Using the HP Z3801A GPS Frequency Standard

Learn how to apply surplus GPS receivers for weak-signal work at VHF and higher frequencies.

By Bill Jones, K8CU

The Hewlett Packard Z3801A is a GPS-based frequency standard that tracks global-positioning satellites to get accurate timing data to adjust the long-term frequency of an internal oven oscillator. It was originally used for synchronizing CDMA cellular land network wireless base stations. It provides highly accurate timing. If a satellite signal is lost, the receiver automatically switches to holdover mode, which ensures system synchronization for up to 24 hours with reduced accuracy. You get the best of both worlds: crystal-oven oscillator short-term stability, and GPS long-term stability.

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This type of frequency standard is roughly comparable to a rubidium standard without the maintenance issues of the rubidium lamp. The frequency accuracy is several parts per billion. This is an exceptional piece of test equipment for a home workshop and ham station. These units have a Hewlett-Packard double-oven oscillator, the HP 10811D/E, with one-part-per-billion stability per day. The frequency output of this GPS receiver is 10 MHz. This is a necessary component in an Amateur Radio station equipped for weak-signal detection at VHF frequencies and above, such as low-power EME work. If you aren't listening on *exactly* the right frequency, you can't pull a weak signal from below the noise level. The 10-MHz output drives an external frequency synthesizer that generates the radio's operating frequency.

This frequency standard is also useful as a home-workshop reference for test-equipment maintenance. I use it to drive a Tektronix frequency multiplier that makes handy marker signals up to 500 MHz.

These GPS receivers are surplus equipment. I'm not aware of the technology change that has placed them into this category. It appears that many cellular-telephone sites have used GPS receivers, judging from the outside GPS antennas visible on the cellular buildings. Look for these antennas. They look like three-inch-tall cone shaped white mushrooms that are mounted on the building roof and not on the cell tower. Nearly every cellular site that I have seen has one of these antennas. This implies that many of these receivers have been made.

GPS frequency standards are expensive if purchased new. *QST* has a remarkable article by Brooks Shera, W5OJM, about making your own GPS standard using a surplus commercial oven oscillator, Motorola GPS boards and a custom-designed embedded PIC controller.[1] I first considered building one of these, but I was able to purchase a ready-made HP GPS standard at a cost comparable to the homemade version.

The HP receiver is a basic OEM unit and has only a simple front panel (see Fig 1). Detailed control is provided via a rear-panel RS-422 serial-control port. I built an RS-422/EIA232 converter into the DB25 connector as shown in Fig 2. An external power supply (Fig 3) and external outside GPS antenna (Fig 4) are also required. My unit needed 48 V dc. This unit runs 24 hours a day, usually unattended.

The HP Z3801A has these rear-panel connectors:

- One 25-pin female DB25 connector. This connector provides two 1-pps timed outputs, two 10-MHz frequency outputs and an RS-422 serial-interface port.
- A 10-MHz output with a BNC connector.
- A remote-antenna N connector.
- A power input connector.[2]

HP supplies a program called *SatStat* that serves as a front panel and control interface for the receiver. I leave the serial cables connected to my PC and check on the receiver sometimes. With my particular antenna mounting method, the receiver always reports a minimum of four to six separate satellites as being actively tracked. Fig 5 is a screen capture of *Satstat* that shows typical operation of the receiver.

[1]Notes appear on page 51.

Common Questions

Q: Where can I buy one of these GPS receivers?

A: The surplus receivers are available on E-bay. That's where mine came from. I looked recently, and prices vary from $200 to $300. They are also available from other sources. Just do an Internet search on the word Z3801A.

Q: What antenna do I need to make this receiver work?

A: The Motorola antenna (ANT62301A/B) of the era when the Z3801A was built included a preamplifier with 24-dB gain, a noise figure of around 2.5 dB and expected 6-10 dB of cable loss. If you can get the original Motorola antenna, use it. The currently available Motorola Antenna97 will probably work as an alternative.[3] Make sure the antenna you use has a preamplifier that will run from the +5-V source the Z3801A provides on the antenna coax center conductor. One site on the Internet claims a homemade helix antenna with no preamplifier will work. Save your time—it doesn't. Other designs that give a desirable omnidirectional pattern use patch antennas, but these have no preamplifier. An amplified exterior mobile-GPS antenna mounted in the clear with a good view of the sky (preferably in all directions, to the horizon) will give you the best results.

