

Technical Topics

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Almost about the HP Z3801A and Z3816A GPS
Everything you want to know



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HP Z3801A GPS Receiver

The Z3801A / Z3816A are high quality frequency/time standards sometimes available on the surplus market.

This article describes:

- What the HP Z3801A / HP Z3816A are and how to obtain one
- What accessories are required
- Low cost home made options for interface and power supply
- Detailed HP application notes on related topics
- Answers to frequently asked questions about the Z3801A
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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.

This type of frequency standard is roughly comparable to a Rubidium standard, without the maintenance issues of the Rubidium lamp. The frequency accuracy is specified at less than one part per billion, on a one day average. This is exceptional for a home work shop and ham station. These units have an HP double oven oscillator, the HP 10811D/E, with a frequency output of 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 work shop reference for test

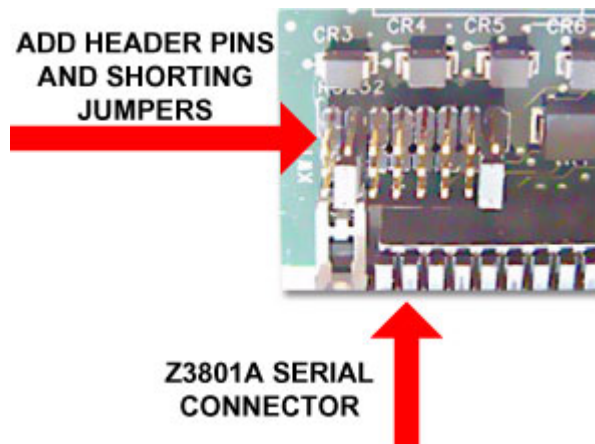
equipment maintenance. I use it to drive a Tektronix 2901A time mark generator that makes handy marker signals up to 500 MHz.

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

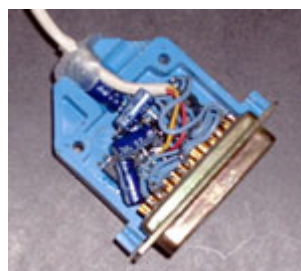
These GPS receivers are surplus equipment. I'm not aware of the specific technology change that has placed them into this category. Since CDMA (a digital spread spectrum method pioneered by Qualcomm) requires each cell site to have an individual GPS receiver, perhaps a network upgrade or revision has released these receivers. This suggests that many of these receivers are becoming available.

The HP Z3801A receiver is a basic OEM unit and has only a simple front panel since detailed control is provided using a rear panel RS-422 serial control port. Since your PC uses RS-232 for serial control, a simple RS-422 to RS-232 converter may be built, or the Z3801A must be internally modified for RS-232 use. I chose to use the external RS-422 interface. Most vendors allow return and exchange of a unit that is not performing. Since there is a chance the unit will be returned, I did not want to modify the receiver. Modifying and soldering components on a new receiver prior to acceptance testing just doesn't make sense.

The Z3801A main board has a set of uninstalled headers marked RS-232 and RS-422. These headers are located inside the receiver near the serial connector on the rear panel. The Z3801A photo below shows this location near the rear panel of the receiver. Install jumper headers and plugs or selectively solder jumper wires to convert to RS-232. It is then necessary to turn the board over and remove five Zero ohm jumpers which hard wire selected the original RS-422 interface option. When these surface mount jumpers are removed, the new headers (or solder wires) will select either RS-422 or RS-232 [5]. The center row of pins is common. Jumper from either marked side of the PC board to the center for your selection.



