mylar capacitor, non-polarized
C8, C9—0.5-uF mylar capacitor 100-VDC
C10—1000-pf polystyrene capacitor 100-VDC
C11—0.016-uF mylar capacitor 100-VDC
D1 thru D6—1N914 diode
J1, J2—BNC jack
Q1—programmable unijunction transistor—2N6027, 2N6028 or HEP S9001. (Note: 2N6028 Available from SOLID STATE SALES, BOX 74A, Somerville, MA 02143.)
R1, R7, R12—390 K, ½-watt resistor, 5%
R2—12 K, ½-watt resistor, 5%
R3, R20, R21—47 K, ½-watt resistor, 5%
R4—1 Megohm, ½-watt resistor, 5%
R5, R14—91 K, ½-watt resistor, 5%
R6, R13—180 K, ½-watt resistor, 5%
R8, R11—820 K, ½-watt resistor, 5%
R9, R10—1.5 Megohm, ½-watt resistor, 5%
R15, R18, R19—68 K, ½-watt resistor, 5%
R16—33 K, ½-watt resistor, 5%
R17—22 K, ½-watt resistor, 5%
R22—3300-ohm, ½-watt resistor, 5%
R23—3900-ohm, ½-watt resistor, 5%
R24a, b — two, linear-taper 200K-ohm pots mounted in a joystick assembly (Herbach & Rademan #TM21K167; address is 401 E. Erie Ave., Philadelphia, PA 19134)
S1—DPST slide switch
S2—SP3T rotary or slide switch
S3—DP5T rotary or pushbutton switch
S4, S5, S6—DPDT slide switch
U1—4024B binary ripple counter
U2—4070B quad EXCLUSIVE-OR gate
Misc: aluminum cabinet, IC sockets.

Note: An etched and drilled printed circuit board for the Imagician is available from *LECTRO-GRAPHIX* P.O. Box 537, Auburn, NY 13021, for $5.90 postpaid to U.S. and Canadian residents. Foreign and overseas orders should include an additional $1.50 for postage and handling, and should remit the cost in the form of a money order or other drafts payable in U.S. currency. Allow 2 to 3 weeks for delivery. NY residents add 7% sales tax.

Current consumption is on the order of 1-milliampere, so batteries will last a long time. Be sure that both batteries are fresh–if they are not, lop-sided displays will result.

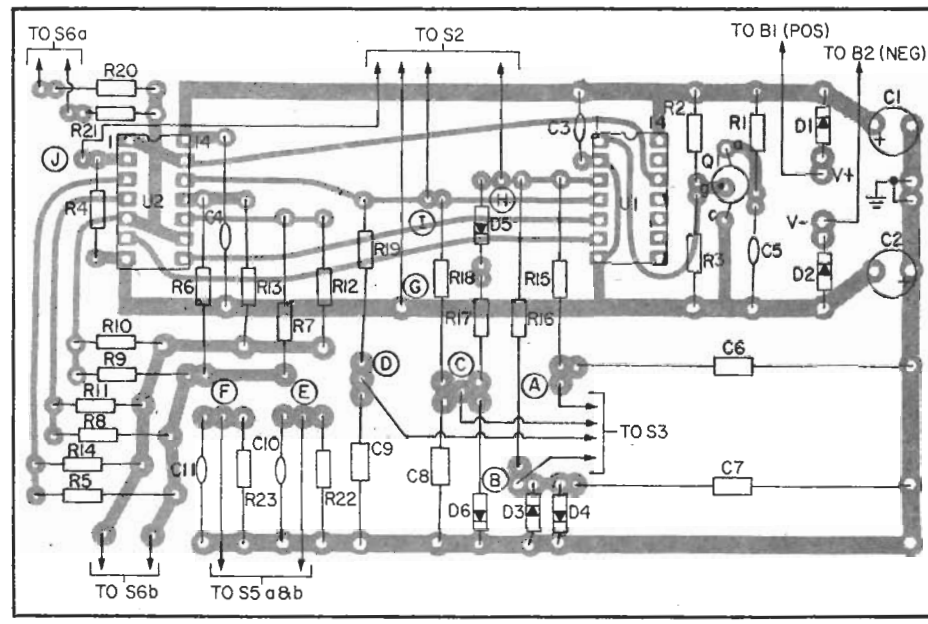
When wiring the joystick, you'll find that it comes equipped with four pots. Use any two pots on adjacent sides of the square support assembly. The potentiometers on opposite sides are ganged together and cannot be adjusted independently.

Checkout and Operation. After construction is complete, the circuit should be given a thorough workout to make sure that everything is in order. Begin by turning on your scope and allowing 15 minutes warm-up time. If the grati-

cule on your scope is removable, as on the older Heath and B&K models, it might be a good idea to take it off; the gridwork of lines serves no useful purpose in this application, but it may distract attention from the display. If the graticule cannot be removed, just turn the GRATICULE ILLUMINATION control completely off.