I mounted an external Magellan GPS mobile antenna (with an internal preamplifier) on a PVC pipe mount that clamps to a roof stack vent on my home (Fig 4). I used a six-inch square aluminum plate as a ground plane to simulate the vehicle's roof. I spliced a length of RG-58 coax to the smaller cable on the mobile antenna to give me enough length to bring the coax into the workshop. Cable length and coax attenuation aren't very critical. The GPS receiver system expects about 10 dB of loss in the cable. The L1 frequency band used is around 1.5 GHz, so take care if you are using "lossy" cable or a very long cable length. Try to keep the cable loss between 6 and 10 dB. I used 20-feet of RG-58 with no problems.[4]

Q: I just got my unit. My receiver appears physically okay, it powers up correctly, the antenna is probably good and is connected, but the Z3801A never reports a GPS Lock on the front panel LED, even after hours of power on time. What's wrong?

A: The Z3801A receiver thinks it is still at the location where power was last turned off. This may have been thousands of miles away. You must initiate a Survey command to the receiver. This instructs the Z3801A to determine its present location. Once this is done, the unit will probably function properly. The Survey command is issued using the *Satstat* software. (Refer to the user manual for details.) Hint: After you first hook up your receiver, the GPS location re-

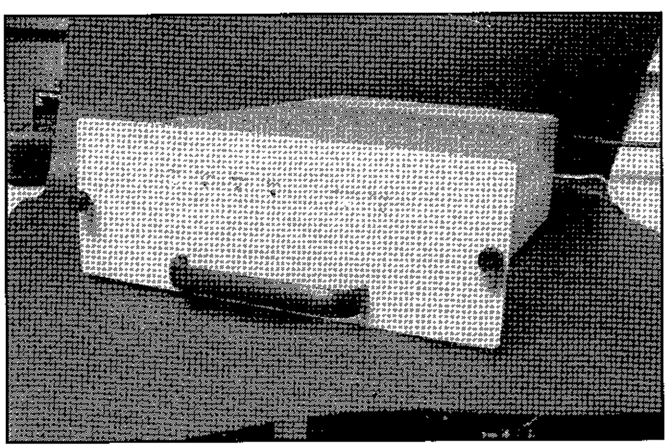


Fig 1—Front view of Z3801A receiver.

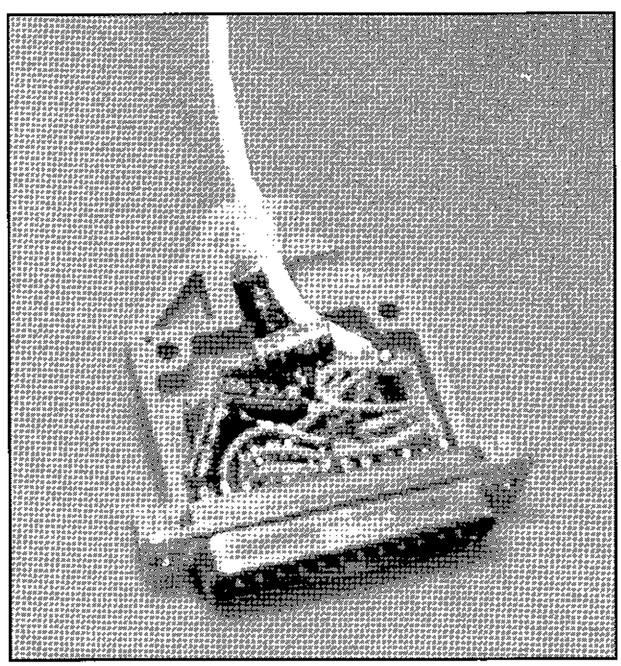


Fig 2—A homemade serial RS422 to RS232 converter, using the circuit of Fig 6B.

ported to *Satstat* is the *old* location where the unit was in service. Write these numbers down before the receiver determines its new location. It's interesting to see where your unit came from and learn its old elevation. My particular unit lived the first four years of its life in a cell-telephone site in Florida along highway A1A. The internal memory told me its exact location when it was last turned off. I have heard of one militarized unit from a government surplus sale that had a prior elevation of 50,000 feet.[5]

