BUILD

Portable Mini Organ

Play music anywhere with this self-contained battery-powered mini-organ. It has its own keyboard, speaker, unique pitch-bender and covers a five octave range

JOHN S. SIMONTON, JR.

A TOP-OCTAVE DIVIDER WORKS LIKE THIS: You pump a high-frequency clock signal into one of the pins and like magic a full octave of equally tempered musical notes come flowing out of the rest of the pins. As you might expect, this is extraordinarily useful for organ-type musical instruments.

In various single or multiple package configurations, they've been around for years. When they were first developed the price was high enough to effectively limit their application to large, expensive instruments. Now, we're getting out on the "learning curve" and while these devices are still not cheap, they are inexpensive enough to become candidates for some "small" applications.

Like, for instance, here's OZ. It's battery-powered and has a built-in amplifier, speaker and keyboard. You can take it anywhere; into the woods, your van, to the beach—places you wouldn't ordinarily expect to find a keyboard instrument. For the musician on the road, it's great for getting your chops down on long bus rides. And as an added benefit, a guitar or other instrument can plug in and share OZ's amplifier. For music students, it's a practice instrument that will fit into the most confining dorm room, apartment or budget.

It's polytonic—which means that you can play notes, intervals or full chords—and its output level is appropriate for most electronic music synthesizers. Yes, it works quite well with the Gnome (**Radio-Electronics,** Nov., Dec. 1975 and Jan. 1976 issues.) To make interfacing easy, OZ features a trigger output that is switch selectable to be either high as long as any key is down, or a short pulse every time a key is depressed.

It has a really slick touch-operated pitch bender that glissandos, vibratos and trills single notes or whole chords up to a full octave. The harder you press, the more the frequency changes.

Let's see how it works

The top-octave IC is the real guts of OZ; but, before we look there, we must start with the thing that makes it all go—the clock.

Two CMOS NOR gates (IC6-a and IC6-b, Fig. 1) are configured in a classical astable circuit in which timing capacitor C20 charges and discharges through resistor R42 and the variable TUNE control R57. The nominal frequency of the clock is 500 kHz and is adjustable with the tuning control through an octave range.

PARTS LIST

All resistors ½ watt, 10%.
R1-R18—330,000 ohms
R19-R36, R51, R53, R54—22,000 ohms
R37—33,000 ohms
R38—3.9 megohm
R39—150,000 ohms
R40, R41, R56, R60—10,000 ohms
R42—2700 ohms
R43—680,000 ohms
R44—100,000 ohms
R45, R46, R47—10 ohms
R48, R52, R55—2200 ohms
R49—4700 ohms
R50—1000 ohms
R57, R58, R59—5000-ohm potentiometers
C1-C18, C24—.005 µF, ceramic disc
C19, C22, C26, C31—.05 µF
C20—47 pF
C21, C28, C29, C30—.01 µF
C23—100 pF
C25, C32—1 µF, 12-volt electrolytic
C27—250 µF, 12 V
C33—0.22 µF, Mylar
D1—1N914 diode
IC1, IC2, IC3—CD4013
IC4—MK-50240
IC5—CD4024
IC6—CD4001
IC7—LM380
J1—miniature open circuit phone jack
J2—miniature closed circuit phone jack
J3—pin jack
LED's (6)—MSL-7-50 light-emitting diode
Q1, Q2—2N5129 or 2N3904 transistor
S1, S3—SPST slide switch
S2—2P5T rotary switch
Keyboard—18-note DPST switching
Miscellaneous hardware, 4 knobs, front panel, vinyl covered case, 8-ohm speaker, speaker bezel, grille cloth, two 5-lug terminal strips, wire, plastic tubing, coaxial cable, bare wire, cable clamps, wire ties, printed circuit board, LED circuit board, pitch-bender circuit board.