A [two page schematic](#) gives the details on a home made power supply and RS-422 to RS-232 cable converter. Three different options for the RS-422 to RS-232 converter are shown. An external power supply (usually 54 volts DC nominal) and external outside GPS antenna are required. HP supplies a program called SatStat that is the front panel and control interface for the receiver. [Other software offerings are available, and some offer significant advantages over HP Satstat.](#)



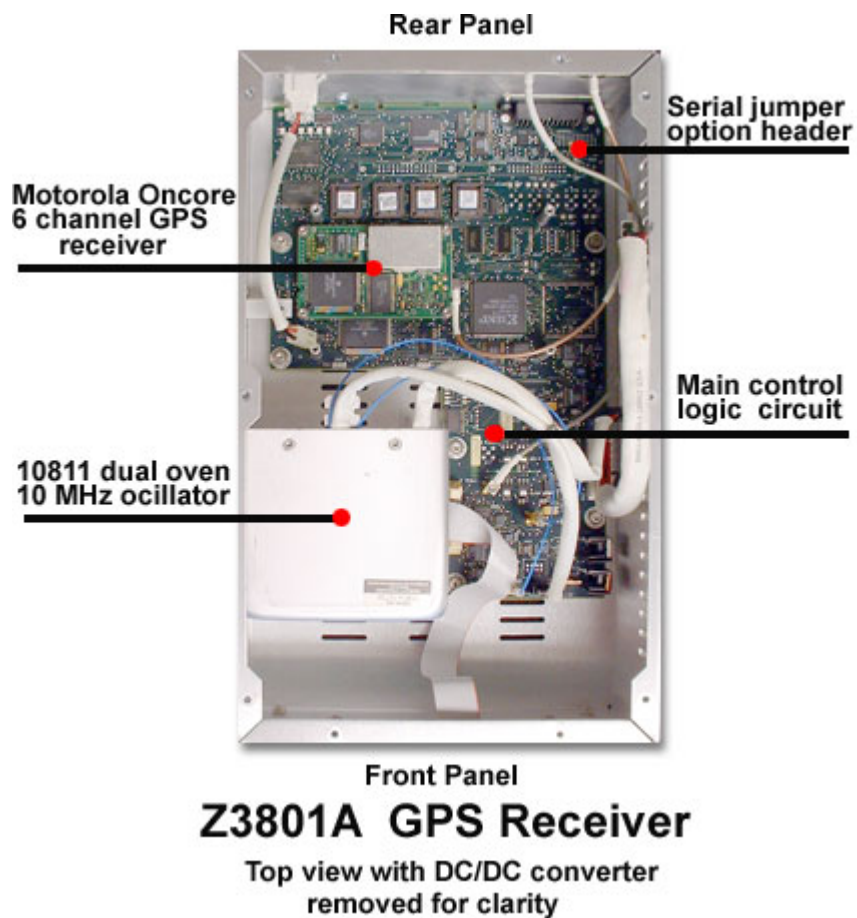
Home made RS-422 to RS-232 Interface

RS-232 Cable Definition

PC Com Port (DB-9M)	Z3801A Serial Port (DB-25F)
2 (Rx)	2 (Tx)
3 (Tx)	3 (Rx)
5 (Gnd)	7 (Gnd)

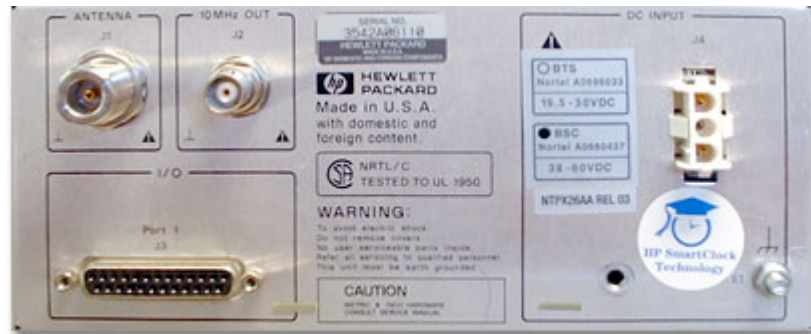
PC Com Port (DB-9M)	Z3816A / 58540A Serial Port (DB-9F)
2 (Rx)	2 (Tx)
3 (Tx)	3 (Rx)
5 (Gnd)	5 (Gnd)

Suggested serial port settings are 19200, ODD, 7, 1.



The HP Z3801A has these rear panel connectors:

- One 25-pin female DB25 connector. This connector provides two 1 PPS time outputs, two 10 MHz frequency outputs, and an RS-422 serial interface port.
- 10 MHz output BNC connector. • A remote antenna N-type connector. • Power input connector [2].



