The

GPSR-A User Manual

A Guide to the HP Z3815A and the CIC GPSR

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Note:
This manual is completely unofficial, and no reference has been made during its preparation to any official HP or CIC manuals for these devices. Therefore, there is room for some errors and considerable misunderstanding in the information contained herein. All errors are those of the author.

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1. Receiver Description

Introduction

The Hewlett Packard / Agilent / Symmetricom Z3815A and the Chongho I&C GPSR-A[1] are designed for use in CDMA cellular phone networks. They provide highly accurate time and frequency outputs used to synchronize cellular base stations.

These GPS Receivers (GPSR) derive their highly accurate timing by reference to the Navstar Global Positioning System (GPS) satellite system. If the satellite system is lost for any reason, the GPSR changes to 'Holdover' mode, which ensures that system timing can be maintained for up to 24 hours at reduced accuracy. This function is achieved through the use of a highly stable internal reference oscillator, controlled by a learning system called a 'Smart Clock®'.[2]

The initial design by Hewlett Packard (now called Agilent) in the early 1990s was sold to Symmetricom, and some later devices bear the Symmetricom logo. There are also some internal differences. During the late 1990s and more recently a device with completely different internal design, but similar external appearance, and identical fit and function, has been made by the Chongho Industrial and Communications Co. Ltd, in Korea. Both units share a common front panel, labelled 'GPSR-A', or GPS Receiver, version A.



Fig. 1. View of the HP Z3815A with cover removed

[1] Hereafter both models called the 'GPSR' except where model differences require otherwise.
[2] Hewlett Packard / Agilent trade mark.

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To date, no manufacturer's documentation has been found for either unit, and this manual is therefore based on a combination of practical experience with these units and comparison with functionally similar units such as the HP Z3801A and the Symmetricom 58503B.

The units have several outputs. The 10MHz sine wave reference is available from a rear coaxial connector block once the system is locked. 19.6608MHz, 4.096MHz and 1.544MHz square wave outputs are available from the backplane connector once the system is locked.

The GPS antenna input is to the rear coaxial connector block. The connector is powered, and intended for a 5V active antenna. DC operating power can be applied to the backplane connector.

Internal points provide access to regenerated system 1pps, 10MHz and 19.6608MHz square wave signals which are present even before the system is locked.

The front panel carries numerous status lights, and an RS232 connector which provides a debug and monitoring facility. There are three front panel recessed buttons providing reset and over-ride capability.

There are no day-to-day user controls on the panel. All control is via the serial communications port. There is no power switch.

Differences between HP and CIC

Functionally, these units are very similar. In appearance, they are certainly extremely similar, although the HP has stainless steel cover, while the CIC has a passivated steel cover. The front panels, mounting features, rear connectors and signals are identical, allowing them to operate interchangeably in their original cellular base station application.

Internally however, the units are very different. In most examples seen to date, the HP uses a single-oven 10MHz HP E1938 'hockey puck' oscillator (seen in Fig. 1). A version with a Symmetricom adaptor fitted with a 5MHz Milliren 260 double-oven oscillator has also been seen. All CIC units use a single-board design with a double-oven 10MHz C-MAC oscillator model STP2145A (branded CIC).

The HP units use a Furuno GT74 GPS module in NMEA mode; the CIC uses a Motorola Oncore GPS in Motorola Binary mode. Both units use Vicor switch-mode power supply modules with heatsinks, but the power consumption of the CIC unit is about 20% lower. Details of the Time Interval (TI) measurement, time keeping and micro-controller are completely different between the two designs.

As to firmware, the HP units seem to follow the SCPI syntax of the HP Z3801A reasonably closely, and software which operates with the Z3801A will generally work with the HP Z3815A. Some functions (error flag management, control of LEDs) are omitted. Communications is at 9600-N-8-1 with XON/XOFF control.

The CIC unit however is quite different. It supports a selection of SCPI commands and responses, but subtle differences are such that the commercial software will not operate. Communications is at 19200-N-8-1, with no XON/XOFF, and with a requirement for 10ms character pacing. Further, at cold start the CIC unit operates a proprietary boot loader, and the SCPI prompt does not arrive until the boot mode has timed out.

There is a communications problem in the CIC which prevents it from knowing current satellite positions, and from correctly removing them from the list once they go below the horizon.

Thus software requirements for the CIC are very different, such that the unit requires specially written software. Other differences in operation and behaviour are very minor in nature.

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2. Getting Started

Front Panel

Refer to the picture on the right. The unit is shown in its normal orientation, as a free-standing unit with a tall-and-thin aspect.

Power

The group of LEDs at the top show the power status. Clearly when there is no power, no LED is lit. The Power On LED indicates that the unit is operating normally. The Power Fail LED indicates while the unit is recovering from a power failure.