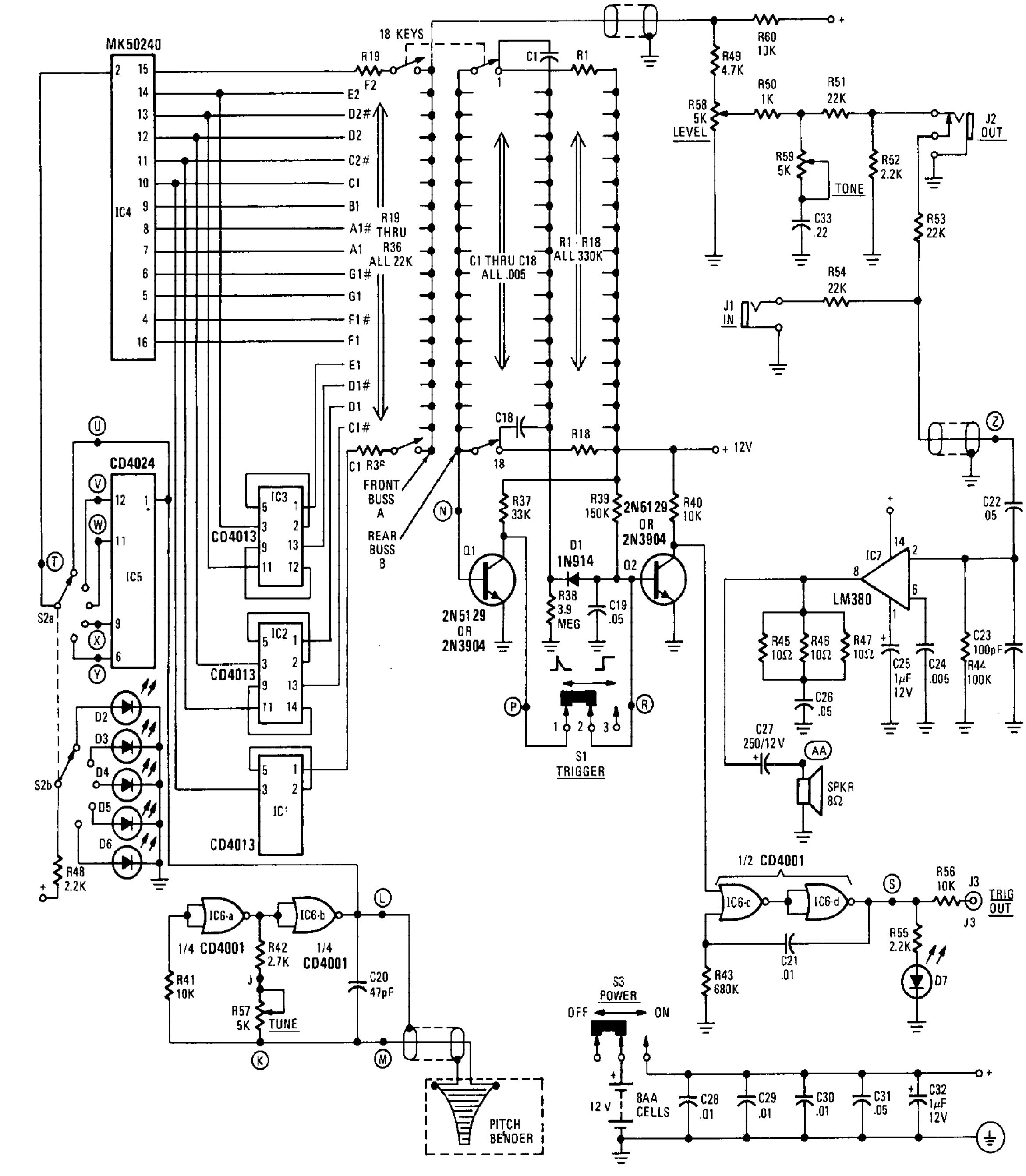


FIG. 1—COMPLETE SCHEMATIC, OZ MINI-ORGAN AND POLYTONIC PITCH SOURCE FOR MUSIC SYNTHESIZERS.

The frequency of this type of astable may also be changed by changing the value of capacitor C20. We don't want to use this as a tuning control for the oscillator, simply because variable capacitors are more expensive than potentiometers.

Wired across the timing capacitor we have a strange looking symbol labeled "pitch bender". This is a small circuit board etched as shown in Fig. 2 and as you can see, it consists of an interlaced grid of conductors.

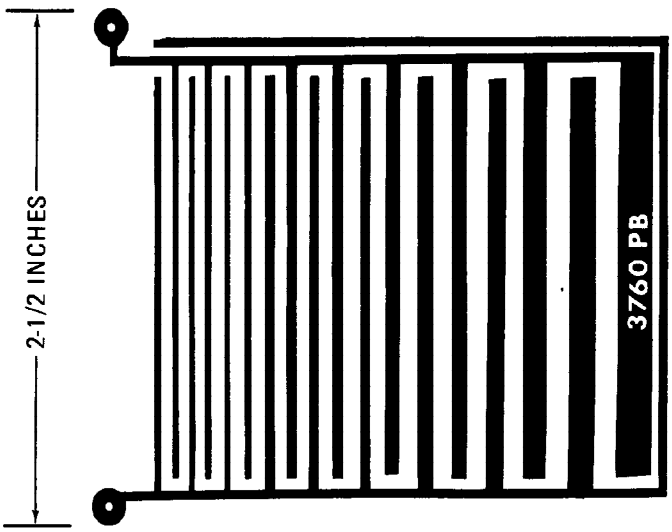


FIG. 2—PITCH BENDER PC BOARD SHOWN FULL-SIZE.

Bending the pitch

This circuit board is a capacitor; but, unlike most capacitors, it is *designed* to be touch sensitive. In actual use, the conductors of the board are insulated by a thin film of paint so that resistance effects are eliminated.