Z3801A rear panel

Z3801A Voltage Converter Assembly

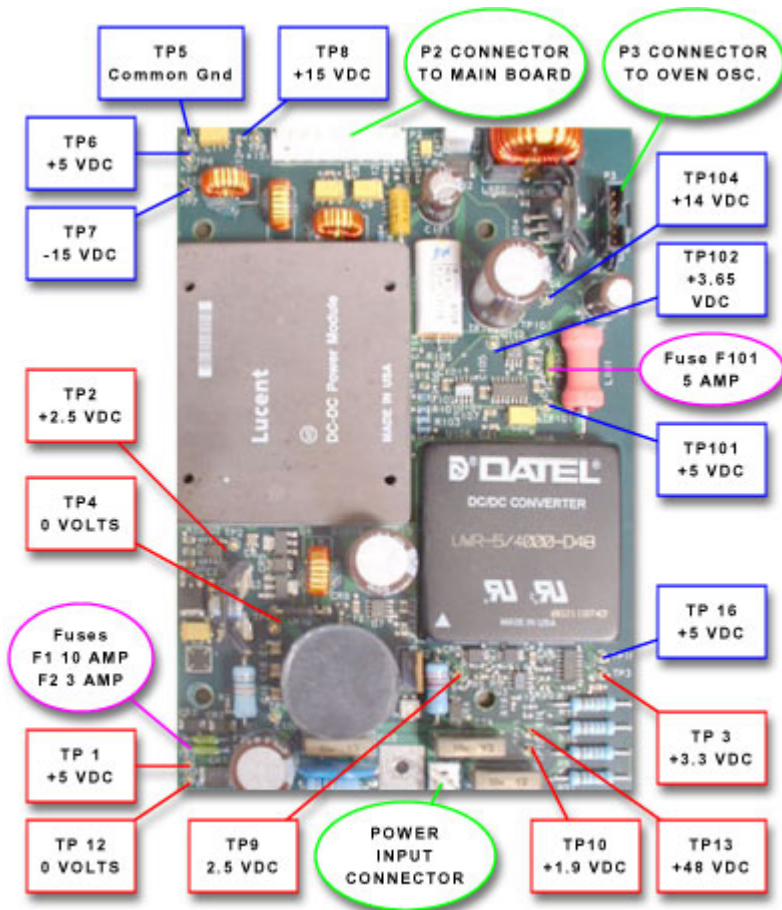
The Z3801A Voltage Converter assembly is 4.75" x 7" in size, and is located on top of the main circuit board. Keyed connectors from the main 54 volt DC input, the oven oscillator, and the main circuit board are easily disconnected. After removing five Torx T10 screws, the complete power supply assembly is ready to remove from the receiver cabinet.

The main 54 volt power input has both leads fused with two small Pico fuses. These are small, solder-in fuses that appear like 1/4 watt resistors. F1 is rated at 10 amps and F2 is a 3 amp fuse. These have no visible indication of a blown condition, and must be tested with an ohmmeter.

Two large DC to DC power converter packages are located on this circuit board. One is a Lucent CW025ACL-M that has input of DC 36-75V@.92A with outputs of DC 5V,5A and plus and minus 15 V at .8A each. The other converter package is a Datel UWR-5/4000-D48 that converts 48 VDC to 5V 4A.

Some discrete active power circuitry is located on the board. A LT1270ACT 10 Amp switching regulator at U104 is used for the temperature regulated oven supply. The input to this regulator is fused by another small pico fuse F101 rated at 5A. Also, a IRF530 FET switch is used at Q1.

Separate grounds are used in this circuit. The input power ground is isolated from the output DC voltage grounds. The diagram of the Z3801A power supply shows typical operation DC voltages. If the box color is **Blue**, the reference ground is TP5 Common Ground. If the box color is **Red**, the reference ground is the minus lead of the input 54 VDC power. A number of voltage test points are available from the component side of the power supply assembly.



