

mission medium. Thus, we might easily end up with HDTV transmission bandwidths that are ridiculously lower than the present NTSC standards.

Most newer HDTV displays will probably be able to accept older NTSC, PAL, RGB, or SECAM program inputs, and even spruce them up a tad before displaying them. The key question is whether an older NTSC television set that inadvertently got plugged into some HDTV program source has to be able to display something viewable. The present ruling makes about as much sense as requiring that all CD-ROM disks be able to output low-fidelity audio when played with a cactus needle on a 78-RPM turntable.

As per usual, I do welcome your comments on this. In fact, let's have us another contest. Write me with your thoughts on HDTV. There will be all the usual *Incredible Secret Money Machine* books for the best dozen or two entries, with an all expense paid (FOB Thatcher, AZ) *tinaja quest* for two for the best entry of all. Naturally, you do not have to agree with me, but the more thought-out and the more coherent your written response, the better will be your odds of winning.

Do send your entries directly to me per the *Need Help?* box, rather than over to the **Radio-Electronics** editorial offices. And, hey, no fair sending the "right on" responses to me and the "up yours" ones over to the letters column.

### Pseudo-random sequences

I have long been fascinated with both random and pseudorandom numbers and their generation.

Truly random numbers are quite difficult to generate, and it is very easy to introduce all sorts of subtle bias into them. One fact that many hardware hackers refuse to accept is that virtually any and all attempts at making something more random will nearly always have the exact opposite of the intended effect.

A *pseudorandom* sequence is some long string of numbers that eventually will exactly repeat, but any short portion of which will appear totally random, and apparently obey all the rules of random

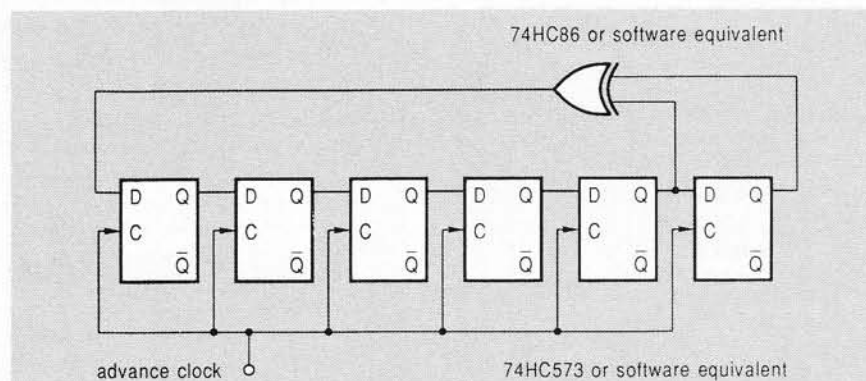


FIG. 1—A SIX-STAGE PSEUDORANDOM sequence generator produces 63 six-bit binary numbers in an apparently random, yet exactly repeating order.

number distributions. The concept of "noise that repeats" is especially handy for industrial testing, for military radars, for security systems, and for such things as a re-deal of the same card hand in a computer game or simulation.

To generate a new pseudorandom sequence, you can use, of all things, a *pseudorandom sequence generator*. Golly gee, Mr. Science.

To do that, you take a plain old hardware or software shift register. You then will choose a few of the outputs and XOR (exclusive-OR) them together and use the resulting one or zero as an input for the next clocking cycle.

One of two things is likely to happen. If you pick the wrong feedback combinations, then the shift register will shortly hang in its all-ones or all-zeros state. But with just the right combination, the shift register will become some sort of a counter of some length, that goes through a series of count values in a repeating and predictable order.

The trick is to pick out the longest possible sequence length for any shift register by finding just the right "magic" feedback combinations.

That is called a *maximal length sequence* and it's always *one less than* the total possible number of states in the register. Shorter groupings within one of those maximal length sequences will appear to be random and obey most of the properties of real random numbers.

Figure 1 shows you a six-stage pseudorandom generator that will generate a sequence that is 63 counts long. You might like to list

all of the states to prove that, sure enough, short samples do appear random, even though the whole sequence does repeat once each 63 clocks. I used that back in my *Psyctone* project, which seems like eons ago, in the "golden age" of **Popular Electronics**.

You can create up to four related maximal-length sequences, a "forward" one and its complement, and a "backward" one and its complement. There is one big gotcha: You must never start with the "all

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STAGES	LENGTH	FEEDBACK
2	3	1, 2
3	7	2, 3
4	15	3, 4
5	31	3, 5
6	63	5, 6
7	127	6, 7
8	255	4, 5, 6, 8
9	511	5, 9
10	1023	7, 10
11	2047	9, 11
12	4095	6, 8, 11, 12
13	8191	9, 11, 12, 13
14	16,383	4, 8, 13, 14
15	32,767	14, 15
16	65,535	4, 13, 15, 16
17	131,071	14, 17
18	262,143	11, 18
19	524,287	14, 17, 18, 19
20	1,048,575	17, 20
21	2,097,151	19, 21
22	4,194,303	21, 22
23	8,388,607	18, 23
24	16,777,215	17, 22, 23, 24
25	33,554,431	22, 25
26	67,108,863	20, 24, 25, 26
27	134,217,727	22, 25, 26, 27
28	268,435,455	25, 28
29	536,870,911	27, 29
30	1,073,741,823	7, 28, 29, 30
31	2,147,483,647	28, 31

FIG. 2—HERE ARE THE "MAGIC" FEEDBACK connections for many maximal length pseudorandom sequences. If two feedback numbers are shown, you XOR (exclusive-or) them together. If four numbers are shown, you XOR by pairs and then XOR the two intermediate results. Either hardware or software may be used.

ure 2 lists the magic feedback combinations needed for various maximal-length sequences. A very few of the longer ones aren't "quite" maximal, but they are the best that anyone has ever found so far.

