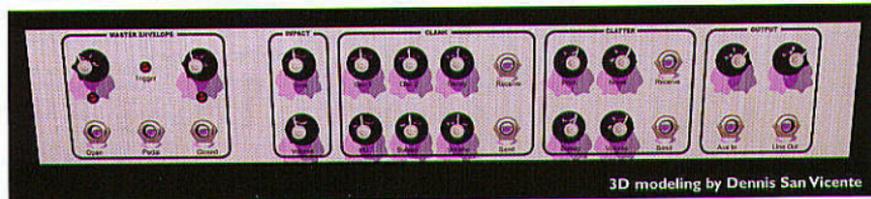


Snap, Clank, Clatter!

Give Neil Peart a Run With this Metallic Sound Synth



The earliest electronic music synthesizers were keyboard-based instruments, played not unlike an organ. Shortly thereafter, clever designers started applying synthesis techniques to drums and percussion. This has revolutionized the music industry and many drummers today augment their set-ups with electronic equivalents, or even forego traditional trap kits altogether in favor of synthesized percussion. Adding to the versatility, electronic drums can be easily put under computer control thanks to the popular MIDI interface. And all this is available

to the experimenter, especially since *Nuts & Volts* magazine has presented a number of construction articles over the years explaining how to build pro-quality instruments from scratch.

But one notable instrument has been missing from the DIY arena ... until now. The cymbal and its relatives (collectively referred to as clangorous instruments) have not been part of most homebrew music systems. The reason for this is that clangorous and metallic sounds are among the most difficult to synthesize realistically, and many experimenters

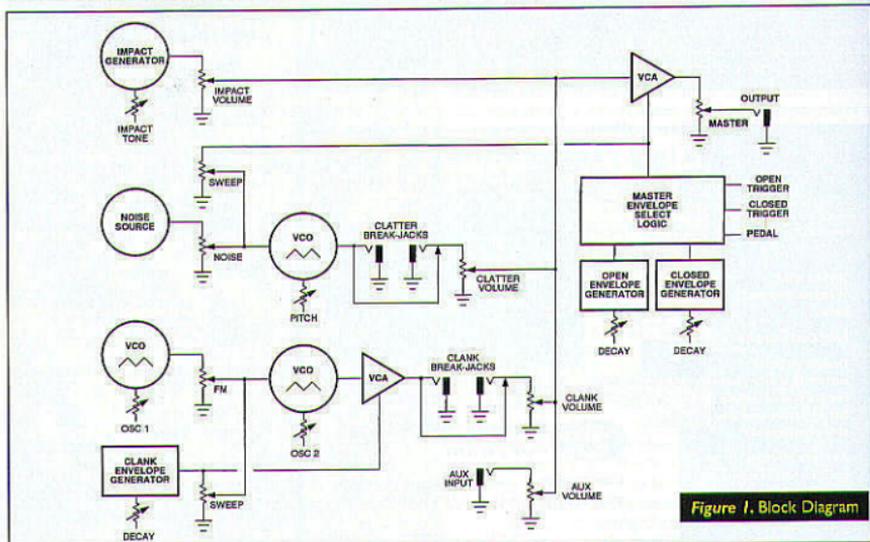


Figure 1. Block Diagram

hardly know where to begin. Bass drums, toms, and even snare drums are fairly straightforward to mimic, since the easily-synthesized damped sine wave is at their heart. But metallic sounds like chimes, cymbals, cowbells, and the like are another matter altogether.