HP Z3801A Power Supply Assembly

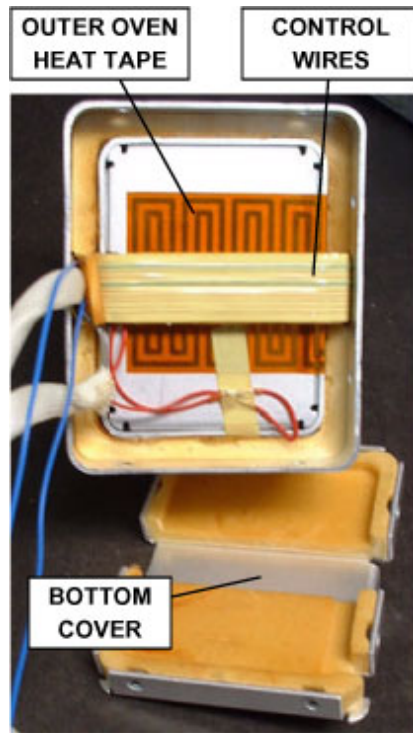
Connector P2 to Main Board Pin	Wire Color	DC Voltage Reading
1 +5RAW	Red	+ 5
2 +5RAW	Red	+ 5
3 DGND	Black	0V
4 DGND	Black	0V
5 +15RAW	Yellow	+ 15
6 AGND	Black	0V
7 -15RAW	Blue	- 15
8 DOVEN-ON	Red	2.1V
9 DOVEN-MON	Green	+ 8.1

Connector P3 to Oven Pin	Wire Color	DC Voltage Reading
1	Gray	2.5V (from thermistor)
2	Gray	Gnd
3	Red	+ 14V (regulated by U104)
4	Red	+ 5 (heater return)
5	n/u	n/u
6	n/u	n/u

Voltage readings are made with all connectors in place and operation stabilized. The outer oven controller as implemented by HP is a standard temperature bridge with the internal oven thermistor as the variable. The circuit consists of U101 (high accuracy +5 volt reference), a bridge unbalance error amplifier op-amp at U102, and a low impedance switch-mode power regulator at U104 (LT1170) acting as the heater power driver for the outer oven.

This circuit will stabilize the outer oven temperature, and the control voltages will vary depending upon the specific state of the outer oven control. In particular, the readings at TP-102 (op-amp error output) and TP-104 (switch-mode regulator output to the outer oven heater) will vary. The values listed are nominal readings measured after extended warm-up.

Z3801A HP 10811 Dual Oven Oscillator



HP 10811 Dual Oven Oscillator

J21 Inner Oven Connector Pin	Voltage Reading
1	0V Agnd
2	+12V for oscillator; ~25 mA
3	0V Agnd
4	-4V oven health monitor (referenced to frame ground)
5	+ 12V oven power
6	- 12V oven return

Oven P3 Pin resistance reading between pins, oven disconnected from circuit.	1 to 2 Gray-Gray	110K @ 25C.
	3 to 4 Red-Red	18 Ohms

Frequently Asked Questions:

Question - Where can I buy one of these GPS receivers?

The surplus receivers are sometimes available on Ebay. The receivers are also available from other sources. Just do an Internet search on the word Z3801A.

Question - What antenna do I need to make this receiver work?

The Motorola antenna (ANT62301A/B) of the time 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. Make sure the antenna you use has a pre-amp that will run from the 5 Volt supply the Z3801A provides on the antenna coax center lead. An outside 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 have had good success mobile Magellan Mobile GPS antennas. These mobile antennas work perfectly and have an "O" ring seal to keep out the weather. I mounted this external mobile antenna (with internal pre-amp) on a PVC pipe mount that clamps to an outside roof pipe on my home. I used a six-inch square aluminum plate as a ground plane to simulate the vehicle's metal roof.

I spliced a length of RG-58/U coax to the smaller cable on the mobile antenna to give me enough length to bring the coax into the work shop. Cable length or coax attenuation isn't too 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 to

10 dB. I used 20-feet of RG-58/U with no problems [3]. With my particular antenna mounting method, the receiver always reports a minimum of at least four to six separate satellites that are actively being tracked.



Question - I have a question about the Magellan GPS antenna mentioned in your article. I am curious about how our weather affects the antenna efficiency. From your antenna photo, I can imagine your antenna having one foot of ice setting on top of it. Please let me know how the weather affects the operation.