When there is nothing touching the surface of the plate, its equivalent capacitance is low—a few pF. But when your hand touches the plate, the capacitance increases—your flesh has a higher dielectric constant than the air it is displacing. Pressing harder puts your hand in more intimate contact with the plate, which further increases the capacitance. Increased capacitance produces lower clock frequencies, which in turn lowers the pitch of the notes produced by the top-octave divider.

The five-position rotary switch S2 is a RANGE switch that transposes the OZ keyboard up and down in pitch by exact octave increments. This could have been done by switching resistors or capacitors in the clock, but by far the easiest and most precise way is to apply the clock to a divider chain and then select the divider-chain output that will serve as a clock signal for the top-octave divider. It is probably not necessary to say, but this works because the output of each successive stage in a bistable divider chain is exactly half the frequency of the preceding stage and in the equally tempered musical scale, a frequency division of one half represents exactly an octave. The divider circuit is a type 4024 CMOS package. Notice that although there are seven stages of division on the IC, we only use four of them. (The fifth position of S2 is a direct connection between the clock circuit and the top-octave IC.)

The second section of S2 is used simply to light front panel LED's that indicate the setting of the RANGE switch (superfluous, perhaps; but mighty handy on a darkened stage.)

Finally, the clock signal gets to where it does some good, the MK50240 top-octave divider that, in gratitude for being supplied with this elegant squarewave clock signal, produces for us a full octave (plus one note) of equally tempered scale.

But wait; here we have 13 notes—but there are 18 keys on the keyboard. If all those keys are going to produce notes we need to find another five semi-tones somewhere. We get these in essentially the same way that we came up with the range switch; that is, by dividing a note that we already have by 2 to get the same note in the next lowest octave. This is the task of the three 4013 dual type D flip-flops, IC1–IC3.

Key switching in OZ is certainly not elegant, but taking into account where we're headed (a pitch source for synthesizers that can be used as a stand-alone practice instrument) it is certainly cost-effective. When a key switch closes, it simply connects the note that the key represents to the common audio bus.

Notice a couple of things here. First, resistors R19–R36 are in essence mixing resistors; they prevent interaction between the outputs of the MK50240. Secondly, because of R49, R58 and R60, the audio bus that all these notes connect to is displaced from ground by a voltage equivalent to half the supply voltage. There's a reason for this. The outputs of the top-octave IC are squarewaves. If we switch the squarewaves to an audio bus that is at ground potential, not only is the squarewave (note) going to appear on the bus, but also the average value of the squarewave (half of supply). The average value is a DC level shift as far as the audio bus is concerned and it will ultimately appear in the output as a horrendous "thump" every time a key goes down. It's the *transition* that we hear and by closing to an audio bus that is already half the supply voltage, we eliminate the transition.

We're almost in a position to produce music, but before we do, we need some controls. For example, R58, which allows for varying the level of the signal that will eventually be applied to the amplifier or synthesizer. We also need some control over the harmonic content of those squarewaves coming onto the audio bus. The low-pass T-filter, consisting of R50, R51, R59 (the TONE control) and capacitor C33, does this for us.

If we're always going to use OZ with its internal amplifier and speaker, we're home free because the next place the signal goes to is the LM380 amplifier (IC7) that drives the speaker.

But we might not always use OZ like that, so we need a few more goodies. J1 is wired as a mixing input to IC7 for play-along situations or interfacing to other musical gear, and J2 is a closed-circuit phone jack wired to disconnect the OZ pitch source from its internal amplifier when a plug is inserted. If you're going out to external processing gear, you obviously don't want to hear anything until after the processing.

What type of trigger?

Synthesizers like to have some kind of triggering signal to let them know when to do things and (because it's the most useful way) these triggers usually reflect the keyboard activity.

Two types of triggers are particularly useful. We will look at a step trigger first because it's the easiest. When a key is pressed, a second set of switch contacts closes just after the audio switches close. As you can see from the schematic, each of these contacts connects to the positive supply line through a resistor (R1–R18), with the other contact of each switch bussed to the other contact of all the other switches; all of which then connect to the base of Q1. If all the keys are up, Q1 is not conducting and its collector voltage is high.

Assuming that switch S1 is closed (which it must be for us to get step triggers) Q2 is being held on by the current flow through R37, producing a low output voltage at Q2's collector. After passing through the two inversions represented by the NOR gates IC6-c and IC6-d, the voltage is still low, and this is what appears at the trigger output jack J3: nothing. But when a key goes down, things change. Q1 turns on, which turns Q2 off, producing a high collector-voltage that passes through the two NOR gates and appears at trigger output jack TRIG OUT as a voltage. This trigger voltage will remain high as long as *any* of the keys are down and will not return to a low state until *all* the keys have been released.

The second useful type of trigger is one that goes high only momentarily each time a key goes down (whether other keys are already down or not). This is ordinarily called a pulse trigger and OZ generates it like this: For pulse triggers, S1 is open. Also, notice that as long as keys are up, capacitors C1 through C18 are charged essentially to the supply voltage through their respective resistors, R1–R18, and the common resistor R38. The charge on these capacitors is such that the end connected to the switch contact is positive with respect to ground.

