Experiments with Programmable Logic Arrays

Useful logic circuit has many applications in waveform generation or digital control.

BY KARL LUNT

THE Programmable Logic Array (PLA) is an important, little-understood electronic circuit which many experimenters would use more if they knew more about it. Described here, to help in such an understanding, is a circuit that can be used to generate a wide variety of output waveshapes with frequencies up to 15 MHz, with complete control over the output waveshape.

With some changes in the timing or output circuit, the PLA can also serve as a switch and light controller for model train layouts, a digital controller and sequencer for simple machine or processing operations, a sophisticated timer-controller for use in a lab, darkroom, or kitchen, or even as an electronic "house-sitter" to control several appliances. This PLA can be built for about $15—less if you have a well-stocked "junkbox."

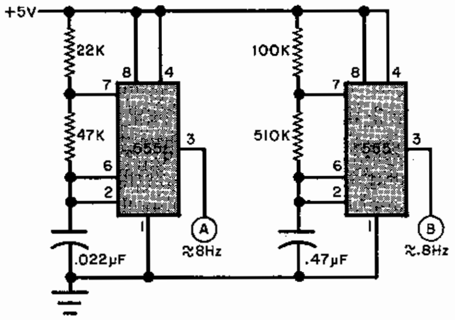


Fig. 1. Frequencies of either 555 can be from 1 MHz to one pulse per minute, depending on selected R and C values.

The circuit consists of three elements: a timer and driver that converts a series of clock pulses into BCD information that selects an input line of the PLA matrix, the PLA itself (in this case a diode matrix), and the output circuit that includes the necessary interfaces to relays, lights, other TTL or a digital-to-analog converter.

Circuit Operation. The basic timer can be built around one of two circuits—a pair of conventional 555 timers as shown in Fig. 1 or the 555-7490 circuit shown in Fig. 2. The output frequencies of the 555's are dependent on their resistor-capacitor values and clock rates can be as high as 1 MHz or as low as one pulse per minute.

The selected outputs of the clock oscillators can be used to drive a one-of-two selector like that shown in Fig. 3. The output of this circuit can be either clock-A or clock-B depending on the signal applied to control input C.

The main circuit shown in Fig. 4, accepts the selected clock output from *IC1* and drives one or more decade counters

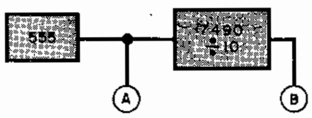


Fig. 2. The 555 drives decade counter in this clock. As many counters as desired can be added for ultra-slow clocks.

(*IC2* is an example of one), and then the final decade counter *IC3* whose outputs are BCD that count from 0 to 9 then automatically repeat.

The BCD outputs are applied to a 1-

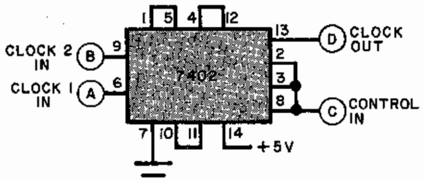


Fig. 3. A one-of-two selector allows PLA to control its own frequency. Output is A or B depending on control input C.

of-10 decoder (*IC4*) with each decoded output applied to a corresponding input line of the PLA—in this case, a 10 x N matrix. The 10 x N means that there are 10 inputs and any selected number (N) of outputs. In this matrix, the diode lines are driven low in sequential order by *IC4* and a diode connected between the selected input and output lines will drive that output low. The outputs are fed to the inputs of the hex inverters within *IC5* and *IC6* that provide both inverting and buffering. The outputs of *IC5* and *IC6* can be used to drive other TTL devices, relay drivers, or, in the case shown in Fig. 4, a simple D/A converter that can be used to create various output waveshapes.