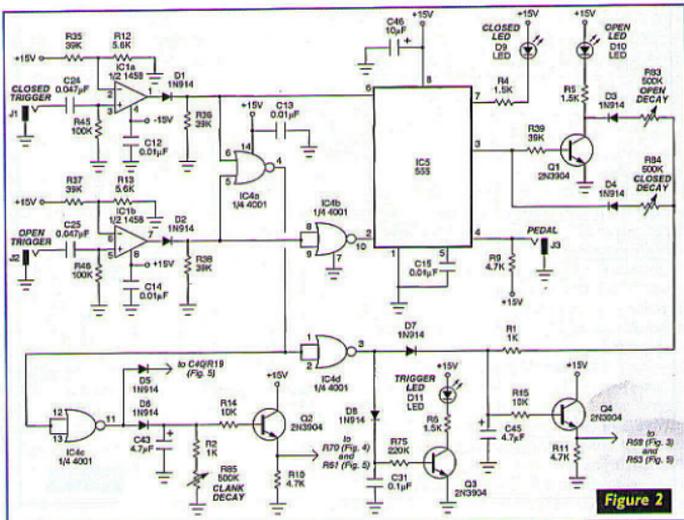
Enter the Clangora! This is a full-featured electronic hi-hat circuit with no commercial equivalent. It's not boasted that it will exactly duplicate the standard hi-hat, but Clangora does suggest the sound more closely than any other analog circuit you're apt to meet. And besides, the Clangora is capable of a wide variety of other metallic sounds. Yes it's a big circuit, but as you'll see, the individual modules comprising it are fairly simple to understand if you consider them one-by-one. Despite its apparent complexity, there is nothing particularly critical about the circuit, putting it within reach of the average weekend project builder. Let's jump right in and see how it works before turning our attention to construction details.

Understanding Clangora's Modules

A cymbal sound consists of at least three main sonic components. First, there is the initial snap of the stick striking a surface. This is called the impact tone and is quite short and sharp. Immediately after this follows a metallic clank, which might hang on considerably longer depending on the mass of the cymbal and how it is supported. Finally, in the case of a hi-hat, there are actually two platters abutting one another loosely and their interaction creates what can be called the clatter. Altogether, a lot goes on when you smack a cymbal! And yet, with a bit of ingenuity, it is possible to imitate these components electronically.

Refer to Figure 1, which shows a block diagram for Clangora. You will notice that there are three major audio components: the impact, clank, and clatter generators. The impact generator sports two controls — one to set the overall volume and one to adjust the tone for bass or treble response.

Next, the clank effect is produced by allowing one voltage controlled oscillator (VCO) to modulate the frequency of



another — called FM. This is a great way to generate metallic sounds. There are controls on the VCOs which permit you to set the initial frequency of each. Another knob lets you dial in the amount of frequency modulation desired, greatly extending the range of possible sounds from realistic to outer-spacey. But even with this, things could be a bit static, so we also sweep the second oscillator in response to an envelope generator. Thus, the harmonic content of the clank changes with respect to time, which is exactly what happens in a real cymbal for various physical reasons. Notice that both the frequency and amplitude of the clank section are modulated by an envelope generator. A separate voltage controlled amplifier (VCA) imposes an amplitude pattern on the clank sound. This is important, since the clank dies out more quickly than the clatter which lingers on as the cymbal gradually dissipates energy.

A pair of jacks — called break-jacks — lets you tap into the clank sound if desired, and insert an additional processor like an audio equalizer, reverb, or ring modulator. This really opens things up for tweaking the sound.

The clatter section begins with a rather exotic noise source. This isn't your usual white noise generator, but in fact, it creates a dissonant mixed-tone effect. And rather than employing the output directly, we force it to control yet another VCO. This yields a tunable noise source which can be dialed up and down across the entire audio band.

Other controls contribute to the fantastic versatility here. The basic pitch of the noise can be set, as mentioned above, but can also be swept in response to the master envelope

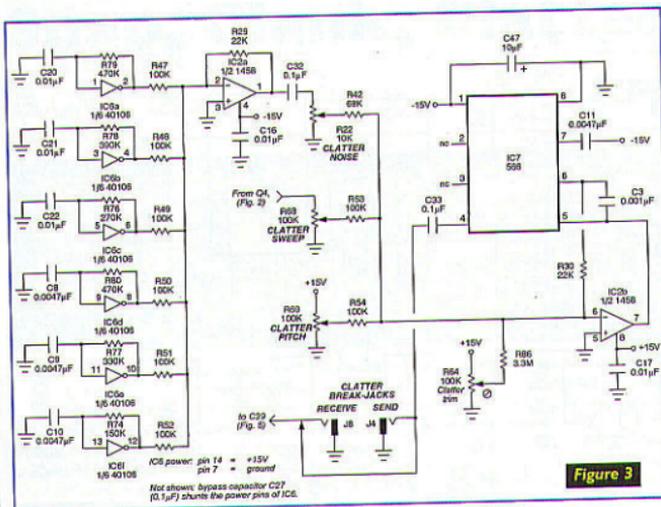


Figure 3

generator. Again, a cymbal sound is anything but static, and by sweeping the clatter over time you get a much more realistic filtering effect. Another set of break-jacks allows you to inject further processing here, as well. There's even an auxiliary input in case you'd like to patch in some other synthesizer circuit.