When a key switch closes (let's take the first one as typical), the end of C1 that was positive is connected to ground through the base-emitter junction of Q1 (Q1 turns on; but with S1 open, Q1 doesn't connect to anything so we really don't care). When this happens, the other (more negative) end of C1 forces the junction of D1 and R38 below ground potential. C1 immediately begins to charge through Q1 and R38, and as it does, it momentarily turns Q1 off. The result–a short positive-going spike at the collector of Q1. Notice that other keys can now close and their associated capacitors will have identically the same effect that C1 did. Q1's collector will respond with a short positive-spike each time.

This spike isn't really quite long enough and modifying this portion of the circuitry to make it longer, would cost us noise immunity–the trigger circuit would begin responding to the "chatter" that goes along with any switch closure (particularly switches of the kind you find on organ-type keyboards). To make the spike longer, we build a pulse stretcher from IC6-c and IC6-d. The output of the pulse stretcher becomes the actual trigger output. The LED is there to indicate to the user that he is getting a trigger and R55 serves as a current limiter for this LED. R56 is simply an isolating resistor.

Construction

A complete kit is available, which gets the monkey off your back as far as gathering together all the bits and pieces (case and keyboard, for example) is concerned. Circuit boards are available separately or if you're used to etching your own, you can duplicate the layout shown in Fig. 3. If you prefer perf-board construction, that's fine, providing you bear in mind the warnings that will follow shortly. But first let me bring something important to your attention.

OZ is one of those devices that could very easily be built with fifty million wires running back and forth between the circuit board, keyboard and control panel. You're going to come up with a lot of wires anyway, but you will notice that in the model illustrated, some parts are on the circuit board (Fig. 4) while others are mounted on terminal strips on the front panel itself. (See Figs. 5 and 6.) This was done to minimize the wire count and I highly recommend that you study the drawings and photos and stick to their precedents as much as possible.

I recommend the following assembly sequence: First, build up the circuit board. All the standard warnings apply here. Watch the polarity of electrolytic capacitors and the orientation of IC's, diodes and transistors; don't heat the parts to the point that they glow cherry red, etc. An additional thing that y. have to worry about is the fact that you're working with CMOS IC's, so you'll want to be careful about accumulated static charges.

With the circuit board assembled, t wires connecting it to the keyboard c be installed. A tip: leave yourself enough length on these wires so that you can have access to the circuit board in case something isn't quite right. But don't make them so long that you are guaranteed to have radiation problems.

Next, wire the front panel (Fig. 5). Note the components that are mounted here rather than on the circuit board. Notice that LED's 1 through 5 are mounted on a small circuit board secured by the shaft of the rotary switch S2. LED 6 is supported by its leads and those of R55. This is not the best way to do the job, but it was the only practical thing we could come up with.

to be continued

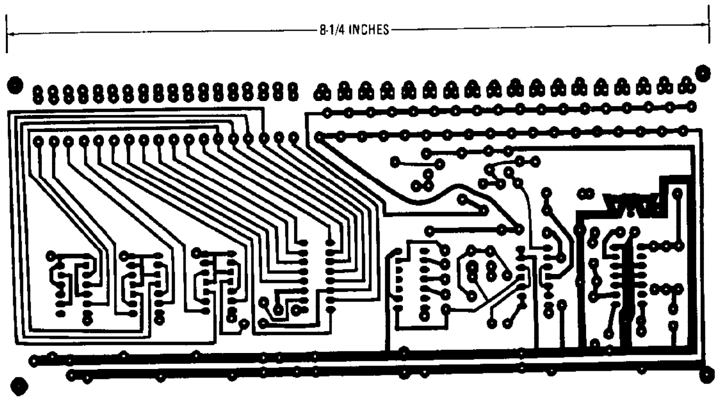


FIG. 3–OZ PRINTED CIRCUIT BOARD SHOWN HALF-SIZE.

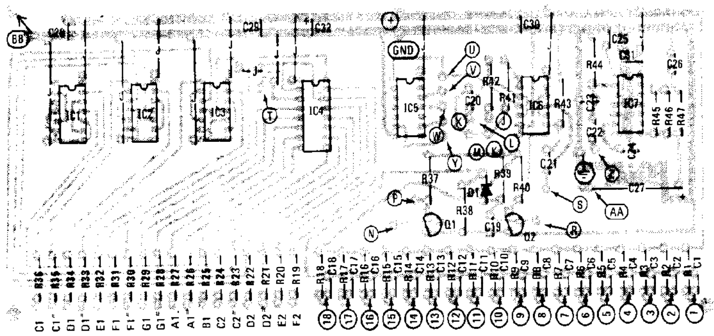


FIG. 4–PC BOARD, PARTS LAYOUT.