Q: I need a manual, power supply details, Satstat *software or interface details on RS422 to RS232. Where can I get these?*

A: Many of the people on the TACS-GPS reflector that were getting HP receivers like this one were buying regulated power supplies and commercial RS-422-to-RS-232 converters. I decided to design and build my own, for cost savings. The schematic diagrams give all the details. Three different options for the RS-422 to RS232 converter are offered in Fig 6. A reliable 48-V dc power supply is shown in Fig 3. Power supply reliability and safety is an issue with full-time operation. In use, the power supply is bolted underneath the workbench out of sight.

The following are available for downloading from author's Web site **www.realhamradio.com**.

- A two-page interface and power-supply schematic in PDF format (Figs 3 and 6 here)
- *SatStat* GPS receiver software in a ZIP file (500 kB)
- A Z3801A manual in PDF format (1 MB)

Visit the Web site for the latest application information.

Two good application note links exist about the technology used in the Z3801A. The first is an HP application note about Smartclock Technology. It goes into the theory behind GPS-disciplined oscillators: **literature.agilent.com/litweb/pdf/5966-0431E.pdf**. The second one also from HP; it explains basic GPS concepts and delves into precision-timing applications with GPS: **literature.agilent.com/litweb/pdf/5965-2791E.pdf**.

Notes

[1]Brooks Shera, "A GPS-Based Frequency Standard," *QST*, July 1998. Brooks has a Web site dedicated to this project at **www.rt66.com/~shera/index_fs.htm**.

[2]The J4 power connector is a three-terminal Amp MATE-N-LOCK connector, Mouser #571-7700181. Two socket pins are also required, #571-7702513.

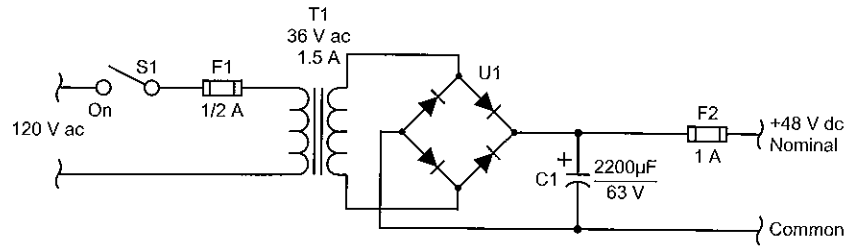


Fig 3—A schematic of the receiver power supply. The output is 54-V dc with no load, 47 V during warm up, 48-50 V during normal operation. This meets the Hewlett-Packard specifications for the 54-V version Z3801A. A regulated supply is not necessary.
C1—2200 µF 63 V; use more capacitance if available.
T1—120 V primary, 36 V 1.5 A secondary (Jameco #104416).
U1—Diode bridge, 100 PIV 1 A, minimum; 10 A suggested.