Both the X and Y inputs should have an impedance of about 1-Megohm. This almost universally is the case, but check your scope's specifications to be sure—especially if a very old model is being used. With the horizontal and vertical inputs grounded, center the dot on your screen. Signals from both channels of the Imagician have peak-to-peak amplitudes of 1.2-volts; set your vertical and horizontal gain controls so that a 1.2-volt signal would roughly span the screen.

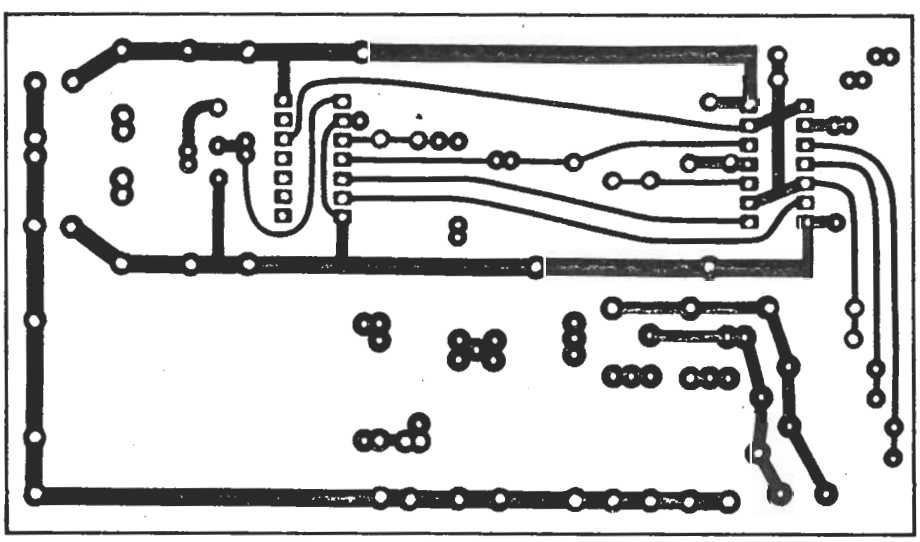
On the Imagician, turn MODULATION switch S6 to OFF, and set SLOW-FIGURE SELECTOR S3 to its PARALLELOGRAM position. Connect the outputs of the Imagician to the appropriate scope inputs with short shielded cables. After turning on the power with S1, you should see an image of some sort on your screen. The display will probably be faint, so rotate your scope's INTENSITY control to maximum. (However, when centering the dot as described above, you should use only *minimal* intensity to avoid burning the scope's screen.) Now, readjust the scope's vertical and horizontal gain controls so that the image just fills the screen. Finally, adjust the ASTIGMATISM and FOCUS controls, if your scope has them, for an image that is sharp and clear at all points on the screen.



This is the component location guide used with the printed circuit board. Just about all of the components used in Imagician, with the exception of the switches, jacks and R24, are mounted directly on the board. Use IC sockets and be sure to orient them properly. Take special note of the takeoff points that lead away to the switches.

S1—Power
S2—Modulation Selector
S3—Slow-Figure Selector:
1 = parallelogram
2 = bow tie
3 = acute triangle
4 = right triangle
5 = straight line
S4—Slow-Figure Reversing Switch
S5—Fast-Figure Reversing Switch
S6—Modulation ON/OFF
R24a, b—Mixer

This table shows which switches perform what functions and, for S3, what figures are generated in each switch position.



This is the etching guide for the PC board, shown in exact scale. If a project of this magnitude is beyond your abilities, you can obtain a ready-made circuit board from LECTROGRAPHIX. Their address and ordering information is shown beneath the parts list.

Bend your Imagician's joystick until you reach the position where a simple parallelogram fills the screen. Next, flip S3 to its four other positions so that the rest of the slow figures may be observed. After viewing them all, return to the parallelogram. Use the joystick now to create new images. Note that this is a "high-powered" control—a seemingly slight adjustment can lend a whole new character to the display. With practice, you'll learn to make images dance and change form at will through skillful manipulation of the stick.

Still using the parallelogram, adjust the joystick until the resultant display has a 3-dimensional character. Turn on the modulation via S6, and check out the various effects produced by MODULATION SELECTOR S2. Manipulate the joystick, too, in order to get different views.

Conclusion. By now, you should be somewhat familiar with the controls on the Imagician. You can proceed to create 3-D patterns based on the remaining four slow figures. Also, check out the effects of the reversing switches, S4 and S5; the effects of S5 are subtle and depend upon the setting of the joystick, so watch closely. If you wish, it's possible to capture some of your prize creations on film with the aid of a Polaroid scope camera, which you might be able to borrow from a school science department. With a little imagination in the photodeveloping process, you may become the first electronic Picasso! ■