by Thomas Henry

Build a Tunable Noise Generator

Electrical noise is most often considered an enemy.

In audio and radio circuits, for example, it can lead to an annoying background hiss or distorted reception. But, in fact, noise can be useful in a great number of applications. For example:

• A medical researcher might use it to study ways of reducing ringing in the ears, a condition known as tinnitus.

• An audio technician can use white noise to equalize a public address system (set the tonal balance) for a particular room.

• An electronic musician uses noise when synthesizing percussive instruments like snare drums.

In these and other situations, we need a reliable source of noise. Now by definition white noise — as it is often called — is a completely random mix of all frequencies, just as white light is a blend of all colors. On the other hand, pink noise is similar, but more emphasis is given to the frequencies within the audio band. It's possible to carry this even further and create other types of noise by emphasizing or shunning various frequencies. This is usually done by following a white noise source with an active filter whose cutoff frequency can be adjusted. The filter can quickly become quite complicated and be touchy to adjust.

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But here's a new approach to the problem. This article describes a tunable noise generator which, instead of using an active filter, employs FM (frequency modulation) to obtain a broad range of sounds. What comes out of it is noise, of course, but it's possible to emphasize certain bands of frequencies.

When sweeping it over its range, the effect is quite ethereal, a sort of "swooshing" not unlike the sound of wind whistling through forest trees. Let's investigate the general procedure first before turning to the circuit itself.

PRINCIPLE OF OPERATION

Figure 1 shows the block diagram of the tunable noise generator. First, white noise is created using standard techniques which then modulate the frequency of a VCO (voltage-controlled oscillator). The depth control is used to set the amount of modulation desired. A separate tuning control adjusts the center frequency of the VCO. The modulating white noise, then, causes the VCO to vary randomly from this center frequency. In this way, a certain tonality is imparted to the sound thus created; it's still noise, but it seems to be focused around a certain band of frequencies. By twisting the tuning control, it is possible to sweep the sound across the entire audio spectrum.

Incidentally, a VCO with a triangle wave output seems to work best here, giving a fairly smooth sound. Squarewaves, on the other hand, lead to a rather harsh and gritty effect. In any case, the output of the VCO is dropped across the volume control which lets you set the amplitude.

So we have arrived at a unique method for "tuning" the response of a noise generator without requiring the use of active filters. Let's check out a practical circuit which implements the block diagram of Figure 1.

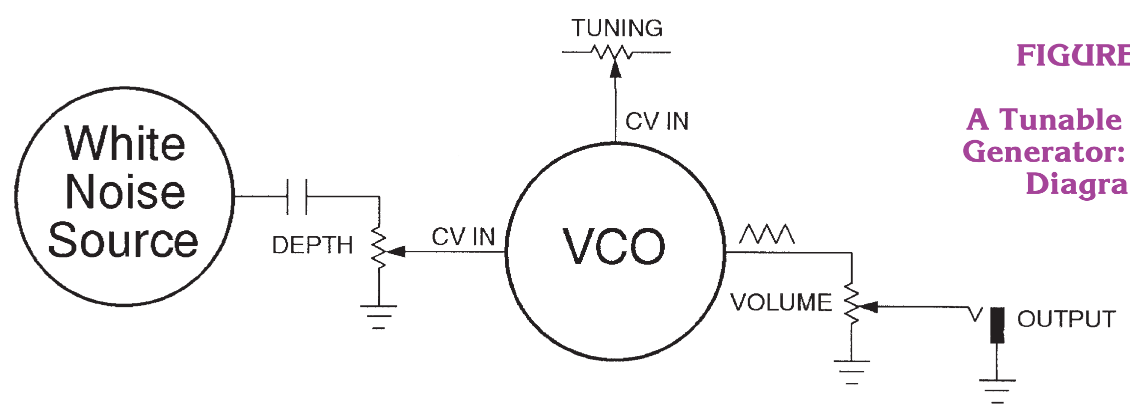

FIGURE 1

A Tunable Noise Generator: Block Diagram

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HOW IT WORKS

Refer to Figure 2 which shows the schematic for the tunable noise generator. Let's start out by analyzing the white noise source first, leaving the VCO portion for later. Notice the unusual arrangement of transistor Q1. The collector isn't used at all, which suggests that Q1 is being pressed into service as a diode. In fact, it's really behaving as a zener diode since the base-emitter junction has been deliberately reverse-biased. Observe that the emitter has been tied high through R18, while the base connects to the negative side of things. Thus, the transistor is straddling a full 30V (+15V and -15V) which is enough to overcome the base-emitter breakdown voltage. This forces it into avalanche mode and produces a really decent source of white noise at the emitter. R18 limits the current flow through the transistor, so that it doesn't fry in the process.