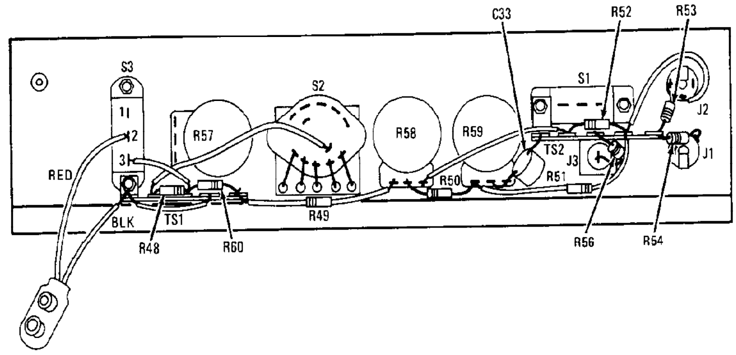
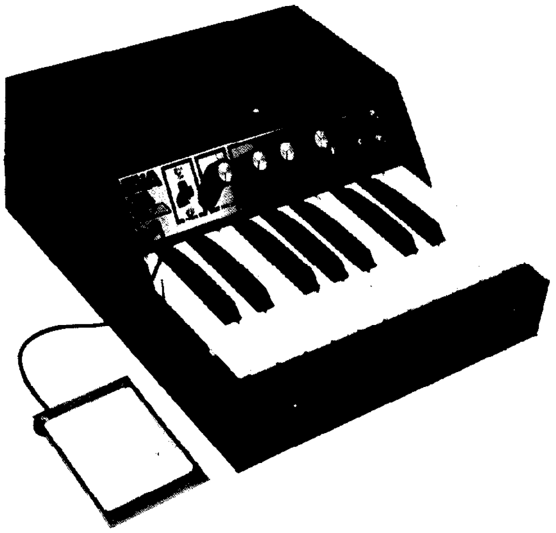


FIG. 5–PARTS MOUNTED AND WIRED entirely on the front panel.



Build Portable Mini-Organ

JOHN S. SIMONTON, JR.

Part II. *Play music anywhere with this self-contained battery-powered mini-organ. It has its own keyboard, speaker, a unique pitch-bender and covers a five octave range*

LAST MONTH, PART I OF THIS ARTICLE introduced Oz and presented the schematic, foil patterns and began the construction details.

This month, the article concludes with the rest of the construction details and a description of how to connect and use Oz.

Mount the circuit board, keyboard and front panel in the housing that you've built or purchased. (Another tip: build a box, then cut it in halves or quarters or whatever, to make it open; don't cut the pieces first then try to put them together so that they form a closing box.) Then wire the connections between the circuit board and front panel (see Fig. 6). The caveats that I mentioned for PC board to keyboard wiring apply equally here. Leave enough slack so if something breaks, it can be fixed without dismantling the entire thing–but not so long that radiation problems pop up.

That makes twice that I've mentioned "radiation problems." Conceivably some of you are wondering what that means. It means this: as we've already noted, the output of the top-octave IC is a bunch of squarewaves. I might now mention that these squarewaves have very respectable rise and fall times. When we have fast rise and fall times, Mr. Fourier tells us that we will have high-frequency components. Mr. Maxwell tells us that high frequencies have a great ability for launching themselves into space in the form of electromagnetic radiation. The longer the wire that these high frequencies have to pass through, the greater will be their ability to leave the conductor entirely.

Similarly, long wires connected to the input of an amplifier will act as antennas that pick up the radiation and amplify it just as it would any other signal. The net result, in this case, is that notes work their way from the tone-generating circuitry to the amplifier and speaker without bothering to go through the keyboard. It becomes our task, then, either to prevent the radiation to whatever extent possible (short wires); or, failing that, to at least contain the radiation (shielding). Besides short wires there are a couple of other things that you can do to minimize–and probably eliminate entirely–this problem.

Use coax to make the connections indicated to be coax on the schematic and in the illustrations: specifically, the signal path from keyboard to front panel and back to the circuit board.

It is not practical to use coax to make all the connections between the circuit board and keyboard; but fortunately it's not necessary either. Most keyboards have a solder lug attached to their frame somewhere. It's there for a purpose–the purpose being that if you ground it, the whole frame of the keyboard becomes one big shield to prevent radiation spilling out into places it shouldn't. Point "BB" on the PC board is ground and has been provided for just this purpose.