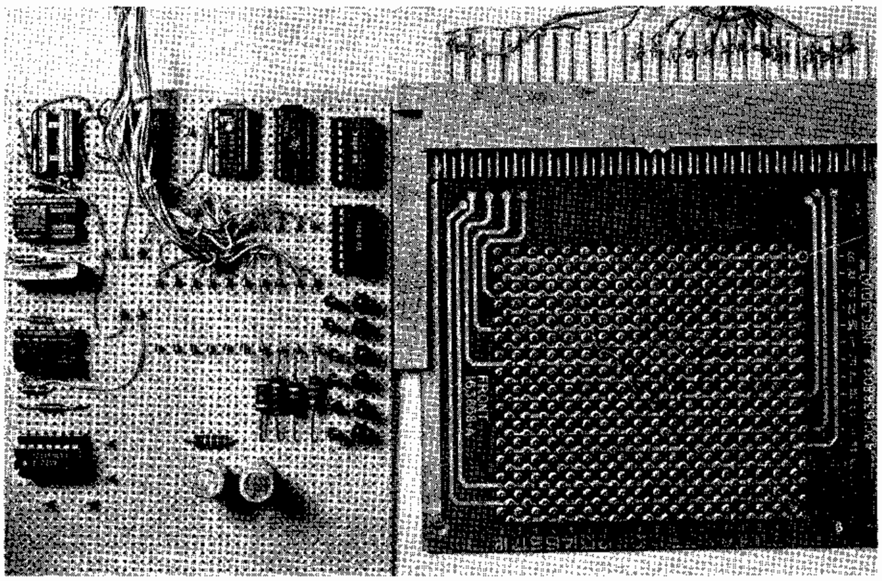


Photo shows the author's prototype of complete PLA project. Diodes are on commercial matrix board at right. IC's and other electronics are on perf board.

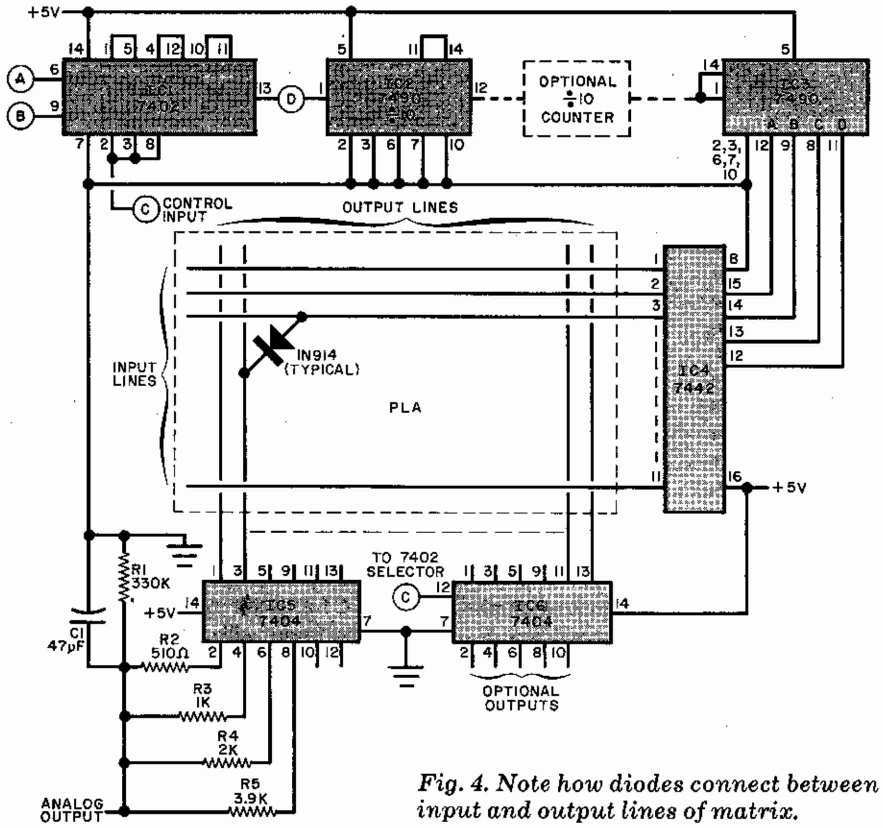


Fig. 4. Note how diodes connect between input and output lines of matrix.