R18 also acts as a load resistor for the noise thus generated. Unfortunately, the signal is a trifle weak just now and needs to be boosted. So, we send it to a preamplifier configured around IC1a, AC coupling it in the process by means of capacitor C6. Notice that C6 is purposely kept fairly small so that the bass frequencies will be attenuated a tad. This helps prevent rumbles in the sub-sonic region.

R1 and R13 set the gain of op-amp IC1a to a factor of 101. But believe it or not, that's still not enough "oomph" to properly modulate the VCO yet to come. So we move on to yet another preamplifier, this time comprising IC1b, R4, and R14. Operating in inverting mode now, this op-amp will have a gain of 10. Put the two preamps together, and we have boosted the white noise by a factor of over 1,000. Now it's strong enough to do what we require of it!

The hefty noise available at pin 7 of IC1b may have accumulated an unwanted offset, so we AC couple it to the next stage via C8. The full strength signal is applied across potentiometer R9, which lets you manually adjust how deeply the noise will modulate the VCO.

And speaking of which, let's look into the VCO now. It was

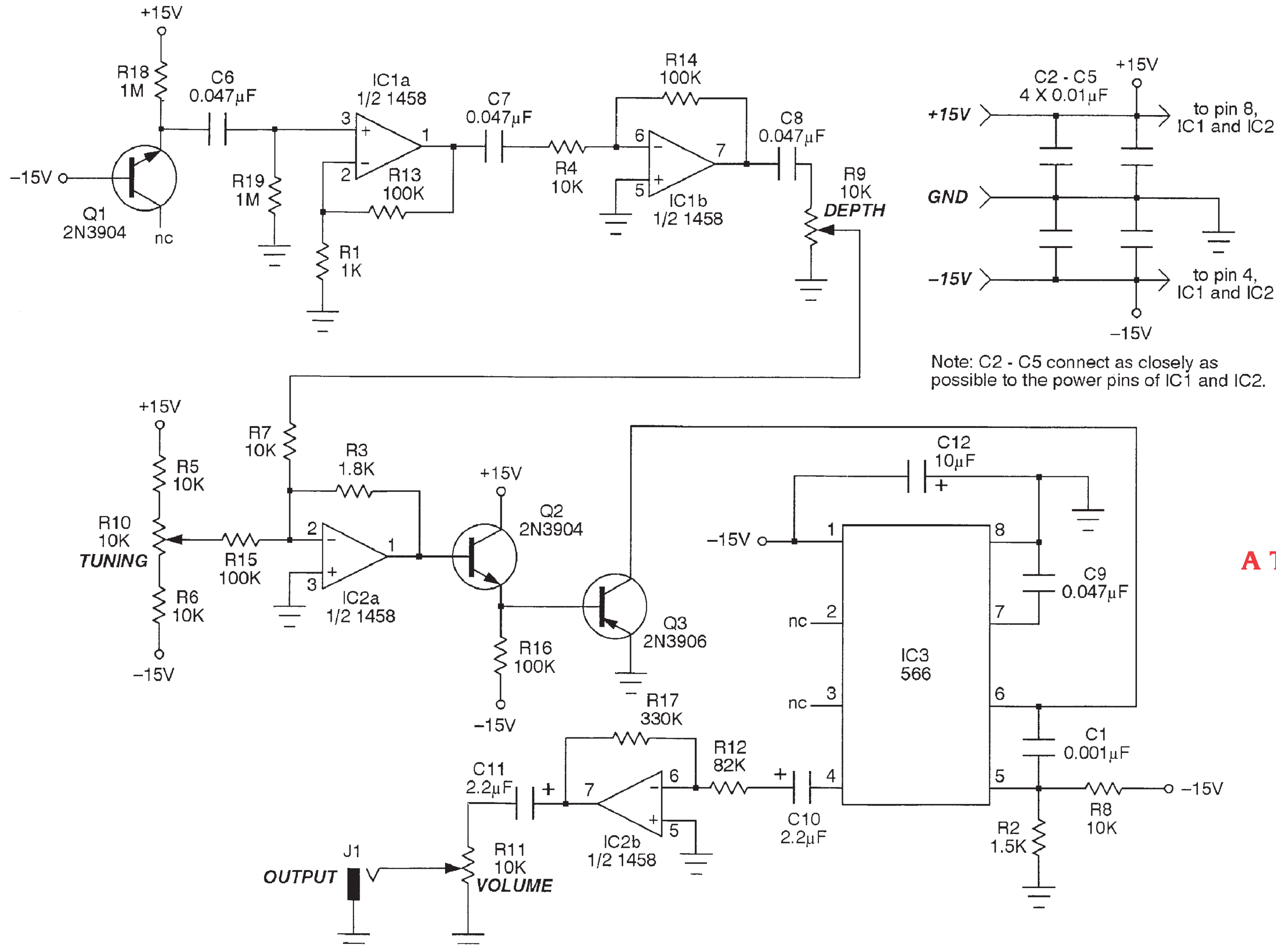

FIGURE 2

A Tunable Noise Generator: Schematic

designed with several important factors in mind; let's overview them before getting into the circuit details.

First, after much experimentation, it was determined that, for best results, the frequency sweep range should be at least 1000:1. Next, to make the device more suitable for audio and musical work, a 1V/octave exponential response seemed appropriate. (Each increment of 1V at the control input should cause the VCO to jump up an octave.)

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The last criterion may seem to be the hardest to overcome, since exponential VCO chips are a rarity nowadays. But here's the surprise: By pulling some clever circuit stunts, we can coerce the 566 VCO chip (which is both common and cheap) to do exactly what we require. Now, as it comes from the factory, this chip responds to a linear control voltage, which has an extremely limited sweep range of 10:1. However, with the addition of just a few garden variety components it is possible to trick the 566 into thinking it understands the exponential language. The approach taken hinges on two basic ideas:

- We can get better control over the 566 by ignoring the linear control voltage input, and throttling the current which charges and discharges the timing capacitor instead.