Just a little more, we're almost done. Special note also needs to be given to the pitch-bender panel. If you really want to, you can eliminate it entirely simply by not wiring it in (in which case it would not hurt to parallel an additional 47 pF across C20). But the ability to tremolo and "glide" single notes and chords is to a great extent what OZ is all about, so I will assume you are going to use it. Connect the pitch bender panel to the rest of the circuitry with small diameter coax, like RG-174/U. Coax is important here because we're working with an element that is capacitance sensitive and we want to minimize the effect that grabbing the connecting cord with your hand will have. The most important part of using coax is to make sure that the shield goes to the *driving* terminal of the clock circuit (the output of IC6-b–point "L" on the circuit board). Figure 7 shows the assembly of

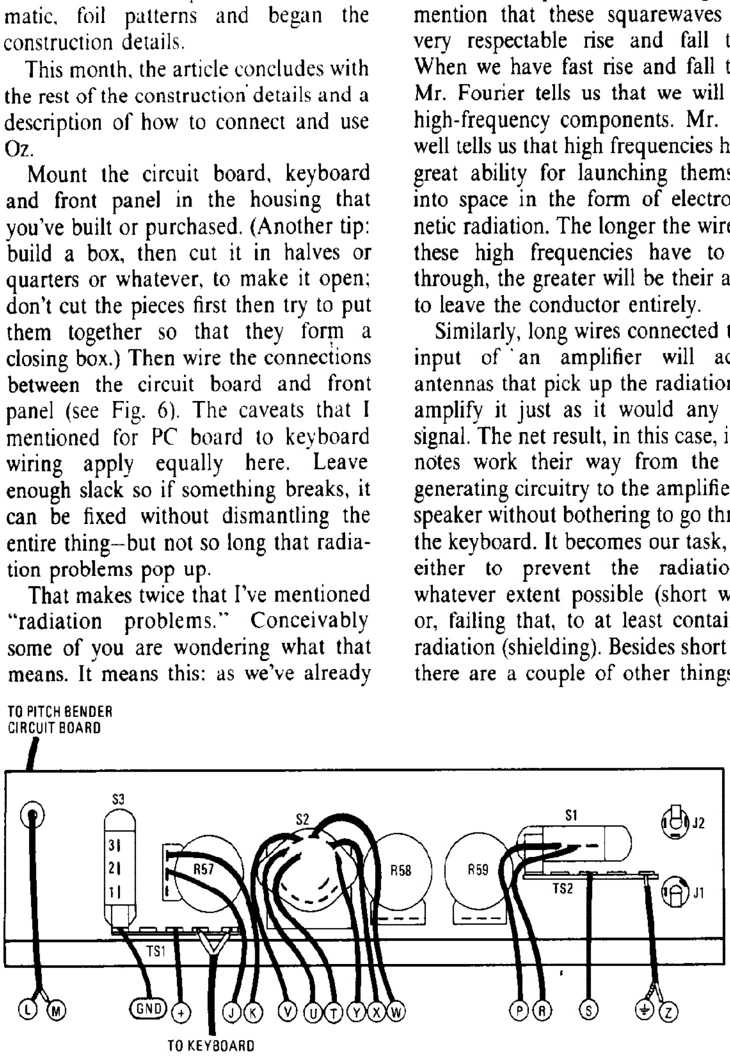
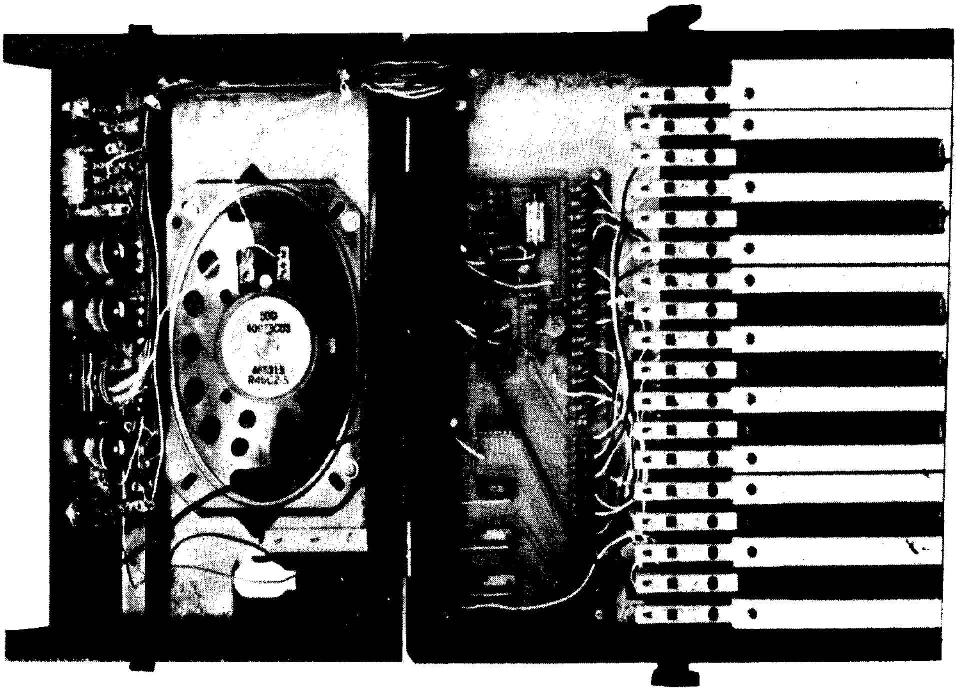


FIG. 6—PANEL-TO-BOARD WIRING.



the pitch bender panel.

