

WWV in a box!

Well, not exactly, but for the price its the next best thing...

HP Z3801A GPS Frequency Standard *Theory and Installation*

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I recently purchased an HP Z3801A GPS Time and Frequency standard along with the necessary power supply and hardware to place it into operation. I am using it primarily for the very accurate and stable 10 MHz frequency source (less than 1×10^{-9} , one day average). This article contains general the theory of operation, installation and operation notes. Never before has this type frequency accuracy been easily available in the ham shack. As a special bonus, you don't have to ship it off for periodic calibration.

The Z3801A GPS Receiver provides highly accurate time and frequency outputs by locking on to the Global Positioning Satellite system and using it's precision timing data to steer



Figure 1. The Main Assembly or the HP Z3801A GPS Time and Frequency Standard. Note that the Antenna/Amplifier Assembly is an essential part of the system. Any good quality 50 Ohm coaxial cable may be used up to 50 to 100 ft with no problem. The power supply, partially visible in this photo is Jameco Part No. 167345 and is rated at 50VDC @ 3.2A. This fully caged switching power supply has enough capacity to power three of these units. Most any 48VDC @ 1A or more power supply, will be adequate.



Figure 2. The HP 58504A GPS Antenna. The self contained 24 DB amplifier is powered through the coaxial cable. The "pie pan" ground plane improves performance of the antenna. While the antenna is weather tight, a pyramid shaped Fiberglass environmental protection cover is available to minimize ice and snow accumulation. Coax connectors are TNC male on antenna end and N-type male on receiver end. Locating your antenna inside is adequate in most cases, however an outside location with a clear shot down to the horizon all way around will give the best results.

a highly stable 10 MHz crystal oscillator. Upon loss of signal, the Receiver automatically 'switches to "holdover" mode, which ensures accuracy up to 24 hours, with somewhat reduced accuracy. Using HP SmartClock technology, the Z3801A has a remarkable capability to continue

it's accuracy and stability should the satellite signals be lost. These units were Original-Equipment-Manufacturer equipment designed to synchronize Cellular Land Network wireless base stations. Due to improved technology being used for cellular networks, these units have become available from various surplus sources. The units are very useful for any requirement you may have for exact frequency and timing accuracy. This level of performance has not previously been available at affordable prices. Assuming that you have a computer with an RS-232 serial port, a complete set-up can be made for well under \$500.

At the risk of insulting your intelligence, the frequency accuracy/error statements using powers of 10 translate as follows:

- < 1×10^{-6} is less than one HZ in one MHZ
- < 1×10^{-7} is less than one HZ in ten MHZ
- < 1×10^{-8} is less than one HZ in one hundred MHZ
- < 1×10^{-9} is less than one HZ in one thousand MHZ (or one GHZ)

As you can see, this tells us the HP Z3801A, when locked to the GPS satellites, can hold the frequency to the equivalent accuracy of one HZ in one GHZ . This is only the short term accuracy... the long term accuracy is much better. This is a remarkable frequency accuracy for a ham shack... at a ham affordable price. It is even more remarkable in that it is self calibrating. It doesn't have to be shipped off some place and calibrated against with another frequency standard with higher level of accuracy. This is why I call it "WWV in a box".

Theory of Operation

During normal operation, the Z3801A's internal precision quartz oscillator is phase-locked to the GPS signal. This is accomplished by comparing the time difference between the 1-pps