PARTS LIST

C1—47-µF, 12-V nonpolar capacitor (two 100-µF units connected in parallel)
IC1—7402 quad 2-input NOR gate
IC2,IC3—7490 decade counter
IC4—7442 1-of-10 decoder
IC5,IC6—7404 hex inverter
R1—330,000-ohm resistor
R2—510-ohm resistor
R3—1000-ohm resistor
R4—2000-ohm resistor
R5—3900-ohm resistor
Misc.—Perforated board, component mounting clips, sockets for IC's, matrix diodes (1N914), 555 timers and passive elements (see text), mounting hardware.

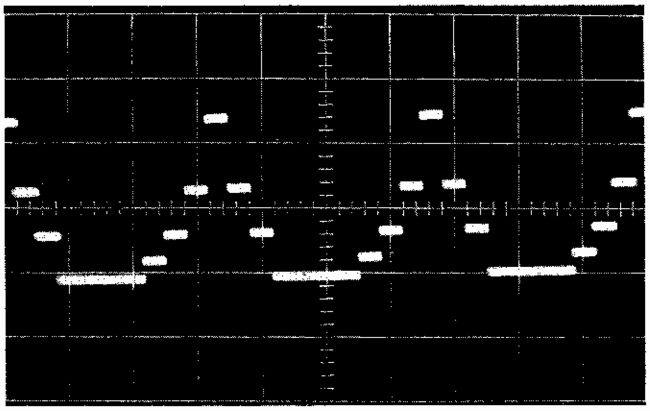
Construction. Layout and lead dress are not critical so any type of construction can be used. Sockets are suggested for mounting the IC's.

The heart of the system is the diode matrix PLA that uses conventional silicon diodes (such as the 1N914) to form the matrix. In the prototype, a commercial pc board with a built-in 18 x 18 matrix of press-in terminals was used, although one can be built of conventional "flea clips" (or similar) with each horizontal (input) row interconnected and wired to its pin on *IC4*. Each vertical (output) column is built in a similar fashion and connected to the *IC5-IC6* inputs. The selected diode clips should be capable of accepting the diode leads. The diodes are installed as shown in the matrix of Fig 4.

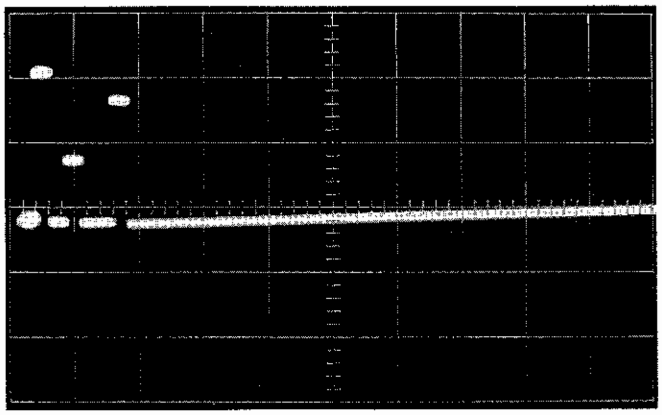
Either of the two oscillators can be selected, with any desired frequency used as the clock input.

The simple D/A converter shown in Fig. 4 consists of four resistors (although more can be added as the matrix is enlarged) that sum across *R1*. The voltage developed across these resistors is dependent on the placement of the diodes in the matrix. The square wave generated across *R1* is smoothed by *C1*. The value of *C1* can be changed as desired, or any other method of filtering can be used.