You're finished. Now, before you hook up the batteries, why don't you check it through one more time? I always do (well, almost always).

OZ requires a 12-volt power source for proper operation. This can be a line-operated supply if you like, but be aware that a portion of the audio bus is connected to the supply lines, so power supply ripple rejection at the output is low. Make sure the supply is well filtered.

The best bet is batteries. "AA" size cells work well and even taking into account OZ's 60-mA typical current drain, a fresh set of quality batteries should last for a month or more of daily intermittent operation.

Testing

Turn the POWER switch ON and observe that one and only one of the range indicating LED's lights. Change the OCTAVE switch and observe that the LED's follow the action of the switch.

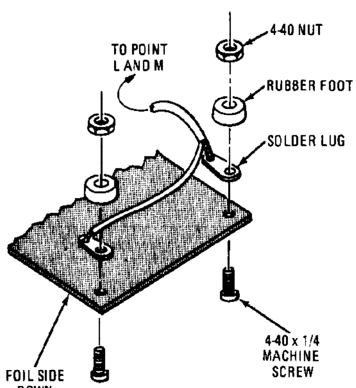


FIG. 7—PITCH-BENDER board assembly.

Depress one of the keys and advance the LEVEL control until a tone is heard from the speaker. Test all the keys to make sure they produce a tone and that the pitch of the tone ascends as you work your way up the keyboard. Confirm that all positions of the OCTAVE switch work and that as the knob is advanced in a clockwise direction the pitch produced changes by octave steps.

While pressing keys, check the operation of the trigger status LED. With the TRIGGER select switch in the STEP position, the LED should come on and stay on as long as any keys are down. In the pulse position of this switch, the LED should wink briefly (very briefly) every time a new key is pressed down.

Try connecting the tone-generation circuitry to an external amplifier by connecting the OUT jack J2 into the input of the outboard amplifier. Under these conditions make sure that signal is being supplied to the external amplifier and that no sound is coming from OZ's speaker.

To test OZ's input jack, you can either run an external program source into J1 (IN) or you can just jumper from OZ's output to its input. If, under these conditions, you still hear sound from the speaker, then the IN jack is working.

Using OZ

There is little to be said about using OZ by itself. You simply turn it on, select the octave that you want to play in, set the LEVEL and TONE controls to your taste and wail!

Interfacing to full synthesizer systems is only slightly more complicated, and more than anything else, requires that you have a firm grasp of exactly what OZ is and what it is supposed to do. Let's pin that down right now: OZ is a combination controller and polytonic pitch source. Nothing more (it doesn't *need* to be anything more). In most synthesizer systems, it will be used in place of—or possibly in conjunction with—a keyboard/voltage controlled oscillator combination.

For example, Fig. 8 shows a "classic" synthesizer configuration. In a patching arrangement like this, there are really two different circuits with which we need to be concerned; the control circuit (triggers, control voltages, etc.) and the audio circuit (outputs of oscillators, inputs and outputs of voltage controlled filters and amplifiers, etc.). In the scheme illustrated, the control circuit can also be broken down into control

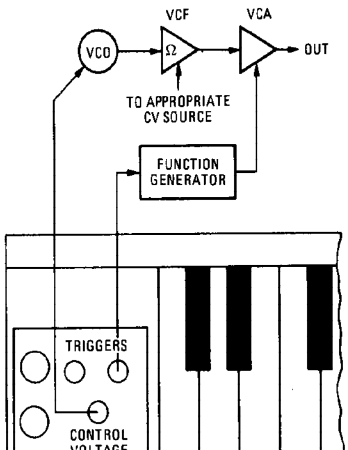


FIG. 8—A SYNTHESIZER PATCH. The initials stand for voltage controlled oscillator, filter, amplifier, and control voltage source.

PARTS LIST

All resistors ½ watt, 10%.
R1-R18—330,000 ohms
R19-R36, R51, R53, R54—22,000 ohms
R37—33,000 ohms
R38—3.9 megohm
R39—150,000 ohms
R40, R41, R56, R60—10,000 ohms
R42—2700 ohms
R43—680,000 ohms
R44—100,000 ohms
R45, R46, R47—10 ohms
R48, R52, R55—2200 ohms
R49—4700 ohms
R50—1000 ohms
R57, R58, R59—5000-ohm potentiometers
C1-C18, C24—.005 μF, ceramic disc
C19, C22, C26, C31—.05 μF
C20—47 pF
C21, C28, C29, C30—.01 μF
C23—100 pF
C25, C32—1 μF, 12-volt electrolytic
C27—250 μF, 12 V
C33—0.22 μF, Mylar
D1—1N914 diode
IC1, IC2, IC3—CD4013
IC4—MK-50240
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IC6—CD4001
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S1, S3—SPST slide switch
S2—2P5T rotary switch
Keyboard—18-note DPST switching
Miscellaneous hardware, 4 knobs, front panel, vinyl covered case, 8-ohm speaker, speaker bezel, grille cloth, two 5-lug terminal strips, wire, plastic tubing, coaxial cable, bare wire, cable clamps, wire ties, printed circuit board, LED circuit board, pitch-bender circuit board.

voltages and triggers. When a key is depressed on the keyboard, a voltage that tunes the VCO appears at the control-voltage output of the keyboard while a trigger appears at the trigger outputs. The trigger activates a function generator that produces a precisely preset time-varying voltage which in this case takes care of controlling the VCA to produce varying attack and decay times. The filter is stuck in there for harmonic control and it can be driven by control voltages from a variety of sources that we're not really concerned about.

