PROGRAM ANY WAVESHAPE *YOU CAN IMAGINE*

A voltage-controlled oscillator circuit with RAMs synthesizes waveshapes without using complex filters

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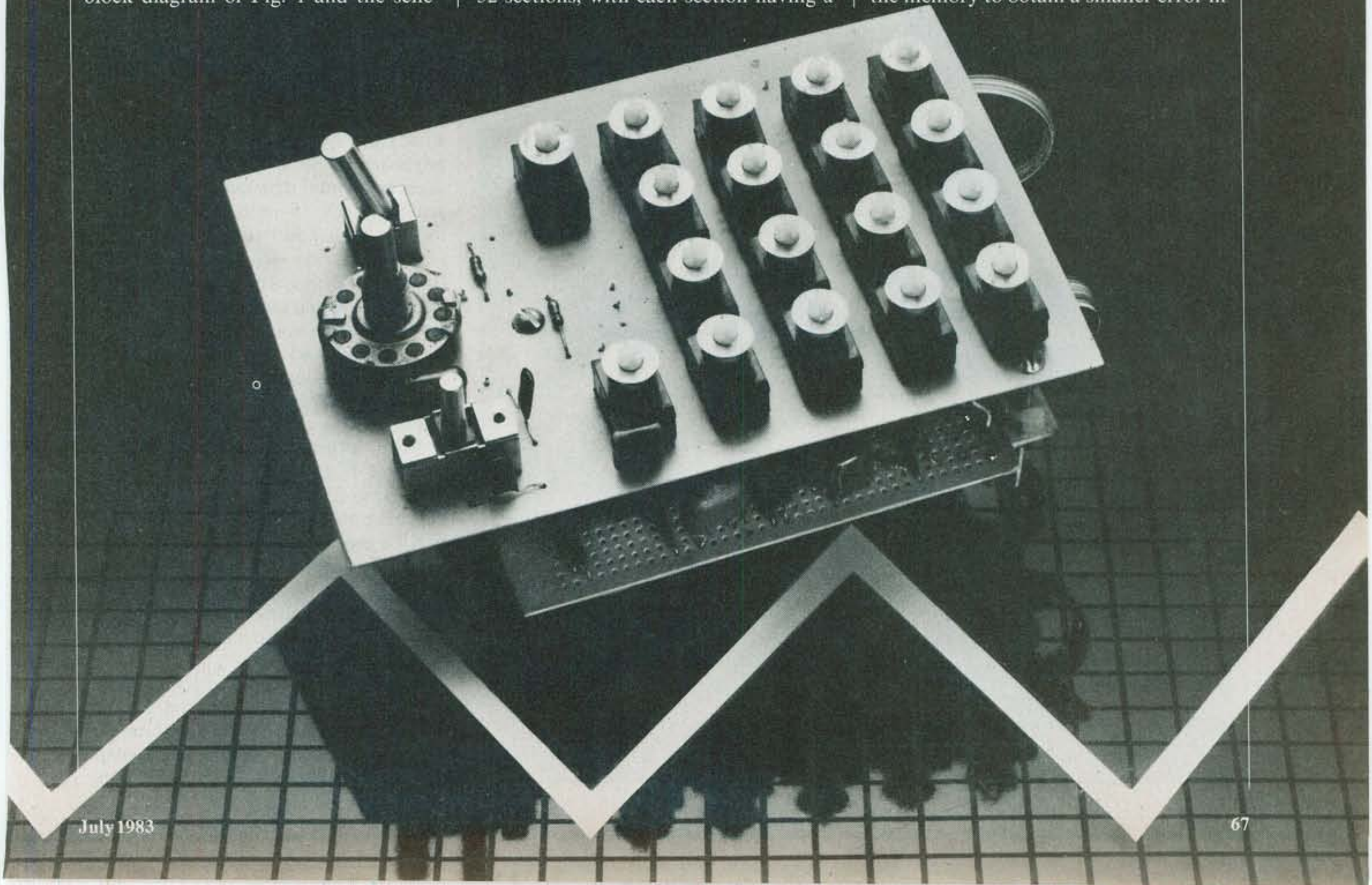
USING a programmable voltage-controlled oscillator (vco) makes it possible to synthesize almost any waveshape without having to pass a fundamental waveform (square, triangle, or sine) through a filter. The circuit shown in this article uses two computer RAM chips to "construct" a waveshape preprogrammed by the user and was designed to replace a conventional voltage-controlled oscillator in a synthesizer. With a few simple revisions, it is possible to use this circuit as a versatile sequencer. The circuit utilizes CMOS devices for high speed and low operating power.