The impact, clank, and clatter tones are all summed at the master VCA. This VCA changes its gain in response to an envelope generator. The attack time is fixed to be as fast as possible, since that's the way most percussion behaves, but the decay is adjustable and can die out over a period of several seconds. A real hi-hat is controlled by a foot-pedal which opens and closes the platters — the decay of the open pair, of course, is much longer than that of a pair snapped up against each other. So, the VCA is managed by two independent envelope generators.

There are separate trigger jacks for these letting you control both aspects of Clangora by computer. And for real-time percussionists using electronic drum pads, there's even a pedal input which lets you "open and close" the cymbals with an SPST footswitch. With this overview of the modules under our belts, let's dig deeper into the electronics and see how the circuit actually works its magic.

How the Circuit Works

Much of the action in Clangora centers around the envelope generators, so let's start with them first. Refer to Figure 2. The master VCA is controlled by one of two envelopes chosen by the envelope select logic — recall that a hi-hat has

both an "open" and a "closed" sound depending upon how tightly the platters are pulled into contact with each other. Jacks J1 and J2 send open and closed triggers to the unit. To ensure that Clangora is compatible with as wide a range of musical gear as possible, op-amps IC1a, IC1b, and their associated components clean up the input triggers considerably. Let's trace the closed trigger as our example, bearing in mind that the open trigger works the same way.

C24 differentiates an incoming pulse and applies it to comparator IC1a. The threshold of the comparator is set at about 1.8V by means of divider R35/R12. The output will snap cleanly when any trigger exceeding

this value comes in, and diode D1 ensures that the swing is only positive.

The squared-up triggers are then fed to the logic circuitry consisting of the NOR gates and IC5 — the 555 chip. Now, before you think you've seen this all before, you might want to note that IC5 is not being used as a timer! In this configuration, it is set up as high power R-S flip-flop. Pin 2 is the set input while pin 6 provides the reset function. Pin 3 is the output. Depending on the state of the output, either D3 or D4 — but not both — is pulled to ground, thus providing a discharge path for C45 (the main envelope generator timing capacitor) through either the open decay control or the closed decay control. Pulling this all together then, an open or closed trigger either sets or resets the R-S flip-flop, and its output selects one of two possible discharge paths.

By the way, it should be obvious that the attack is fixed, and is created by dumping a charge onto the timing capacitor, C45, via diode D7. Notice that D7 passes current when either the open or closed triggers occur. That's because NOR gate IC4a is followed immediately by the inverter IC4d. You get a NOT-NOR out of the deal, which is nothing more than the simple OR operation. The timing capacitor is charged rapidly giving a near instantaneous attack — it's the decay that is adjustable by either R83 or R84.

Pin 4 of the 555 acts as a master reset control. It will override whatever the chip is currently doing and pull the output to ground, thus closing the hi-hat. An ordinary SPST footswitch can be plugged into jack J3 for pedal control. By the way, two LEDs give an indication of which decay control is currently selected. D10 lights when the open decay con-

Snap, Clank, Clatter!

trol is in effect, while D9 indicates that the closed control is engaged. And in case you're wondering why an off-the-shelf flip-flop wasn't used, consider that it has to sink a substantial amount of current in this application. The 555 shines in this respect, and at the same time, provides all of the niceties, like a master reset (pin 4) and an auxiliary output (pin 7) for the LED. As mentioned above, the currently selected envelope voltage is developed across C45, and the emitter follower made up of Q4 and associated components buffers the signal. Q3, along with D8 and C31, acts as a pulse stretcher and makes sure that the trigger indicator light D11 shines long enough for the human eye to detect.

The clank circuitry requires its own independent envelope generator. A straightforward one comprising D6, R2, R85, and C43 creates the desired envelope that's buffered by Q2. All in all, it's a very simple affair, but does work quite well.

