HARDWARE HACKER

A 1-Hz square-wave source, faking plated-through pc holes, low-power voltage regulators, and more

By Don Lancaster

Uh, is anyone still around after last month's April-Fool tease? Marcia is, well . . . Marcia. That aside, let's start off on this month's bunch of new goodies . . . .

I need a low power 1-Hz oscillator.

Low power is easy; its micropower that gets tricky. One obvious way to get a 1-Hz oscillator is to take a $4 stick-on LED clock and grab the colon output, stepping it up to a suitable voltage.

Chances are you need something fancier, or less klutzy, possibly with multiple outputs. Figure 1 shows the "stock" low-power way of getting one-pulse-per-second and related outputs. You start with a 16.384-kHz crystal, available from *Statek* for under $5, and use the built-in oscillator of a 74HC4060 oscillator/divider, a $1.20 part. Out comes a 1-Hz square wave, along with higher binary multiples. Not bad for five parts.

Total supply current is around 5 mA at 5 volts. Which doesn't sound like a lot, until you try to get this current out of a 9-volt battery for three months or more.

Let's see. A 9 volt battery is roughly a 0.25-ampere-hour device. So 5 mA of current drain will last around 250/5 = 50 hours, or a tad over two days, which may be okay in some applications. However, a client of mine needed a system he could literally bury for six months. Every 15 minutes, the system has to "wake up," record a single digital value, and then go back to sleep. It had to be small and powered by a single 9-volt battery. Obviously, five mils just won't hack it.

Let's review the rules for low-power operations. You should use CMOS devices, of course. Only it turns out that older 4000 series CMOS draws less dynamic current than does the newer 74HC stuff. You should run at the lowest possible supply voltage, and all unused inputs should go solidly to ground or to the supply's V+ bus. All real inputs should be fast-rise square waves. Above all, no input should ever be allowed away from either supply rail except for a very brief rail-to-rail transition.

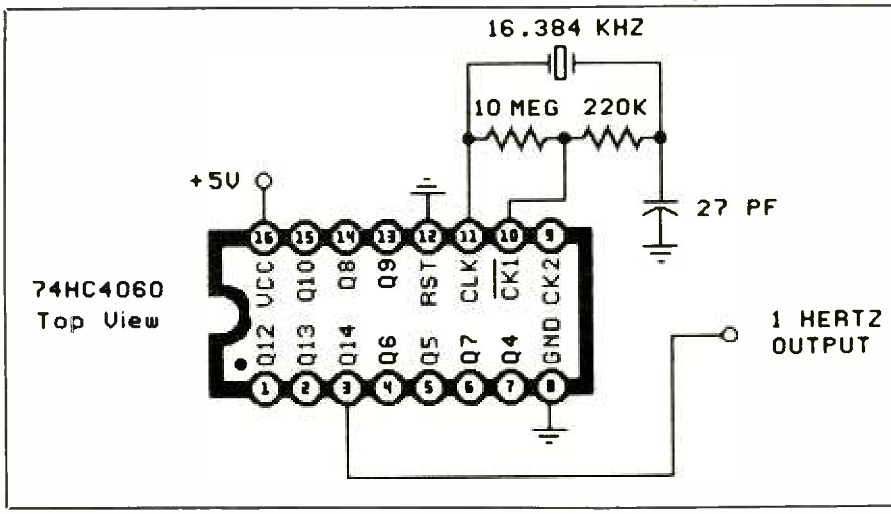


Fig. 1. Here is a "standard" way of getting a 1-Hz square wave. Current drain of 5 milliamperes however, is excessive for very-low-power, long-term use.