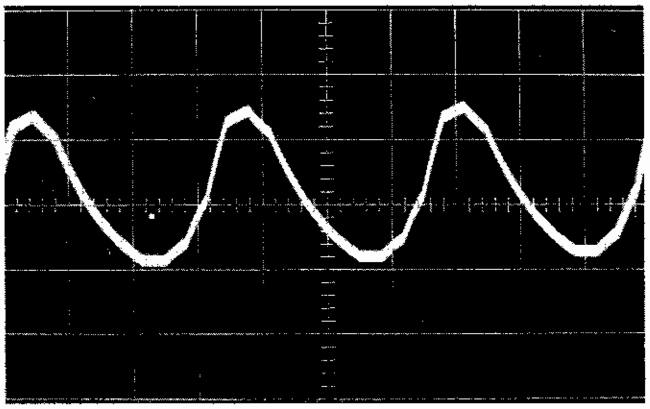
Once the basic circuit has been built, it should be powered and an oscilloscope used to make sure that all perti-



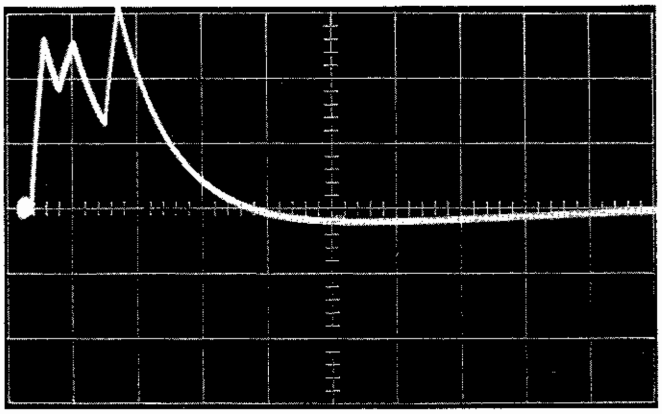
A



C



B



D

Oscilloscope photo (A) shows the output of the digital/analog converter with C1 (Fig. 4) removed at a frequency of 8 Hz. With C1 in, the output would form a sine wave such as that shown at (B). More elaborate filtering will smooth out the sharp edges. Waveform (C) shows how the PLA controls its own clock frequency. The first pulses are about 8 Hz followed by a 2.5-second delay until triggered again. Photo (D) is the PLA controlling its own frequency. The peaks inside the pulse are all 8-Hz rate, while the next pulse will not occur for more than 2 seconds.

nent waveforms are present and have the required fast rise and fall times suitable for TTL.

Use. There are two ways that the diode matrix can be used to control the output frequency. The simplest approach is to tie the "reset-to-zero" inputs (pins 2 and 3) of *IC3* to an unused output line of the matrix and, if a diode is connected to this line, the circuit will recycle back to zero. The obvious disadvantage to this approach is that it becomes impossible to use any diode positions beyond the reset point.

The second method is to change the clock frequency coming from the driver circuits. A simple 1-of-2 decoder such as the 7402 shown can be used to switch either one of two independent clocks (Fig. 1) or one of two frequencies derived from the same clock (Fig. 2). In the case of Fig. 1, the clocks may operate out of sync, therefore the clock in Fig. 2 may be used for more accurate timing. The control input of the 1-of-2 selector (Fig. 3) can be tied to an unused output line of the matrix, and the clock frequency that drives the system can be controlled using a diode on that particular line.

The system shown uses a 7490-7442 combination to produce a 10 x N matrix. If desired, a 7493-74154 combination can be used to produce a 16 x N matrix. The output waveform shape can be changed by varying the value of filter capacitor *C1* and the clock frequency. You can experiment with either of these values and observe the results.

It is possible to trigger the timing cycle with a pushbutton switch coupled to a monostable multivibrator. This allows the PLA to be used as an envelope generator in an electronic music system. It is also possible to generate two independent outputs from *IC5* and *IC6*. Either output can be switch selected.

Although the circuit described is not presented as an actual construction project, it can be easily assembled, and the various parameters altered to create just about any reasonable output signal or waveform the builder can use. ◇