That pretty much covers the envelope generator stuff, so let's move on to the clatter circuitry. Refer to Figure 3 now. Six separate Schmidt trigger oscillators form the main noise-making bank. You might not have seen this approach before. These oscillators were tuned empirically, right at the workbench, to create a deliberately dissonant effect. The sound is quite weird and already begins to seem metallic in nature. The six outputs are summed by mixer IC2a, and then coupled to the clatter noise depth control R22. But rather than tapping this as an audio output, let's continue by using the signal to modulate a VCO. This is a sweet way to make the noise source tunable over the entire audio spectrum, yielding deep bass rumbles on up to brittle treble screams.

The noise output is used to modulate the frequency of a 566 VCO chip and associated components. Like the 555 we saw earlier, this is a very non-standard configuration which may be new to you. For starters, notice how the chip is powered. Usually pin 1 is grounded, and +15V is applied to pin 8. But in this situation, we put pin 1 at -15V and pin 8 at ground. Don't let this strangeness worry you — as far as the 566 is concerned, there's still a positive 15V potential straddling its supply pins. The reason for taking this odd approach is that we can now do clever things to obtain a much wider and predictable response. The details of how it works are beyond the scope of this article, so let's just note that the internal current source of the 566 (accessed via pins 5 and 6) is placed within the feedback loop of op-amp IC2b. This has the effect of forcing

the control voltage to be referenced to ground, and also offers up a response which covers the entire audio range of around a dozen octaves. (The span of the 566 is normally limited to a piffing several octaves).

IC2b sums the voltages that control the VCO's output frequency. As mentioned earlier, the noise output is applied via potentiometer R22. A center frequency or pitch is set via a fixed voltage supplied by control R69. And the clatter envelope generator can sweep the frequency of the noise source dynamically, thanks to the input applied to pot R68. All in all, you get a tremendous amount of control over the sonic qualities of the clatter here. Incidentally, trimmer R64 ensures that the lowest points on the dials still produce a legitimate sound.

Finally, notice that the clatter output is AC coupled from pin 4 through C33 before passing on to the break-jacks mentioned earlier. Use these to insert additional processing if desired; otherwise, the signal simply moves on to the master VCA, yet to come.

Now turn your attention to the clank section in Figure 4. As described above, two VCOs are pressed into service here, one modulating the frequency of the other. IC8 is the controlling oscillator — this 566 chip being configured in the standard way, since we don't need much range here. C26 and R23/R3 provide the main timing elements. The usual FM input at pin 5 is simply biased up to a convenient point to ensure the 566 oscillates across the entire range of R23's span. The output is a triangle wave, found at pin 4.

The second oscillator, IC9, is configured like that in the

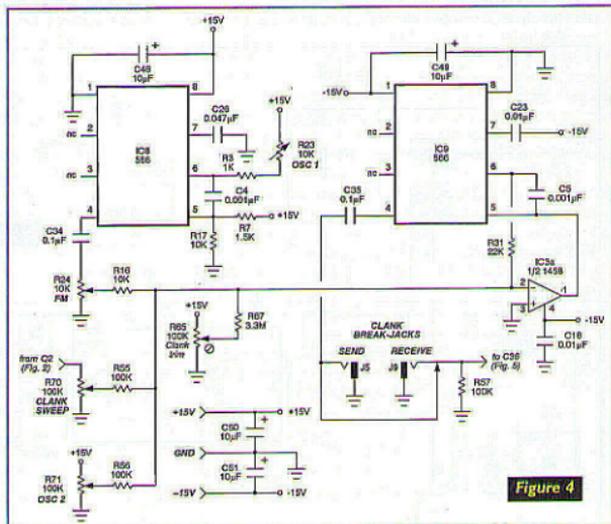
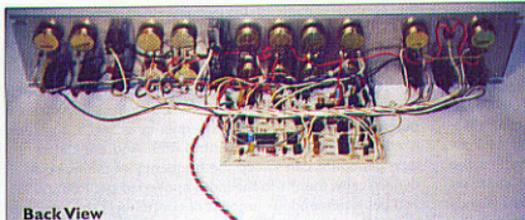


Figure 4



Back View

clatter section. IC8 modulates it under control of potentiometer R24. The basic operating frequency is set by R71. Finally, R70 applies a voltage tapped off of the clank envelope generator described back in Figure 2. These three control signals are summed by op-amp IC3a and then applied to the 566. The frequency modulated triangle wave coming out at pin 4 sounds uncannily like the ringing of metal — once we impose an amplitude envelope on it we'll have cymbals, cowbells, and other clangorous effects at our fingertips.