- The collector current of a bipolar transistor is exponentially related to the base-emitter voltage.

So, we'll whip up an exponential converter based upon the transistor characteristic mentioned above, and let that current directly govern the charge/discharge cycle of the timing capacitor.

That's the general idea. Now let's get back to specifics by examining Figure 2 in more detail. The first thing you'll notice is that the power supply connections to IC3 — the 566 — seem a little weird; -15V and ground (instead of the usual ground and +15V) connect to pins 1 and 8, respectively. Of course, from the 566's point of view, this makes no difference since there's still a +15V differential across pins 1 and 8. The reason we take this unusual tack will become clear in just a moment, so let's continue.

As mentioned above, the linear control voltage input at pin 5 is too seedy for our purposes, so we'll simply bias it at a fixed value and leave it there. The bias is determined by voltage divider R2 and R8. By the way, C1 is nothing more than a simple compensation cap which keeps the sensitive linear input from breaking into spurious oscillations.

Capacitor C9 sets the basic operating range of the VCO. On the other hand, the current fed into pin 6 sweeps the VCO's frequency up and down. And now we can see the reason for the somewhat exotic power supply arrangement.

The exponential converter — to be described next — is a current source and pin 6 of IC3 is a current sink. Voila — an exact match! (Had we employed the usual power supply arrangement, both the exponential converter and the 566 would have been current sources.)

Let's see how that magical exponential converter works. Recall that linear changes in the base-emitter voltage on Q3 will cause exponential changes in the collector current which feeds IC3. The base of Q3 needs to be driven by a low impedance source, so Q2 acts as a simple emitter follower. More importantly, the two transistors

All of the components are commonly available, and there's nothing particularly tricky about the construction.

tend to act in harmony to reduce VCO frequency variation caused by temperature changes. (The theory of this can get pretty complicated in a hurry, but the basic idea is that if the emitter saturation currents of the two transistors are reasonably close to each other, then temperature dependence is reduced.)

There are a couple more details to consider, then we'll have this exponential converter under control.