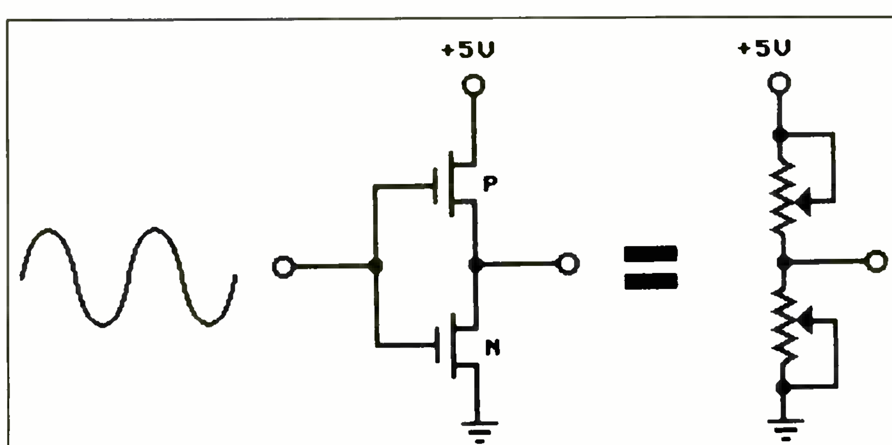
Where does the Fig. 1 circuit fall short? The oscillator uses an inverter that is purposely biased into its linear region, half of the way up to the supply voltage. As Fig. 2 shows, this is bad news.

If a CMOS inverter has its input connected to ground, the top p-channel field-effect transistor turns on, and bottom n-channel field-effect transistor turns off. The output goes positive, since there is a very small resistance to the positive supply and an essentially open circuit to ground. Most importantly, there is no conductive path from supply to ground, so the inverter draws essentially zero power when it is sitting in its low state.

Make the input high, and the opposite happens. The n-channel FET at the bottom turns on and the p-channel FET at the top turns off—a low output, with a low-impedance path to ground. Again, there is no positive-to-ground path, and essentially zero power is consumed.

This "no internal current path" is ty-

Fig. 2. When a CMOS circuit is not driven rail-to-rail, a resistive path appears from supply to ground, excessively raising the operating current.



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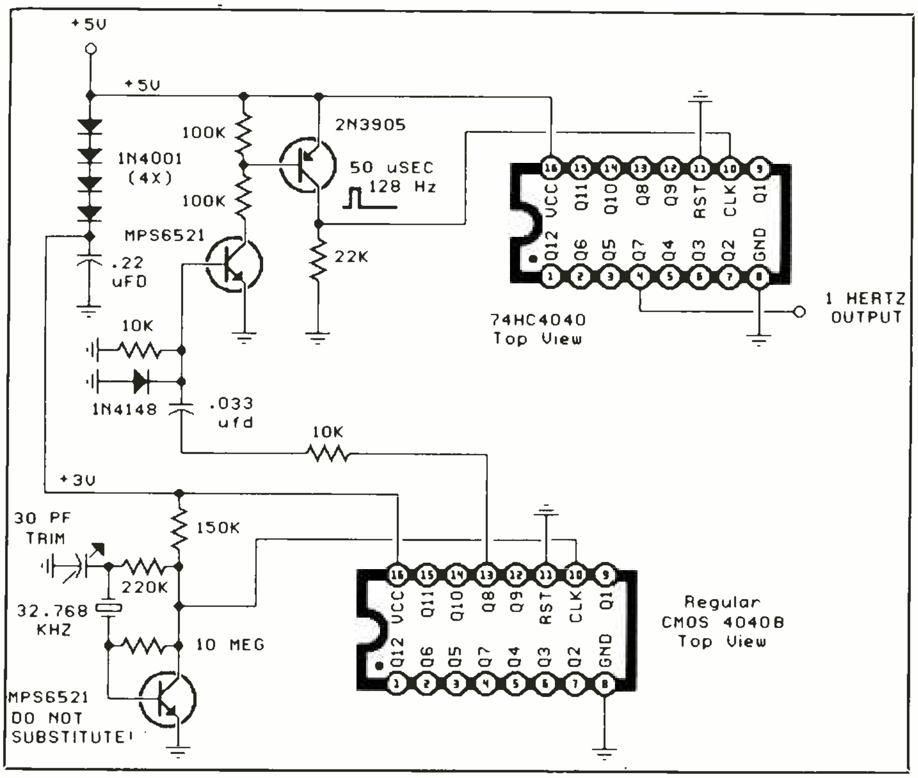

Fig. 3. Improved circuit needs only 15 microamperes of supply power. It is trimmable, offers better stability, and uses a less expensive and easy-to-obtain crystal.

pical of CMOS operation. The only time you need any supply power is when you *change* the output, charging or discharging unavoidable stray capacitance. The more often you change an output, the greater the supply current. Thus, the operating currents of most CMOS circuits are proportional to frequency.