A very interesting pseudorandom generator for computer use appears in Fig. 3. This is a 31-stage register, giving you a sequence length of 2,147,483,647 before it repeats. Yet, it is able to deliver an apparently random one or zero in 40 microseconds or less with most personal computers.

The all time whiz-bang expert on random or pseudorandom anything is Donald Knuth in his *Art of Computer Programming* volumes. They are available at any large technical library. I've also gotten into that rather extensively in my *Apple Assembly Cookbook*,

where you will find several ways around the fatal flaws in that Applesoth random-number generator, along with lots of useful ways to generate and test random and pseudorandom numbers of any size.

### A white noise source

As a quick and dirty example of a 31-stage pseudorandom generator, Fig. 4 shows you a short machine-language routine that makes an Apple IIc, IIe, or IIgs sound as if it is frying itself in its own grease. I'll leave it up to you to dream up some of the more fiendish and unusual uses for this short code module.

On every binary one, the speaker cone gets whapped, while it stays where it is on a zero. As shown, the code is very slightly pinkish, rather than a pure white

zeros" state or your generator will hang, permanently outputting zeros.

For many uses, you'll want to use much longer sequences. Fig-

noise. I'll let you add the few extra bytes needed to equalize the timing so each loop takes exactly the same time, regardless of when the cone gets moved.

You can use similar code to explore other pseudorandom lengths. As the lengths get shorter, you will first note some structure. For even shorter lengths, actual tonal color will result.

And here's something not quite related that you might like to play with: If you take any old 30-bit digital word and whop the speaker on the ones and not whop it on the zeros, different *timbre*, or tonal values will result depending on the strengths of the harmonics you are listening to.

For instance, getting a very strong fundamental and no low harmonics should result in a flute-like sine wave, while any waveform with a strong third, fourth, and fifth, but a weak first and second should give a major chord, *although you are only pushing a*

*speaker cone all the way in or out.*

Thus, you can easily generate a pure tone, as well as two or three apparent notes at once by using that simple technique.

Now, it is easy to pick words at random and listen to the results, but how do you *purposely* design your selected word for the desirable harmonic structure?

*Fourier series anyone?*

### Resources for electronic music

As with any other field, the bookstores, tech journals, and popular magazines that service electronic music interests are your starting place. It also helps if you can carry a tune in a bucket.

The *Electronic Music Resources* sidebar lists some of the more important and more interesting places to go to get started.

Probably the best collection of the electronic music, synthesizer, MIDI, audio, and video production books in the world is available through the *Mix Bookstore*. Their

### NAMES AND NUMBERS

#### Allied Electronics

PO Box 1544  
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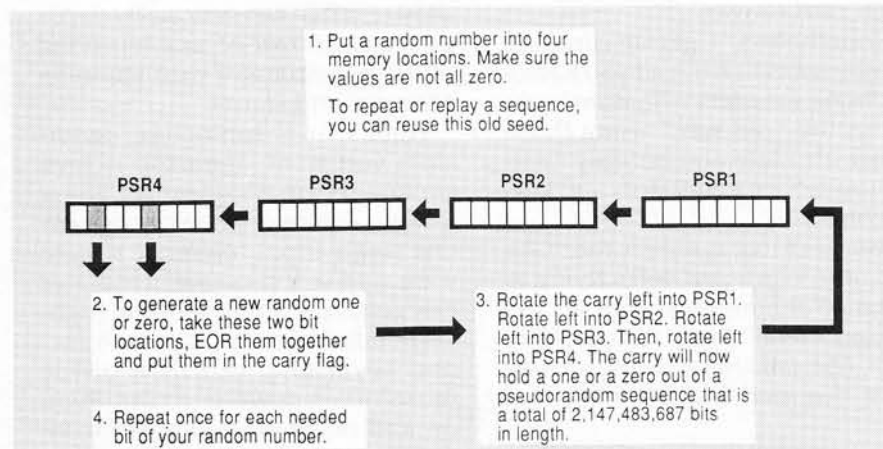


FIG. 3—A THIRTY-ONE STAGE PSEUDORANDOM sequence generator done in software produces a "random" string of 2,147,483,687 ones or zeros before it will start to exactly repeat. Typical execution time is under 40 microseconds.

(1) On an Apple II+, IIc, IIe, or IIfx, get into **BASIC.SYSTEM** and do a **CALL -151** to get into the monitor.

(2) Then, enter the following code:

```
0300: 4C 07 03 27 0C A1 C9 AD <cr>
0308: 06 03 0A 0A 0A 4D 06 03 <cr>
0310: 0A 0A 90 03 2C 30 C0 2E <cr>
0318: 03 03 2E 04 03 2E 05 03 <cr>
0320: 2E 06 03 4C 07 03 11 11 <cr>
```

(3) Finally, do a **BSAVE KFC.VIRUS, A\$0300, L\$28, D2**

(4) To test, use, or abuse your code, do a **BRUN KFC.VIRUS**

FIG. 4—THIS WHITE-NOISE GENERATOR makes an Apple computer sound as if it is frying itself in its own grease. A 31-stage pseudorandom generator is used. Except for stress-induced medical effects on the system owner, the code is more or less harmless.

free catalog is an absolute must.

Of all the publications that are listed though, I think the *Journal of the Audio Engineering Society* has the best long-term track record on both the tech fundamen-