Look back quickly at Figure 2. Note again that IC4a is a NOR gate, but that this is followed immediately by inverter IC4c. Thus, the output passed on by diode D5 will snap to attention if either an open or a closed trigger occurs. Now move on to Figure 5 to see how this is used to fire the impact generator. The pulse is applied to a simple tone control consisting of C40/R8, C41/R19, and potentiometer R25. Here we have a simple circuit, but it gets the job done.

Throw in control R27 and you now have the power to adjust both the volume and tone of the impact effect.

So, we've got all the sounds we need and we have the various envelopes. The time has come to pull them all together and route the signals to the VCAs. IC10, which is the amazing NE570 compander chip, is pressed into service (again in a slightly unconventional manner) to act as a dual VCA. Let's follow the path of the clank generator which was described earlier. This is applied to pin 3 of the 570 after suitable scaling and coupling by R18 and C36, respectively. Trimmer R66 lets you compensate for any DC offsets at the gain cell input, reducing undesirable "thumps." (This may seem strange in a drum circuit, but the only thumps we want are those we create on purpose!)

The usual rectifier circuit is disabled by bypassing pin 2 to ground via C28. Instead, we inject a VCA control voltage at pin 1, after it's restricted appropriately by resistor R61. If you trace this back to Figure 2, you'll discover that the control voltage comes from the clank envelope generator. Recall that the attack time is very short, so the VCA opens up almost instantaneously, yielding full volume. But then as the timing capacitor discharges through decay pot R85, the amplitude dies away slowly. The effect is that we've imposed an amplitude envelope onto the basic clank generator, and even with just this much it's beginning to sound like you struck a piece of metal and made it vibrate for a while. The tone eventually dies away.

But to finish up the VCA, the gain cell output is sent to an op-amp internal to the NE570 whose gain is set by R32 and R40. C1 limits the supersonic high end, just to nail any RF garbage in its tracks. Potentiometer R26 is the master clank volume control, and then the signal is routed to the remaining VCA.

The second half of the NE570 compander chip is configured in an identical fashion to create a master VCA. Notice that the various audio inputs (clank, clatter, and impact tone) are summed first by mixer IC3b and then applied to the voltage controlled amplifier. The mixed output is tamed by volume control R28.

One final detail — on all of the figures, you might have noticed some capacitors that

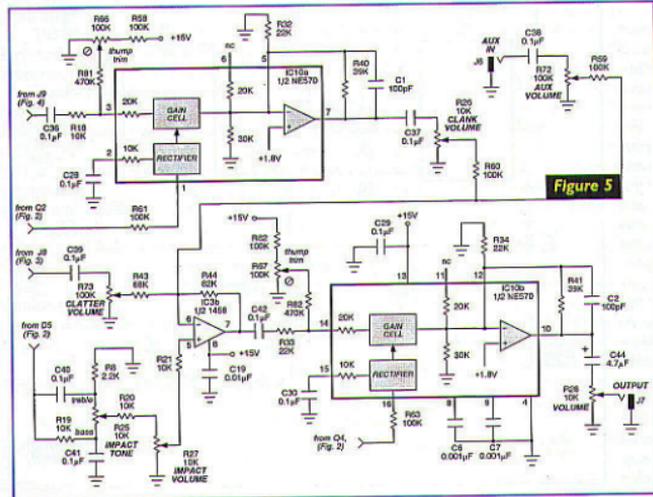


Figure 5

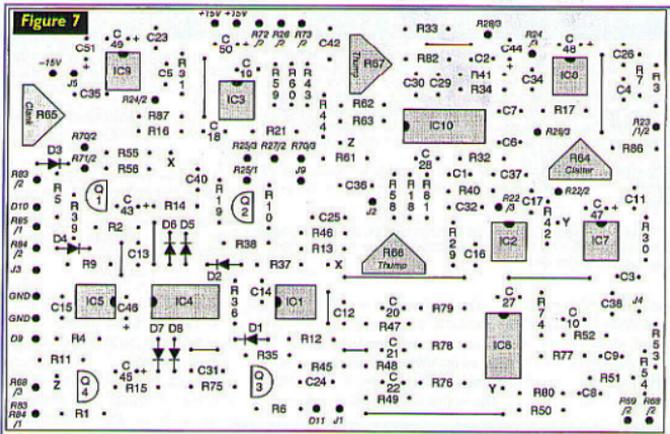
weren't mentioned. Most of these are bypass or decoupling caps. These should be attached as closely as possible to the power supply pins of the various chips. Their purpose is to prevent undesirable interaction as any garbage attempts to hitch a ride down the power supply rails. These capacitors are important to pro-quality sound equipment, so don't skimp on them.