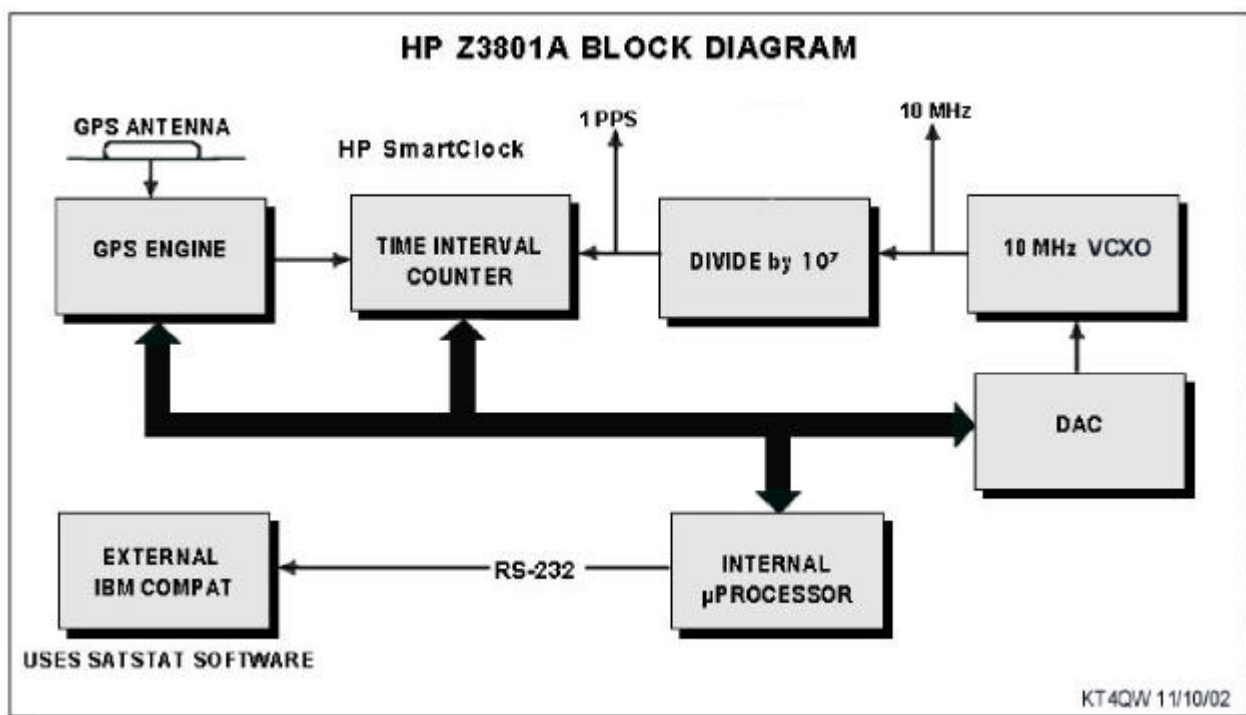


Figure 3. Block Diagram for the HP Z3801A GPS Receiver

signal from the GPS engine to a similar signal derived from the internal oscillator as shown in the block diagram shown in Figure 3.

While locked to the GPS system, it employs learning techniques to measure the aging and temperature characteristics the internal quartz oscillator. This information is accurately measured using the reference signal from the GPS engine and is stored in internal memory. The data thus stored are used to control frequency accuracy and stability as needed.

Normal operation of the timing modules begins by tracking four or more GPS satellites to determine accurately the geographic position of the antenna. Initially, the timing module uses a short time constant to control the oscillator, thus providing rapid time setting of the module. Following a series of checks of the overall operation of the module, the time constant incrementally increases to its final value over a period of from 2 to 18 hours. At this point, the timing module is fully functional and should meet all of its specifications, except hold-over.

While locked to GPS, the timing module starts learning the characteristics of the internal 10 MHz oscillator. The learning algorithm requires 48 hours of data to ensure that an adequate determination of the aging can be made. The learning process continues while the unit is powered and locked to GPS. Data from the most recent 48 hours is stored in memory. The module shares the long-term stability of GPS when locked. In the short-term, the timing module stability is directly determined by the short-term stability of the 10 MHz oscillator. For averaging times greater than 24 hours (86,400 seconds), the frequency accuracy is better than 1×10^{-12} . Timing accuracy of better than 110 nanoseconds at the 95 percent level is achieved.

Once the Z3801A receiver is setup and operating, it requires no detail supervision. The Z3801A has very limited front panel display and no keypad entry capability. Detail monitoring and setup commands are communicated to/from the unit from a user furnished computer via a 25-pin RS-422 serial interface port. The RS-422 port may be changed to the RS-232 configuration by individual users by making internal changes. The original design provided for this change. The only information displayed on the front panel of the Z3801A Receiver is shown by six Light-Emitting-Diode (LED) indicators. These indicators show the following key functions (left to right as shown Figure 1 above):

- Power**
- Enabled (user defined)**
- Active (user defined)**
- Alarm**
- GPS Lock**

Two types of outputs are available from this unit which are: (1). A 10 MHZ, 1.9 V peak-to-peak signal of unusual stability and accuracy. And (2). A one p.p.s., 10 to 50 microsecond precise timing pulse. Of course "housekeeping" information is available to an external computer via the RS-232 port. The Z3801A is not only accurate, it is continuously traceable to the National Bureau of Standards at all times the G.P.S. lock is maintained.