The bad scene takes place when you bias the input halfway up. Both n- and p-channel FETs conduct, and you get a fairly heavy current path directly from the supply to ground. In the Fig. 1 circuit, the oscillator's inverter is intentionally biased this way. Virtually all of the 5 mils gets burned up in this first stage.

Even if you do not bias this stage halfway up, if you input a sine wave or even a slow-rise square wave, current conducts directly from supply to ground during the times the input is not sitting on a rail. The slower the rise time, or the smaller the signal, the worse things become.

CMOS Schmitt triggers won't help much in solving the problem. They also draw excessive supply current when their inputs are not sitting on a supply or ground rail. Schmitt triggers do convert a slowly changing input into a fast-rise square-wave output, but this route will get your currents down only into the hundreds of microamperers.

Figure 3 shows a circuit I came up with. Total supply current is under 15 microamperes, giving over a 300:1 improvement in battery life. the secret is to run the fast part of the circuit at 3 volts, the minimum supply for 4000 series CMOS. At this supply voltage, even when the n- and p-channel FET transistors are on simultaneously, they cannot draw very much current, since they are only weakly turned on.

You can get 3 volts with four series diodes as shown. Otherwise, use a low-power regulator for extra stability. Needless to say, a resistive divider is a no-no.

Action starts with a bipolar oscillator, using a special Motorola transistor that has exceptionally high gain at very low collector currents. In general, bipolar oscillators have more stability and higher gain than CMOS oscillators. Also, use a stock 32.768-kHz clock crystal. These are cheaper and easier to get, and are more robust and offering much higher output.

The oscillator directly drives a regular 4040B CMOS divider. Thanks to the low supply voltage and the large input swing, the current is very low. You can trim the oscillator's frequency for exact timing.

You divide the signal down as far as you can. Unfortunately, you cannot reach 1 Hz this way. An 8-Hz square wave is the lowest you can get with one chip.

In the intended application, I needed outputs from 128 Hz on down. I also needed operation at +5 volts. Fortunately, even 128 Hz is so slow that it really doesn't matter what you do at that rate. To prove it, I put in a bipolar pulse shaper to translate the 128 Hz up to a 5-volt pulse. The pulse is made some 50 microseconds wide, and this two-transistor translator and all its resistors draws something like 0.75 microampere. Why so low? Because the shaper is totally off during most of the time.

The translated 128-Hz signal then drives a 74HC4040 binary divider to give the needed 1-Hz output. You could use a plain old 4040 here just as well.

The result: A 5-volt oscillator/divider that runs at 15 microamperes total supply power. By hand picking parts, you can even get down under 5 microamps total.

What is wrong with it? Though still cheap enough, there are too many parts, and some slight instability is introduced by the voltage dropping diodes. You could probably eliminate the translating transistors by using the hard-to-find 74HCT4040 instead, along with a single resistor and capacitor. Note that you must keep the input to the 74HCT at ground most of the time, or it will gobble up hundreds of microamperes worth of supply current.