Circuit Operation. As shown in the block diagram of Fig. 1 and the schematic of Fig. 2, the circuit includes five basic building blocks: the vco, a 6-bit counter, a memory, a keyboard and encoder, a digital-to-analog converter, and an output stage. The vco is a precision circuit that produces a square-wave output whose frequency is linearly proportional to the input voltage level. The operating point of *IC1* is determined by *R11* and switch-selected *C1*, *C2*, or *C3*. Three frequency ranges can be selected by *S2*: 100-10,000 Hz for audio, 1-100 Hz for very low frequencies, and 0.1-1 Hz for sequencer applications.

The square-wave output from pin 7 of *IC1* is divided by 32 in *IC2* to form a six-bit address for memory *IC3* and *IC4*. This divides the desired wave shape into 32 sections, with each section having a unique voltage level. The voltage level of each section is loaded into the memory formed by *IC3* and *IC4*, two random-access memory chips. (A 15-bit number signifying a specific voltage level is stored at each memory address.) As each address is called in order by *IC2*, the output changes to the voltage level preprogrammed by the user.

The effective size of the memory is 6 bits by 5 bits but can be expanded to 7 bits by 5 bits. However, it was found that, if the memory is expanded past 6 bits, the frequency of the vco is much higher than the maximum operating limits. If the circuit is going to be used only on the lower two frequency settings of *S2*, it is possible to expand the memory to obtain a smaller error in



the final output. It should be kept in mind, however, that for each address of memory, a voltage level will have to be keyed in. This will make it necessary to key in 128 numbers.

Digital-to-analog converter *IC5* changes the digital output to an analog current signal. The latter is then converted into a voltage signal suitable for use in a voltage-controlled synthesizer by op amp *IC6*.

To enter a waveform into the memory, the memory should be switched into the WRITE mode by applying a high (via *S2B*) to pins 8 and 6 of *IC8*. The 6-bit counter, *IC2*, should be reset to zero by applying a high to pin 2 of *IC2* via *S4*. The 16-key keyboard is decoded by *IC7*. As a key is closed, *IC7* sends a data available signal to *IC8A*. If READ/WRITE switch *S2* is in the WRITE mode, a high is passed to *IC8*, and the gate will produce a low at pin 10 when the data is to be written into the memory. This is done because, if the data or the address is changed while the memory is in the WRITE mode, the data could be lost. Therefore, after the data is stabilized, the READ/WRITE signal is brought low to begin the next address.

The keyboard is comprised of 16 keys, used to program *IC3*, and SHIFT key *S3*, which will program *IC4*. The SHIFT key allows the use of just 16 keys instead of 32. The 16 keys are debounced by an internal circuit of *IC7* and *C5*. This capacitor also controls the time delay between the data output signals and the data-available signal, since *C6* controls the sampling rate of *IC7*.

When there are no keys depressed, the output enable, pin 14, is forced into a low state. This forces the data output pins into a high-impedance or a three-state mode. When a key is depressed, the data-available signal goes high and, if the READ/WRITE switch is in a WRITE position, *IC8* produces a low signal. This enables the output pins into their respective levels, depending on which key is depressed.

Construction. The oscillator can be wire-wrapped using lengths of wire that are as short as possible. Keep in mind that, when an output frequency above 10 kHz is desired, there will be a signal above 500 kHz passing through the *S2* circuit, so keep these leads as short as possible. Handle all CMOS chips with care to prevent static breakdown. A grounded metal enclosure should be used to reduce any r-f interference generated by *IC1*.

"A number of vco's can be used to create a series of waveforms that will generate avant garde music."

The power supply can be any source of voltage between ±4 and ±6 volts dc, with a typical circuit that can be used shown in Fig. 3.

Use. The circuit can be used in either of three modes: as a vco, as an envelope generator (which is essentially a low-frequency signal), or as a sequencer. Other than the programmability, there is very little difference between this vco and any other.

To program the circuit, use a graph having 32 divisions vertically (voltage) and 64 divisions horizontally (time) and sketch the desired waveform between these bounds. With READ/WRITE switch *S2* set to WRITE, depress *S4* to RESET the system to zero, then use the keyboard to enter the voltage value at each horizontal division. If the voltage scale exceeds 15 units, use the SHIFT switch (*S3*) to add 16 to the key number.

To convert the circuit to a sequencer, break the connection between pins 2 and 3 of *IC2*, and connect pin 3 to parallel-connected pins 1 and 2 of a spare gate within quad gate *IC8*. This forms an inverter. Connect the output of this inverter at pin 3 to pin 13, one input of another spare gate within *IC8*.