HOUSKEEPING FUNCTIONS

The various functions necessary for initial set-up and continued monitoring the HP Z3801A GPS Receiver are accomplished with an external IBM compatible computer via the RS-232 serial port. Note that monitoring is not necessary for operation after initial setup. The computer uses the HP generated "SatStat" software. I am not aware of Apple compatible software being available, however commands and status can be accomplished using a "dumb

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Hewlett Packard SatStat (Demo)
File Edit CommPort Function Style Help
received status
----- Receiver Status -----
SYNCHRONIZATION ..... [ Outputs Valid ]
SmartClock Mode _____ Reference Outputs _____
>> Locked to GPS: frequency is stable TFOM 3 FFOM 0
Recovery 1PPS TI +32.8 ns relative to GPS
Holdover HOLD THR 1.000 us
Power-up Holdover Uncertainty _____
Predict 11.5 us/initial 24 hrs

ACQUISITION ..... [ GPS 1PPS CLK Valid ]
Satellite Status _____ Time _____
Tracking: 6 Not Tracking: 1 UTC 09:26:32 11 May 2002
PRN E1 Az SS PRN E1 Az 1PPS CLK Synchronized to UTC
5 47 168 118 25 10 302 ANT DLY 250 ns
6 51 314 142 Position _____
16 51 100 109 MODE Hold
17 22 238 81
20 70 252 147 LAT N 37:19:32.124
24 29 48 77 LON W 121:59:51.872
ELEV MASK 10 deg HGT +71.12 m (MSL)
HEALTH MONITOR ..... [ OK ]
Self Test: OK | Int Pwr: OK Oven Pwr: OK OCXO: OK EFC: OK GPS Rcv: OK

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Figure __. A screen image of the SatStat software when connected to the HP Z3801A via the RS-232 connection. The User's Guide includes a detail explanation of the commands and status screen.

terminal" approach. The SatStat software has been available via internet download from several sources on the internet. I believe it is still available. By reviewing the following sample computer screen you will get the general picture of the usefulness of monitoring the operation and status of the unit.

A User's Guide available for the receiver, in Acrobat (.pdf) format via internet download. The manual has comprehensive coverage on set-up and monitoring the receiver's status. Note that you may observe the time from the receiver as an alternate to the status screen. The following Figure __ shows the time display. This displays advances each second and reflects very accurate time, less some software and circuit delays .



Figure __ You may select the time display as an alternate to the status display. Display increments each second.

THE 48 VDC POWER SUPPLY

The Z3801A Receiver requires an external power supply. The Z3801A is manufactured with one of two power options, 24 vdc and 48 vdc. A label on the rear panel is clearly marked to indicate power supply requirements. It seems as if the most commonly available models on the surplus market are built for 48 vdc operation. Power requirements for the 48 vdc model is approximately 700 ma at start-up, falling back to approximately 350 ma after the ovens (an oven within an oven) have reached operating temperature. The units are quite tolerant of voltage and are happy with 48 to 60 vdc. The power supply I use is Jameco Part No. 167345 and is rated at 50VDC @ 3.2A. This fully caged switching power supply has enough capacity to power three of these units.

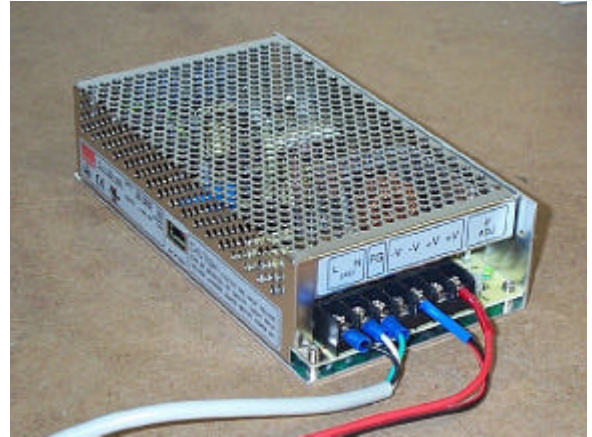


Figure — This power supply is Jameco Part No. 167345 and is rated at 50VDC @ 3.2A. This enclosed switching power supply has enough capacity to power three of these units. The voltage is adjustable over quite a range and is well regulated. Most any 48VDC @ 1A or more, will be adequate.

Note:

Technical information relating to specifications, and theory was gleaned from Application Note 1279, HP SmartClock Technology and the Z3801A GPS Receiver, User's Guide, Symmetricom 097-Z3801-0, May 00. I have no way to determine if the detail characteristics of the Z3801A is exactly the same as that described in various HP application notes..