Show us the best improved circuit you can come up with that outputs a 128-Hz

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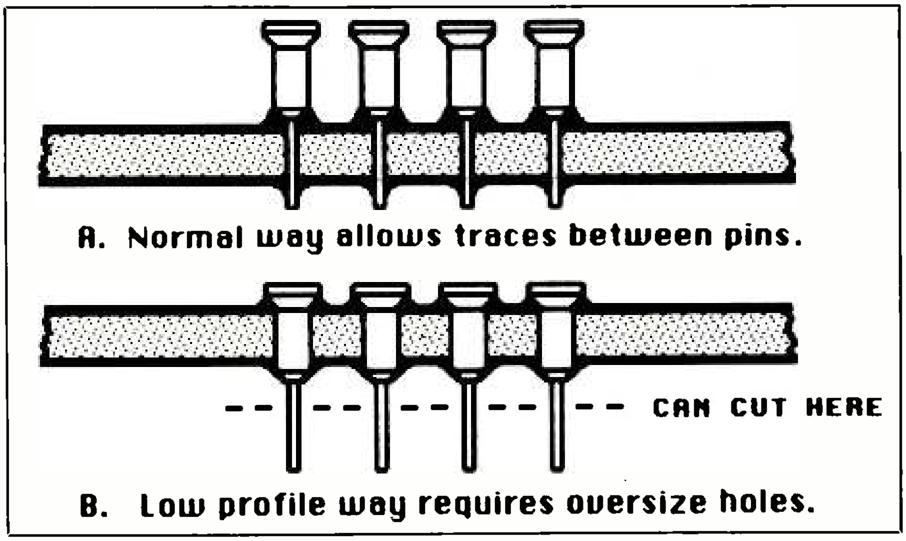

Fig. 4. Plated-through circuit boards can be faked by using pins from machined-contact DIP sockets. This approach is far simpler and cheaper for prototyping.

and lower square wave at 5 volts with 10 microamperes or less of total current.

Have fun.

How can I fake pc-board plate-through holes?

Making single-sided printed-circuit boards is no big deal. Most people can handle this one on their own or in a school or club lab lashup. Going double sided is not that much more complicated. All you have to do is repeat the single-sided process twice, being very careful to register the two sides to each other, and to protect the back side. Plated-through holes is the sticky problem.

Fortunately, prices are dropping on commercial prototype plated-through boards. But there is still the hassle of onesie-twosie orders not getting the attention they deserve.

The trick for your first prototype boards is to fake plated-through holes. Use a plain hole and put something through it that you can solder to the traces on both sides of the board. Figure 4 shows two good methods.

You can get machined-contact pins from the same sources that sell machined-contact pin sockets. Just do a double-sided board without plate-through, drill the holes, and push these pins through the board. Then solder the pins to both top and bottom traces.

In the normal way, you use small holes so that only the tail of the socket fits through. Solve the hassle of soldering under sockets simply by not using sockets. Use the pins only, and every side of every pin is then reasonably available. If you are *very* careful about your soldering, you can even have traces running between pins.

With the low-profile way, you use larger holes that hold the body of the socket. The tops of the socket pins are more nearly flush with the top of the pc board, and you end up with a lower profile and a neater appearance—except that you must be very careful about drilling and keep in mind that traces between pins are not permitted.

One source of continuous socket pins that are cheaper than most is *Mark Eyelet*. *OK Machine* also has solid pins that can be used to do the same thing, except they are fairly expensive and cannot be used as sockets. OK Machine also has a convient inserting tool.

What is in Enhance II?

By the time you read this, my latest book *Enhancing Your Apple II, Volume II* should finally (!) be in print. Check *B. Dalton's*, other bookstores, or your local computer dealer. Stock number is SAMS #21425. It can also be ordered directly simply by dialing the 1-(800)-428-SAMS, the Sams order hotline.

It's chock full of goodies for Apple II/II+/IIe/IIc users. There are enhancements on microjustifying and proportional spacing word processors, an absolute reset for the IIe or IIc, a *vaporlock* exact field synchronization scheme that requires no hardware mods or software royalties, more on the tearing method, and a thorough and detailed disassembly script and source code capturing procedure for *Applewriter IIe*. There are even an escape map and playing hints for *Castle Wolfenstein* and the usual response cards, reader helpline, companion diskettes and update service.

The vaporlock is particularly neat, since it lets you mix and match text, HIRES, and LORES in any combination anywhere on the screen, besides allowing for flawless, glitch-free animation. Locking time is extremely fast, compared to older versions.

Is there a micropower voltage regulator?