Let's Build It!

Your first step is to gather together all of the components; refer to the Parts List. There's a lot of them, but fortunately most are pretty easy to find. The NE570, which was an extremely popular chip 20 years ago, is perhaps a little harder to locate nowadays. However, as a service to readers, arrangements have been made so that you can obtain it by mail order especially for this project. See the Parts List for details.

There's nothing especially critical about the Clangora, so it could be wired by hand as long as you are patient and neat about it. But since it's a large circuit, perhaps the easiest way to go is by means of a PCB. Figure 6 shows the lifsize artwork, and can be seen on the *Nuts & Volts* website (www.nutsvolts.com). You can find suppliers for most of these circuit board production items in the advertisements within *Nuts & Volts* magazine.

Figure 7 shows the parts placement guide. The orientation of the components should be obvious, but be sure to double-check your work as you go along. In particular, make certain you get the polarities of the electrolytics right, and watch the positioning of the transistors and diodes. Finally, note that there are 14 jumpers on the board (the price for not going with a double-sided PCB!). You can use leftover snip-



pets of component leads, or short pieces of bare buss wire for most of these. However, note that three connections must be made with insulated wires. These join the individual pairs of pads labeled X, Y, and Z, respectively.

Now's the time to start working on the front panel and enclosure. To make the Clangora compatible with other studio rack-mounted gear, a standard 2U panel is perhaps best. This has the dimensions of 3-1/2 inches by 19 inches, and is usually made of 1/8 inch aluminum stock. Figure 8 shows a suggested layout. After marking and drilling all holes, consider using a computer art program with decal transfer sheets to label everything. Several coats of clear plastic paint will protect the panel from most abuse. By the way, you can use tiny angle brackets and #4 hardware to secure the PCB board behind the front panel.

To complete the wiring, refer back to Figure 7. You will notice that the connections to the various pots, jacks, LEDs, and so forth are clearly indicated with italic lettering. For example, a designation of R69/2 means that you are to wire this pad to the second (middle) lug of potentiometer R69 —

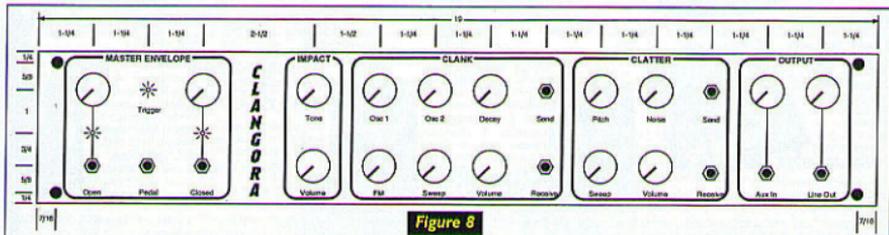


Figure 8

BUILDING IT! — NUTS & VOLTS CAN HELP!

Clangora is a big circuit, so necessarily the description here has had to be short and to the point. But if you're the type of experimenter who clamors for more details, then you need look no further than *Nuts & Volts*. Over the years, *Nuts & Volts* has published a number of articles which directly influenced the implementation of Clangora here. Pull these issues down from your home reference shelf, or check out the availability of back issues on the *Nuts & Volts* website.

- "Build the ADV-Snare," by Thomas Henry and Jack Orman, July 1996, pp. 71-75 — lots of info on essential electronic drum design techniques
- "Build the ADV-Bass," by Thomas Henry and Jack Orman, November 1996, pp. 56-59 — the simplest electronic drum to build, great for beginners in drum synthesis

the clatter pitch control. Also, observe that some parts (C38, C39, C41, R8, and R57) mount directly behind the front panel, strung between various potentiometers or jacks.