Remove the lead coming from *S2A* at pin 1 of *IC2*, and connect the switch lead to pin 12 of *IC8*. Both inputs to this gate are now made. The output at pin 11 will be the inverse of the clock signal when the counter is in the first 64 counts. When the seventh bit goes high, the gate (*IC8*) will be inhibited and the count will stop if pin 11 of *IC8* is connected to pin 1 of *IC2*.

To start the sequence, apply a high to pin 2 of *IC2* via RESET pushbutton *S4*. This will reset the counter and force the seventh bit low, allowing clock signals to pass through *IC8*. Counter *IC2* con-

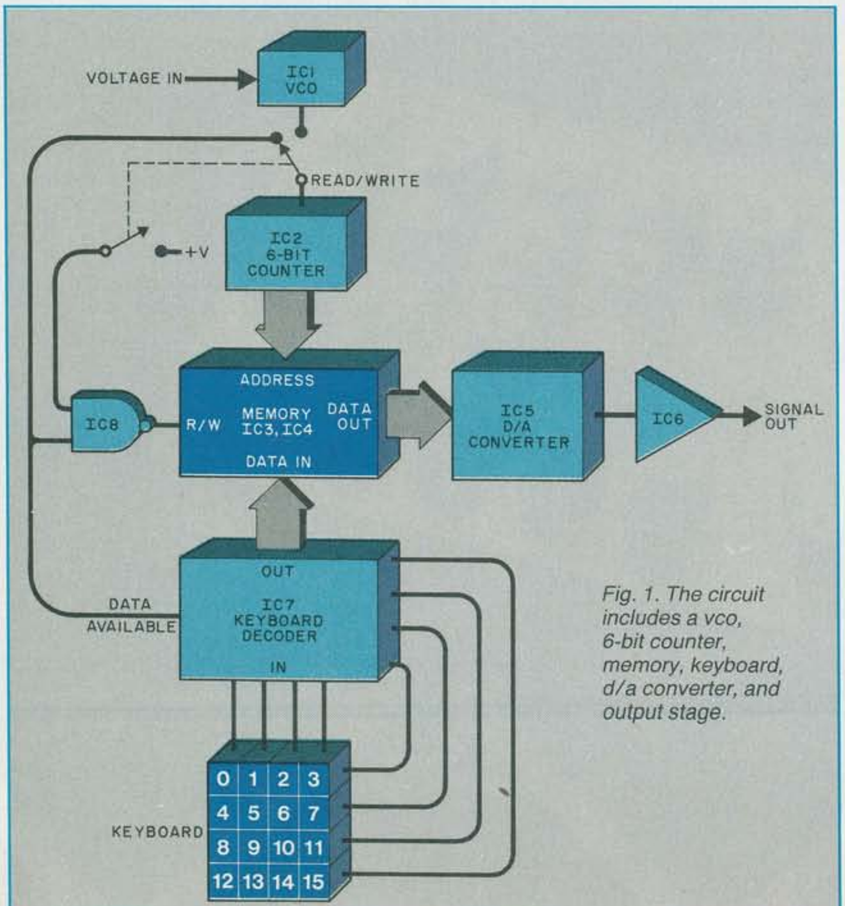


Fig. 1. The circuit includes a vco, 6-bit counter, memory, keyboard, d/a converter, and output stage.