You bet! The *Intersil* gang has long advertised and cataloged an absolute jewel called the ICL7663. Trouble is that nobody stocks it and dealers have been less than enthuastic about custom ordering it.

A second source, *Maxim*, now is producing the part in volume. This one is readily available, at a cost of around \$3.60 in onsies. *Bell* is one distributor.

Modern Electronics advertisers please note: This one is a real winner, so PLEASE offer it.

The basic circuit for using this device is shown in Fig. 5. The regulator accepts up to 16 volts in and can output almost any voltage down to 1.3 volts, set by the divider between the output and the SET pin. The resistor values shown are good for 5 volts out. Maxim's "-A" version has tighter specs, so you normally do not need to trim the exact output voltage.

Supply current is around 5 microamperes total, *including* the output divider. Yes, that's *micro*amps, not milliamps.

This device is ideal for the oscillator/divider discussed earlier. The input and

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output capacitors, required for stability, should have short leads.

Figure 6 shows some added bells and whistles. There is an automatic current limiter that senses maximum load current. Maximum output current is around 25 milliamperes with the Fig. 5 circuit. Adding the pass transistor in Fig. 6 ups this to as high as 1 ampere. The part number and size of the pass transistor depends on output load current and duty cycle, but almost any old medium-power, high-gain npn transistor should hack it.

The formula for the current-limiting resistor is that 0.7 volt shuts down. Thus a 0.7-ohm resistor senses one ampere, while a 27-ohm resistor limits to 25 mils or so. Ohm's law and all that.

The formula for the divider says to attenuate the output until it is 1.3 volts and then feed it back into the regulator, where it can be compared against the internal 1.3-volt precision reference.

You can turn the output on and off with the gating pin 5. A low here turns the output on and a high turns if off. Input gating current is negligible.

For extremely long duty cycles on very small batteries, it may be better to gate the supply with a series pnp transistor or p-channel FET. This transistor is not needed if your application can get by with a continuous drain of microamps.

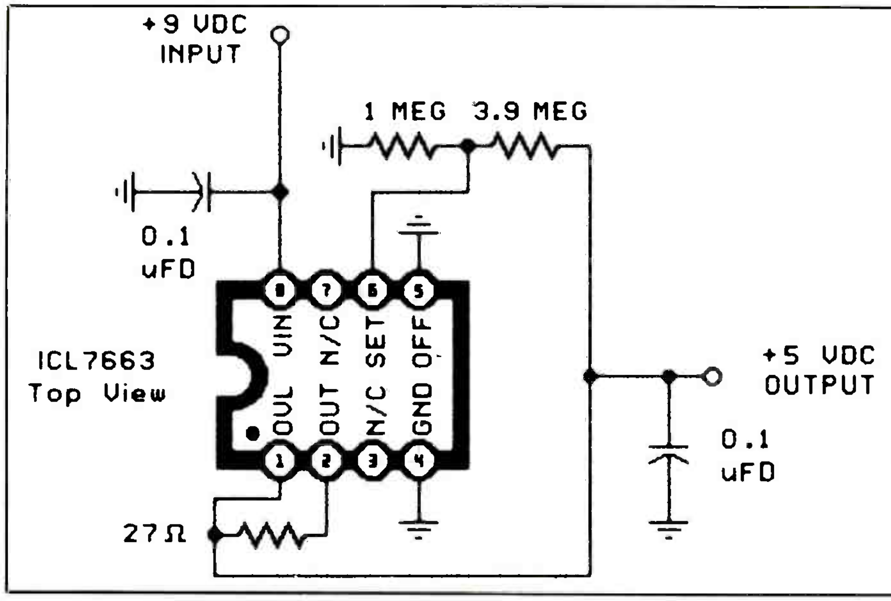


Fig. 5. This micro-power regulator circuit draws only 5 microamperes of standby power. In operation, it can deliver up to 50 milliamperes to the output load.