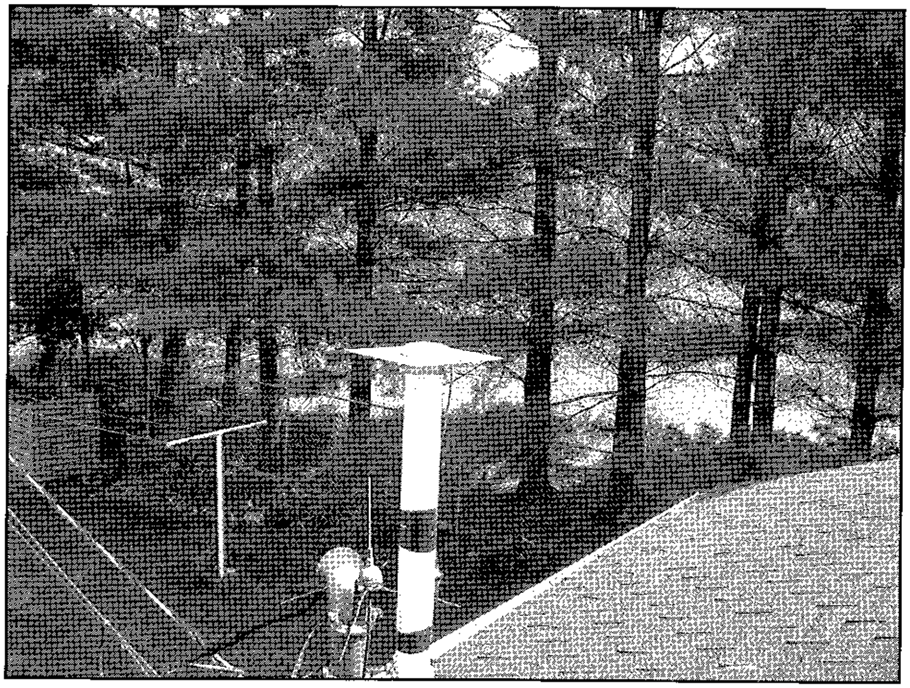


Fig 4—Photo of a mobile GPS antenna mounted on house roof.