Lastly, note that there is an extra ground pad (labeled GND) which is used to bring ground to the front panel. To avoid ground loops and the insidious hum they can cause,

Resources

As a special service to readers, a set of one NE570 and three 566 VCO chips is available for \$25.00 from Midwest Analog Products. This price includes shipping by first class mail anywhere in the US. Minnesota residents please add 6.5% sales tax. Readers from other countries please inquire first for exact shipping charges.

Order from: **Midwest Analog Products**
 P.O. Box 2101
 N. Mankato, MN 56003
 Email: contact@midwest-analog.com
 Web: www.midwest-analog.com

- "User's Guide to Special Audio Processing ICs," by Ray Marston, May 1997, pp. 55-59 — details on the inner workings of the NE570 compander chip used in Clangora
- "Add MIDI to Your Electronic Drums," by Thomas Henry, October 1997, pp. 62-67 — the title says it all
- "Secrets of Making Attractive Rack Panels," by Thomas Henry, December 1998, pp. 72-75 — the ins and outs of designing beautiful homebrew rack mount equipment
- "Build a Tunable Noise Generator," by Thomas Henry, November 1999, pp. 25-27 — explains how noise can modulate a VCO, as used in Clangora

ground should tie to the front panel at one point only. The remaining GND pad is employed, along with the +15V and -15V pads, to provide connection to your regulated bipolar power supply.

After you've double-checked all of your work, it's time to fire up Clangora and adjust the trimmer pots. Assuming you pass the smoke test with flying colors, patch a source of triggers into the open and closed jacks, and connect the audio output to an amplifier and speakers. Watch the volume control until you get used to what's emanating, just to avoid bruising either your equipment or your ears. While triggering the unit repeatedly, adjust the two trimmers (R66 and R67) to minimize any undesirable thumping in the VCAs. Next, tweak trimmers R64 and R65 to set the sweep range for the clatter and clank, respectively. You want to attain the largest sweep range possible, avoiding any dead spots where the VCOs might stall.

And that's it! Now comes the big (but fun) job ... learning the controls. Whatever you do, be patient. Like with any fine musical instrument, it is possible to create some angelic

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PARTS LIST

All resistors are 1/4 watt, 5% values.

R1 - R3	1K ✓
R4 - R7	1.5K ✓
R8	2.2K ✓
R9 - R11	4.7K ✓
R12, R13	5.6K ✓
R14 - R21	10K ✓
R22 - R25	10K linear taper
R26 - R28	10K audio taper
R29 - R34	22K ✓
R35 - R41	39K ✓ (used)
R42, R43	68K ✓
R44	82K ✓
R45 - R63	100K ✓
R64 - R67	100K trimmer taper
R68 - R71	100K linear taper
R72, R73	100K audio taper
R74	150K ✓

R75	220K ✓
R76	270K ✓
R77	330K ✓
R78	390K ✓
R79 - R82	470K ✓
R83 - R85	500K linear taper
R86, R87	3.3M ✓

All capacitors are 16V or better.

C1, C2	100pF disc
C3 - C7	0.001µF mylar
C8 - C11	0.0047µF mylar
C12 - C19	0.01µF disc
C20 - C23	0.01µF mylar
C24 - C26	0.047µF mylar
C27 - C30	0.1µF disc
C31 - C42	0.1µF mylar
C43 - C45	4.7µF electrolytic
C46 - C51	10µF electrolytic

Semiconductors

D1 - D8	IN194 or IN4148
D9 - D11	red LED
Q1 - Q4	2N3904 NPN
IC1 - IC3	1458 dual op-amp
IC4	4001 CMOS NOR gate
IC5	555 timer ✓
IC6	40106 CMOS Schmidt trigger
IC7 - IC9	566 VCO ✓
IC10	NE570 compander ✓

Other components

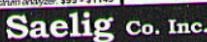
J1 - J7	1/4" phone jack, NO
J8, J9	1/4" phone jack, NC

Miscellaneous: printed circuit board, LED holders, IC sockets, front panel, knobs, wire, etc.

sounds and some extremely ugly ones. So you'll want to put in a fair amount of time experimenting to discover exactly what the effect is for each control and which settings work

well together. But if you give it the rehearsal time it deserves, you should come away mastering one of the most versatile electronic drum circuits ever. **NV**

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