The audio circuit is from the output of the VCO, through the VCF, through the VCA and finally to some sort of amplifier or recording device.

The part of this circuit that OZ replaces is *only* the keyboard and VCO and the control voltage path between the two. The rest of the patching configuration remains unchanged as shown in Fig. 9. The biggest difference is that by using OZ in place of the keyboard/VCO, you can now play full chords instead of the one-note-at-a-time restriction you previously had. Notice that the processed output can, if you wish, be routed back to OZ's amplifier. You do have one drawback—OZ's output is basically a squarewave rather than the multiplicity of waveforms that you have available from most VCO's; but, with appropriate filtering (at the VCF), that is not really as much of a pain as you would first think.

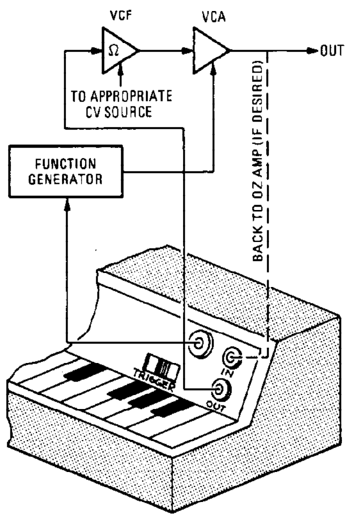

FIG. 9—OZ REPLACES KEYBOARD/VCO.

Many of you will (I hope) be using OZ with the Gnome Micro-Synthesizer (See **Radio-Electronics,** November and December, 1975, and January, 1976, issues.) That's great; that really is what it's designed for. But, you're going to have to make some very light-weight changes to the Gnome before OZ and the Gnome are compatible. Specifically, you're going to have to add an external audio input to the Gnome audio bus.

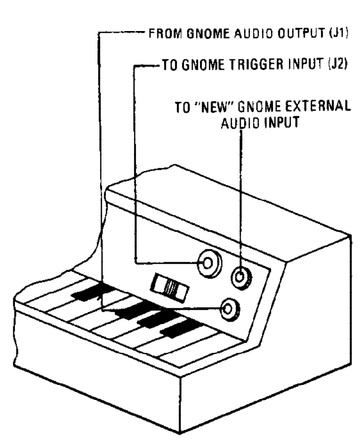

FIG. 11—CONNECTIONS TO GNOME.

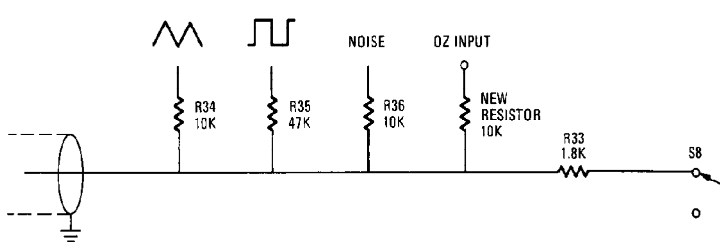

FIG. 10—THE GNOME'S AUDIO BUS, showing the added input and 10K resistor.

Figure 10 shows the audio bus of the Gnome as it was illustrated in the series of articles, and you can see that we have added a new resistor that connects to this bus.

How this new input is made available to OZ is largely a matter of personal preference. In mine, the other end of the new resistor connects direct to a piece of co-ax which then drops out of the seam at the back of the Gnome case and terminates in a miniature phone plug. (In fact, the resistor is inside the plug that terminates the coax—but I'm particularly lazy.) A word of advice—**Do Not** connect both ends of the shield of the coax—there should be one and only one ground connection between OZ and the Gnome and that should be part of the line that runs between the Gnome's output and OZ's input. Multiple grounds in different locations are like an insurance policy guaranteeing hum problems. Ground the shield of the coax mentioned above at the plug that *terminates* the line *only.*

From there, the interconnections are simplicity personified. Your "new" audio input cable connects to OZ's output, OZ's input goes to the Gnome output, and the trigger jacks of both tie together. These connections are shown in Fig. 11.

Playing the Gnome/OZ combination is not very different from playing either one separately—though they are very definitely a synergistic pair. As a matter of fact, only one point need really be brought to your attention. It's this: leave the Gnome's VCA SUSTAIN switch in the sustain position. If you don't, the Gnome's percussion "mute" function will drive you bananas. **R-E**