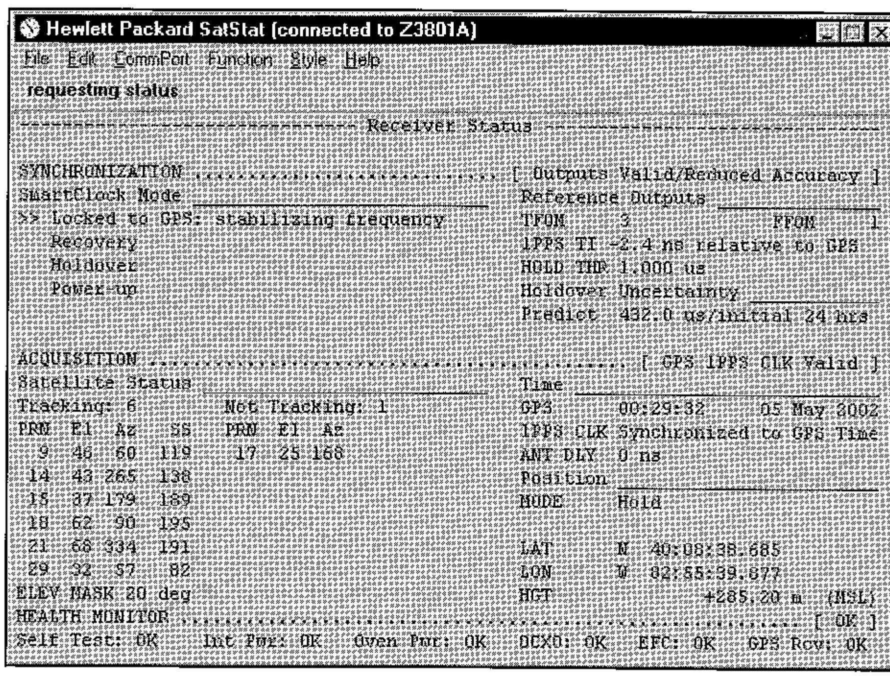
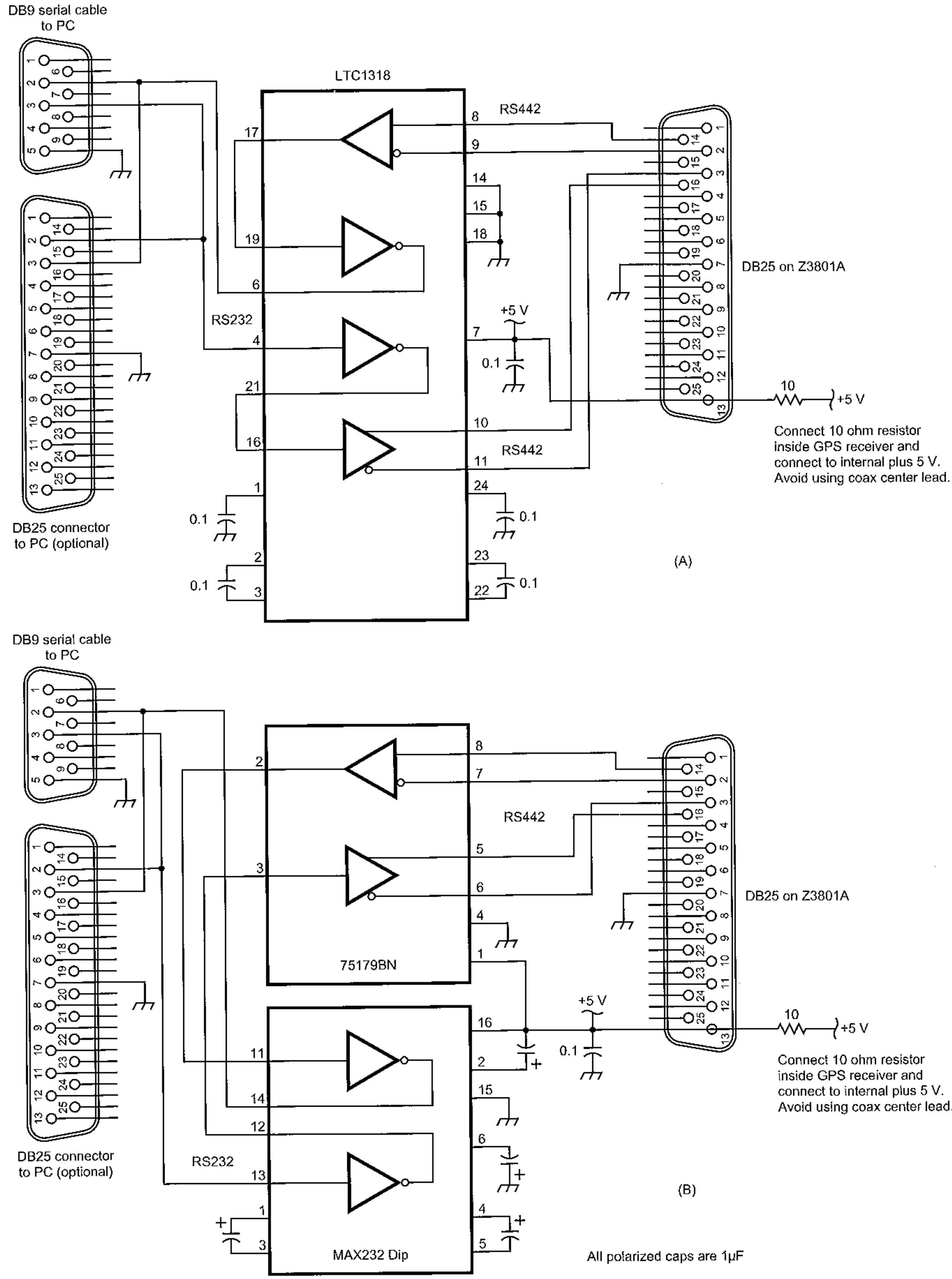