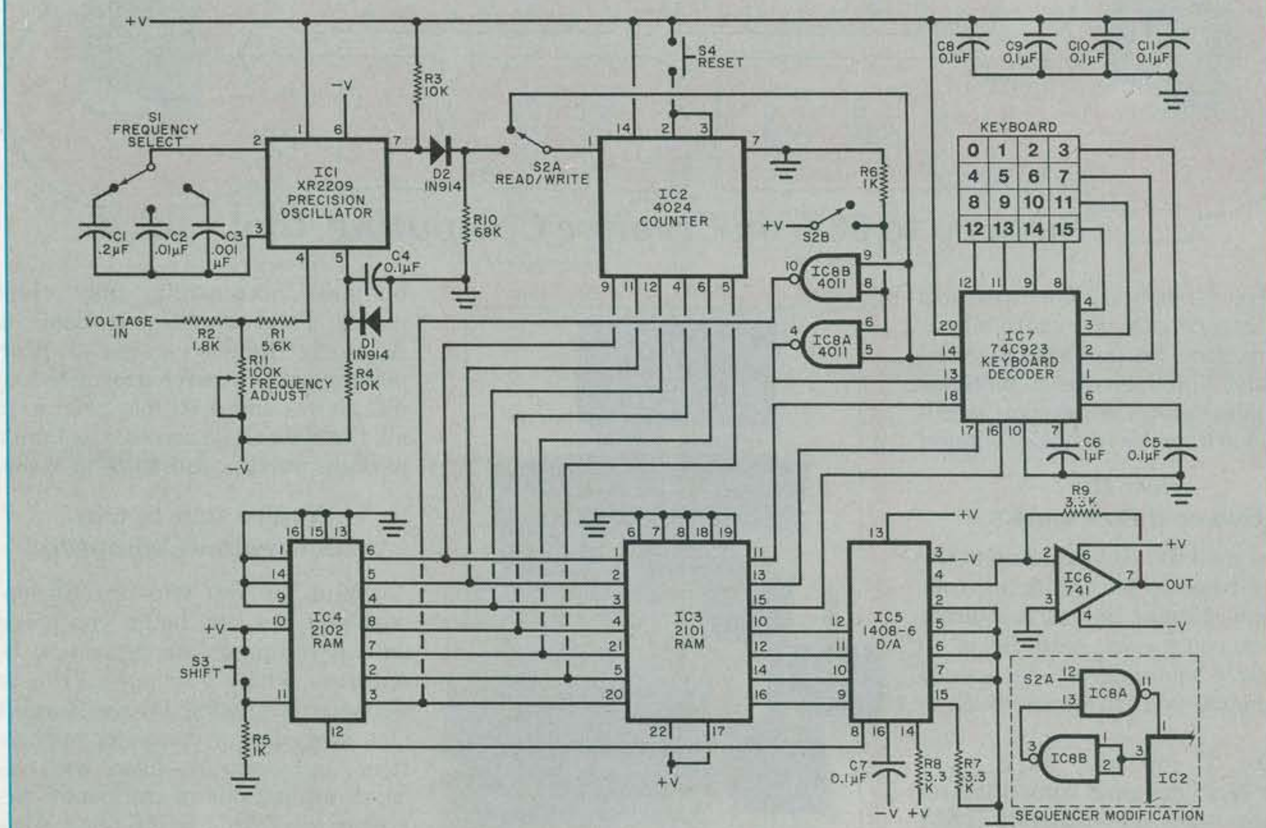


Fig. 2. The vco produces a square-wave output whose frequency is proportional to the input voltage.

PARTS LIST

C1—0.2-μF capacitor
C2—0.01-μF capacitor
C3—0.001-μF capacitor
C4,C5,C7 through C11—0.1-μF capacitor
C6—1-μF capacitor
D1,D2—1N914
IC1—XR2209 precision oscillator (Exar)
IC2—4024 7-stage binary counter
IC3—2101 256 × 4 static RAM
IC4—2102 1024 × 1 static RAM
IC5—1408-6 digital-to-analog converter
IC6—741 op amp
IC7—74C923 keyboard encoder
IC8—4011 quad 2-input NAND gate
R1—5-kilohm resistor
R2—1.8-kilohm resistor
R3,R4—10-kilohm resistor
R5,R6—1-kilohm resistor
R7,R8,R9—3.3-kilohm resistor
R10—68-kilohm resistor
R11—100-kilohm potentiometer
S1—Sp3t rotary switch
S2—Spdt switch
S3,S4—Normally open pushbutton switch
Misc.—16-key keypad, hookup wire, suitable enclosure, mounting hardware, etc.

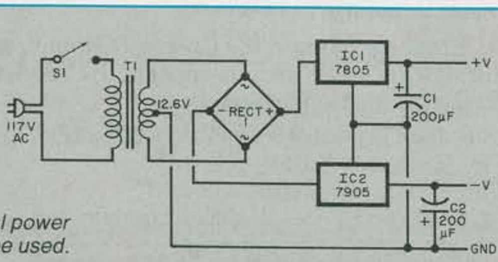


Fig. 3. A typical power supply that can be used.

PARTS LIST

C1,C2—200-μF, 25-V capacitor
IC1—7805 5-V positive regulator
IC2—7905 5-V negative regulator
RECT1—1-A bridge rectifier
S1—Spst switch
T1—12.6-V, 500-mA transformer

tinues to count until the seventh bit goes high, inhibiting the clock signal.

Both the programmable vco and the sequencer can be used in a number of ways. For example, the vco can be programmed for any waveform the user can imagine, making it ideal for music synthesis. The user can define the required waveform so that a vco (voltage controlled filter) is not required. This allows for re-programming the same sound without having to consider programming a vco. A number of vco's can be used to create a series of unique waveforms for *avant garde* music. On the other hand, the sequencer can be used to program any function that uses a voltage as a control. ◇