Like most microwave signals, GPS L1 band at about 1.5 GHz is attenuated by snow, ice, and even birds sitting on the antenna. Using the mobile mount Magellan, I have been able to be pretty successful, even with a couple inches of snow. The holdover mode of the Z3801A will keep a reasonable frequency at the 10 MHz output during periods of signal loss. Professional outside permanent GPS antennas are designed to shed snow and ice and deter birds. They look like inverted funnels with the tip pointed skyward. Motorola offers one called the "Timing2000".



Question - There are six diagnostic LEDs on the main printed circuit board below the power connector. Does anyone know how to interpret them? One of mine is flashing.

The six LEDs are:

1. 'Boot code' if ON, Normal if Flashing, 'broken' if OFF
2. EPROM failure
3. CPU failure
4. RAM failure
5. UART failure
6. QSPI, FPGA, interpolator, GPS, power failure

In normal operation all should be off except #1 which should be flashing. Above is from page 6-29 of the Symmetricom 55300A User's Guide.

Question - 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?

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. From this point, the unit will probably function properly. The Survey command is issued using the software Satstat.

Issue this command to the receiver: :PTIME:GPSYSTEM:POSITION:SURVEY ONCE

Hint: after you first hook up your receiver, the GPS location reported to Satstat is the OLD location where the unit was in service. Write these numbers down before the receiver determines its new location. Its interesting to see where your unit came from and its old elevation. My particular unit lived the first four year's of it's life in a cell telephone site in Florida along highway A1A. I determined the receiver's age by the internal component date code markings. The receiver internal memory told me it's exact location when it was last turned off.

You can also easily determine how long your new receiver has been powered up. Using Satstat or similar, issue the command :DIAG:LIFETIME:COUNT? which returns the total time that the GPS Receiver has been active. The value returned by the GPS receiver is in increments of 3 hours. So if you get a number like 1000, this means your receiver has been powered-on for 3000 hours. Mine showed a value of about 3.5 years when I first got it.

Question - I got a bit confused while trying to setup a HPZ3801A. The sticker in the back says that it is a 38-60VDC unit. I have a Lambda power supply capable of delivering 0 to 60 VDC. The unit has two wires, a Red and a Black. What would a typical power connection look like?

I assumed that I connect the plus(+) side to the red and the minus(-) side to the black and connect the ground, but this is not working. How do you have your unit set up?

Since this is telephone type equipment, the negative convention is used in the HP power supply specification. This makes it confusing for some folks. If your Z3801A is not defective, hooking the power supply Positive wire to the top pin of the power connector, and the Minus wire to the bottom pin should get you going. Ignore the wire color. The Z3801A user's guide page 1-5 shows a picture of this. The HP power supply spec indicates that minus 46 VDC or more negative is required when starting. If your unit will still not start up, try moving the power supply toward the minus 60 volt area. The power supply specification summary is located on page 5-4 of the Z3801A User's Guide. It indicates that this is a nominal 54 volt device.

User feedback: ...My unit required at least 52 volts to power up...It is now working perfectly.

Question - My Z3801A GPS receiver now appears completely functional. Can I use the 10 MHz output frequency for test equipment calibration, and claim NIST traceability?

Maybe. The National Institute of Standards and Technology (NIST) has an informative [web page](#) on this subject. They also suggest that the frequency accuracy of GPS frequency standard receivers may have an accuracy of 10^{-12} since Selective Availability (SA) has been turned off. SA is the intentional reduction in GPS accuracy introduced by the US Department of Defense. It was turned off in the year 2000, allowing full GPS accuracy for all users.

Question - Now that the GPS unit is running, should I turn it on when I need an accurate frequency source, or just leave it powered up and active? If I leave it on, what about a backup power supply?

Some measurements suggest a typical locking and warmup time period of about 20 minutes is sufficient time for acceptable results from a cold start. An oven oscillator that is "old" in terms of power on time is actually better than a brand new one. These receivers were designed to run 100% of the time and are really not "WWV on Demand" or immediately ready at power switch turn-on. Leaving the unit active guarantees that any initial warmup or locking time is eliminated, and the receiver is ready when you are.