First, when Q2 and Q3 do their thing, the response from the VCO will be "backwards;" the smaller the input voltage, the higher the frequency. Moreover, the scaling factor of the converter isn't quite right. It can be proven via some rather tedious calculations that the VCO frequency will double for every 18mV decrease at the base of Q2. (Recall that we want a 1V/octave response, i.e., a doubling for every 1V increase.) Both of these problems are easily dispatched by IC2a.

First of all, notice that this has been set up as an inverting amplifier. That takes care of getting the sense of the control voltage correct; an increasing voltage at the input leads to an increasing frequency of the 566. Also, the ratio of R3 and R15 set the gain of IC2a at about 0.018. So, when the input changes by one volt, the output of the op-amp changes by 18mV, as required.

R15 is driven by the wiper of R10, the tuning potentiometer. The top and bottom ranges of this control have been limited appropriately by R5 and R6, respectively. With this pot you can sweep the VCO's basic frequency from about 20Hz to 20KHz in one fell swoop; there's lots of usable range here!

But here is the key to the whole circuit. Recall that the white noise generator output can be picked off the wiper of R9, the depth control. This signal feeds R7, which then sums into IC2a. Thus, the noise modulates the basic frequency of the VCO, completely at random. Potentiometer R9 lets you adjust how much modulation you want. Naturally, when set to zero, the circuit performs as a normal VCO.

And that brings us up to the output of the entire circuit. There are two waveforms available from the 566 chip, a squarewave (pin 3) and a trianglewave (pin 4). Feel free to use either waveform, but in general, the triangle output sounds quite a bit smoother. But note that pin 4 rides on a rather heavy DC bias which needs to be blocked, and the amplitude of the triangle there is only about 2.4Vp-p. Capacitor C10 AC couples the signal to op-amp IC2b, which then boosts it up to about 10Vp-p. The output is applied to volume control R11, which can tame the signal as desired before it finally appears at output jack J1.

BUILDING THE TUNABLE NOISE GENERATOR

Checking out the Parts List makes it clear that this would be an easy and inexpensive weekend project. All of the components are commonly available, and there's nothing particularly tricky about the construction. You can build it using just about any method, from breadboards to wire wrap to printed circuit boards. For best temperature stability, though, be sure to mount Q2 and Q3 so that they're touching each other. You might even want to epoxy them together. And be sure that the wiring around the two transistors is neat since some rather low currents are involved.

When using the tunable noise generator, be careful not to blow out either your loudspeakers or your ears! The output of this device is pretty hefty (up to a max of 10Vp-p). This higher value was selected so that the circuit would be compatible with analog synthesis equipment. On the other hand, if using the tunable noise generator with standard hi-fi gear, you'll want to turn volume control R11 down to give an output of around 2Vp-p.

Finally, if you're looking for some other uses for the tunable noise generator, be sure to check the Internet site mentioned in the Parts List. You'll find modifications and hints concerning this circuit there. **NV**

ACKNOWLEDGEMENTS
I wish to thank the following two authors whose writings provided key information used in the design of the VCO portion. First, the 566 power supply trick was suggested by John Simonton, in his article, "Potpourri and the Apple Connection," Polyphony, November 1977, pp. 28-31. Next, Terry Mikulic explained the operation of the exponential converter in his article, "Exponential Converters," Electronotes, Volume 5, Number 37, pp. 2-4.

PARTS LIST

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

R1	1K
R2	1.5K
R3	1.8K
R4 - R8	10K
R9, R10	10K linear potentiometer
R11	10K audio potentiometer
R12	82K
R13 - R16	100K
R17	330K
R18, R19	1M

All capacitors are 16V or better.

C1	0.001 mfd. mylar
C2-C5	0.01 mfd. disc
C6-C9	0.047 mfd. mylar
C10, C11	2.2 mfd. electrolytic
C12	10 mfd. electrolytic

Semiconductors

Q1, Q2	2N3904 NPN transistor
Q3	2N3906 PNP transistor
IC1, IC2	1458 dual op-amp
IC3	566 VCO chip

Other components

J1	1/4" phone jack

RESOURCE

Modifications, hints, and tips concerning the Tunable Noise Generator are available free of charge on the Web page of Midwest Analog Products.
http://mall.lakes.com/~map
E-Mail: map@prairie.lakes.com