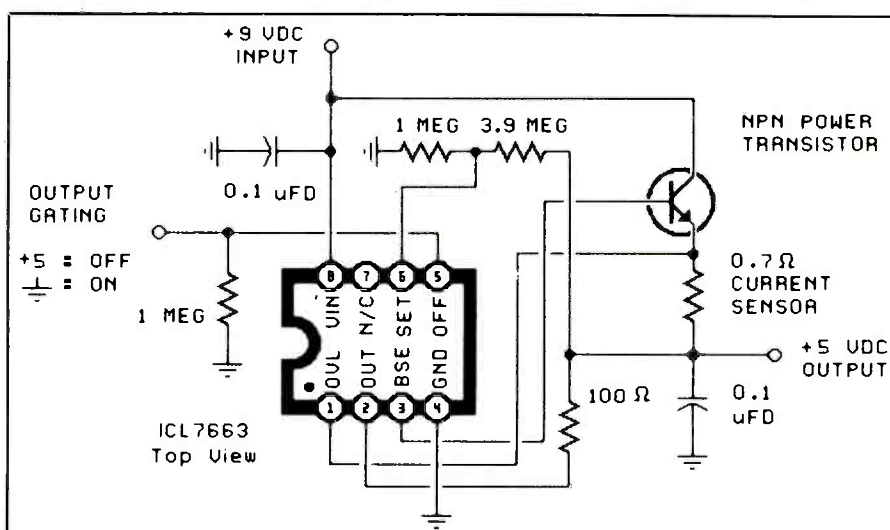
What is the word on ProDOS Applewriter?

There is a brand new version of *Applewriter* that runs under the ProDOS operating system and has bunches of new features. These include faster operation, better compatibility with other ProDos programs, easy hard-disk access, a built-in send and receive modem, settable screen margins for "what you see is what you get," spreadsheet editing to 240 columns, an optional page/position display, and many other improvements and performance upgrades. Best of all, the new version is unlocked, unprotected, and freely copyable for any number of backups. Even the source code is capturable.

What's wrong with it? Very little. A few parallel printer cards will not work properly on first try, notably the *Grappler* and the *Pkaso*. But I have a free patch that cures this. The NULL patch is no longer needed, since a [_] can be substituted. The "shortline" problem remains, but I have another free repair patch to overcome it.

Many people grossly and utterly underestimate Applewriter. Give it a chance, and once you really get into it, there is virtually nothing it cannot do in a fast and friendly manner. Its greatest abilities lie in its being totally program-

Fig. 6. You can add an external power transistor to boost output to 1 ampere.



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Names and Numbers

Apple Computer
20525 Mariani Ave.
Cupertino, CA 95014
(408) 996-1010

Applewriter Upgrade
Box 306
Hale Moon Bay, CA 94019
(408) 996-1010

Bell Industries
1705 West 4 St.
Tempe, AZ 85281
(602) 267-7774

Intersil
10710 N. Tantau Ave.
Cupertino, CA 95014
(408) 996-5000

Mark Eyelet & Stamping
169 Wakelee Rd.
Wolcott, CT 06716
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Phoenix, AZ 85018
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OK Industries
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Bronx, NY 10475
(212) 994-6600

Howard W. Sams & Co.
4300 West 62 St.
Indianapolis, IN 46206
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Statek
512 N. Main St.
Orange, CA 92668
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Box 809
Thatcher, AZ 85552
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mable through a companion programming language called WPL. Thus, word processing tasks can easily be customized or automated in any manner you like.

Cost of the latest ProDOS version is $150 from your local Apple dealer. But, there is a $50 upgrade service if you send in any older Applewriter first factory disk and a manual cover to *Applewriter Upgrade* to obtain it.

I've even been able to add full micro-justifying and proportional-spacing, author's keyword indexing, multiple columns, HIRES dumps, and unique self-prompting glossaries to it, along with code extensions and many other goodies.

I have some free *Applewriter* patches available specifically for you. Just ask. I also have my own $59.50 *sixteen* diskette-side toolkit that really puts a final polish on Applewriter. You can order this directly from *Synergetics.*

Until next time, keep those cards and letters coming! **ME**

Need Help?

Phone or write your hardware hacker questions and comments directly to:

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