A backup power source is a good idea. A low cost [battery backup project](#) is described on this site. Not only will it keep the oven stable during power outages, it also provides protection from rapidly changing AC line power surges. A relatively simple backup supply may be constructed by series connecting four 12 volt batteries. A 55.4 volt charger always connected will trickle charge the four batteries. Alternately, surplus 48 volt commercial backups are sometimes available on Ebay [4]. Another choice is to use the AC UPS units sold for personal computer power backup. This will supply AC power to your existing receiver power supply during power outages.

Question - My 3801 displays the time as 15 seconds fast than compared to WWV or my "atomic" clocks. What is wrong do you think? All tests and lock appear to be normal...tracks 5 or 6 satellites, etc.

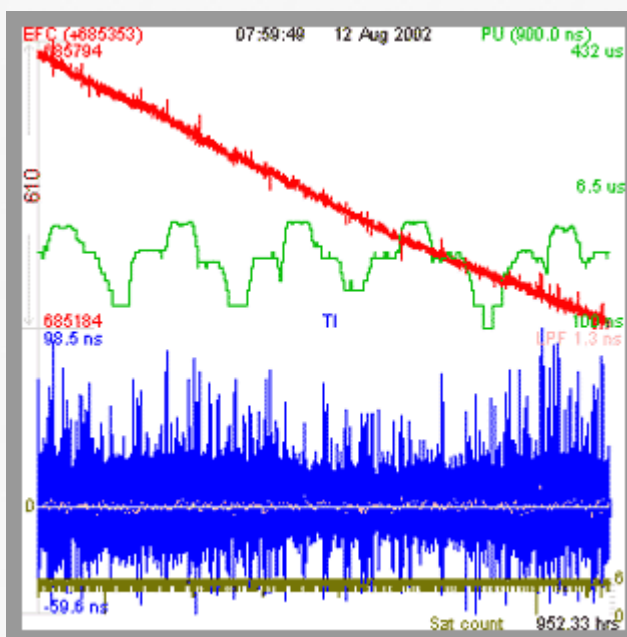
Your unit is set to the GPS time scale instead of the UTC time scale. Currently there is a 15 second difference between these time scales because of leap seconds (GPS time ignores them).

Issue the command `:diag:gps:utc?` If it returns 0 you are in GPS mode; if 1 you are in UTC.

Use the command `:diag:gps:utc 1` followed by physically turning power off then back on again will reset the UTC mode.

Question - My receiver's Predicted Uncertainty fluctuates between 200 ns and 2us. Why would the number change? The receiver always shows a GPS lock.

There is no visible reason for it. This may be an anomaly of the Z3801A software because the fluctuation is very cyclical. The long term chart of the receiver shown below illustrates this activity.



The Z3801A receiver EFC is red, the 1 PPS to GPS phase is blue, Predicted Uncertainty (PU) is green, and the satellite count is olive green. This recording was taken over a period of about 40 days. The cyclical nature of the PU is clearly evident.

[Click here for more details of the GPSCon software](#) that made this plot possible. This software is also very helpful in making an initial evaluation when you first receive your

unit.

[Download](#) 

[Download K8CU's two page Z3801A RS-422 interface and power supply schematic](#)



[Download John MacConnell's Z3816A Windows utility and null modem information \(15K\)](#)

[Download John MacConnell's Z3816A DOS utility program GPS-dos2.exe in Zip format \(50K\)](#)

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Notes

1. Brooks Shera, W5OJM "A GPS-Based Frequency Standard", QST, July 1998 .
2. J4 power connector is a three terminal AMP MATE-N-LOCK connector, [Mouser Electronics](#) part number is 571-7700181. Two socket pins are also required, p/n 571-7702513.
- 3 .R. Dean Straw, ed., The ARRL Antenna Book, 18th Ed. (Newington:ARRL, 1997), includes on floppy disk a useful transmission line loss calculator named TL, written by Dean Straw, N6BV.

4. A 48 volt UPS made by Lucent, and new in the box were available from Ebay. They weighed about 50 pounds. These units have perhaps more capacity than normally required, but would provide extended outage protection.