Fig 5—(right) A screen capture of *Satstat* software in operation with a Z3801A.


DB9 serial cable to PC
LTC1318
RS442
RS232
DB25 on Z3801A
DB25 connector to PC (optional)
Connect 10 ohm resistor inside GPS receiver and connect to internal plus 5 V. Avoid using coax center lead.
+5 V
0.1
10
(A)
75179BN
MAX232 Dip
(B)
All polarized caps are 1μF

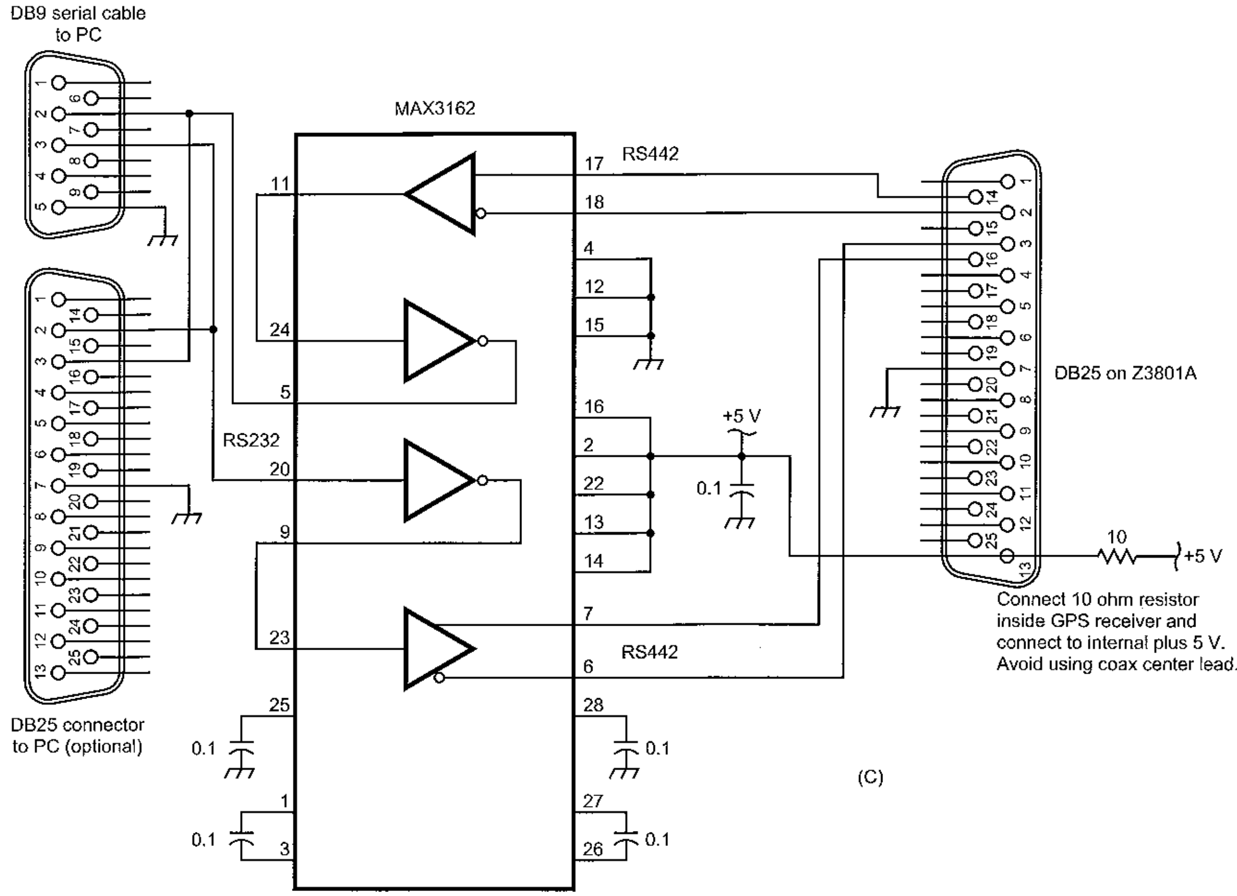


Fig 6—Schematics of several serial-interface options. (A) The LTC1318CN (24-pin DIP) or LTC1318CSW (wide surface mount) are available from Digi-Key (www.digikey.com) or www.Linear-Tech.com. (B) uses DIP components available from RadioShack (RadioShack.com). (C) uses the Maxim MAX3162 28-pin surface-mount package. Maxim offers free samples of this device; visit Maxim-ic.com for details. With care, an interface using any of these chips can be built inside the DB25 backshell as shown in Fig 2.

[3]The Motorola Antenna97 is available from TAPR at **www.tapr.org**. If you need help on another type of GPS receiver, inquire on the TAPR GPS Reflector.

[4]*The ARRL Antenna Book*, 18th Edition, 1997 includes, on floppy disk, a useful transmission-line-loss calculator named *TL*, written by Dean Straw, N6BV. Later versions are *Windows*-based.

[5]Thanks to Tom Van Baak at **LeapSecond.com** for helpful advice on this receiver.

Bill Jones, K8CU, has been an active radio amateur, CW DXer and home project builder since first receiving his license in 1966 at age 17. Bill is an electronics professional with experience ranging from radar maintenance in Vietnam, analog and digital telephone PBX design, to imbedded-controller implementation. He spent 18 years at Optek Inc designing hardware and writing assembly-language software for embedded microcontrollers used in specialized electro-optical controls.

He has written about several of his Amateur Radio projects in ARRL publications. His current employer is the Ohio Department of Transportation, where he works in radio communications. Some recent interests include small gas engines, 6-meter DX and maintaining his personal Web site **RealHamRadio.com**, *on which he has placed some entries from his notebooks. A member of a nearby sports-man's and conservation club, Bill can sometimes be found fishing with his wife, Bonnie.* □□