Status

The Status group of LEDs near the top indicate the nature of the locked reference behaviour. Active indicates that the unit is locked and available (the normal condition). Standby is indicated when the unit is not active, although this has no meaning in a stand-alone context. The Block LED at the bottom of this group indicates whether the operation is blocked by some external command (backplane?) or by release of the front panel catch (see below). This also has no meaning in stand-alone use.

The Unlock LED indicates that the reference is still in the process of acquiring, or has lost, frequency lock (syntonicity).

GPS

The Available LED in this group indicates when the GPS timing engine has a valid fix. The Holdover LED indicates when there is no fix available and the holdover management system is actively managing the reference oscillator.

Alarm

The lowest group of LEDs indicate various alarm conditions. The Fail LED is active when any condition exists which requires operator attention. This includes software faiilures, but does not include software syntax errors. These alarms can be examined and reset via the debug facility, although if the fault involves a hardware failure, the alarm may not clear, or may soon recurr.

The Operation LED is lit when the alarm has been reset but the fault remains active. In normal operation neither LED is on.

Under normal operating circumstances three green LEDs are lit: Power On, Status Active and GPS Available.



Fig. 2. Front view of GPSR-A

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Push-Button Switches

Three recessed momentary contact switches are provided on the panel, approximately in the centre. The top switch (Block Active or Standby) has no useful function in a stand-alone environment. The centre switch (Bypass Warmup) enables the rear panel outputs even if the GPSR is not locked.

The lower switch (GPSR Reset) acts as a reset for the GPSR hardware and microcontroller. The GPS module is also reset, but the ephemeris and almanac are not lost. Using the GPSR Reset switch initiates a warm start, but the unit will still take a day or two to reach peak performance.

RS232

The RS232 debug port is toward the bottom of the front panel. The connector is DB9-F, which would normally be wired as a DCE (Data Communication Equipment). Unfortunately in both units the connector is wired as a DTE (Data Terminal Equipment) and so requires a special cable to communicate with a computer or terminal.

Latch

At the very bottom left of the front panel is a latch used to release the unit from the cabinet. In stand-alone use this latch serves no function, except that is operates a switch behind the panel. This switch operates the Block function, and the Status Blocked LED. It has no effect on the operation of the unit or the stand-alone outputs from the unit, and should be left closed.

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Rear Panel

Two connectors feature at the back of the units. See the picture to the right – although the back panel looks slightly different (no labels on the CIC unit, and the connector numbering is different), the connectors are identical and the connections are the same.

Coaxial Connector Block

The white connector block (top right) contains eight coaxial 50 Ohm connection points, one for the GPS antenna, and three for 10MHz sine wave output. The purpose of the other four connections is unknown.

Backplane Connector

The black connector which occupies most of the right side of the rear panel carries all the other signals. It is a 65 x 4 connector with 2.54mm pitch in both directions. It will accept conventional PCB header pins and connectors.

Power can be applied to this connector, and many output signals are available from the connector. The purpose of many of the connections remain unknown.

Most output signals from the backplane connector are pseudo-ECL balanced signals, with + and – pairs in the same row of the connector.

Note the serial number and manufacturer plates on the example photograph – both Agilent and Symmetricom! The uppermost label carries the NIST calibration certificate, dated January 2000.

The known connections to this backplane connector are given under ‘Features and Functions’, Section 4.



Fig. 3. Rear view of GPSR-A

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Installation

The GPSR should be mounted vertically, i.e. with the front panel labelling in the correct orientation, with the base at least 15mm above the supporting surface, in order to allow for free convective air flow. One suitable technique consists of making a 100 x 300mm plinth from a block of wood or Aluminium plate, and mounting the unit on 15mm pillars bolted through ventilation holes near the corners of the lower side panel. Temporarily the same effect can be achieved by propping the unit up on a pair of matchboxes!

The CIC will also operate safely lying flat, provided there is adequate ventilation (nothing on top or near the sides), but the HP will run excessively hot and could be damaged when running in this manner. It may be possible to fan-cool the units while mounted horizontally (such as in a 2U rack unit) but great care with air flow design will be required to provide sufficient air flow without the draught compromising the reference oscillator stability. Check that the exhaust air temperature in any mounting situation is below 40°C, and preferably below 35°C.

Power can be applied to pins A59 – A63 (DC In A) and pins A54 – A58 (DC In B), using PCB strip connector pins with 2.54mm spacing. The polarity of the supply is unimportant, as the unit includes a bridge rectifier.



Fig. 3A. Back panel indicating DC power connections

Note:
If power is applied to any other pins, serious damage will occur!

Do not use an AC supply! The supply should be 24 to 48V DC at about 25W continuous, and capable of providing 40W for 10 minutes while starting (absolute limits are 20 to 56V). A switch-mode supply is appropriate, provided it will handle the starting current. As a guide, a no-name Asian switch-mode supply rated at 24V 2A operated both units with no trouble, and the CIC would operate from a similar 24V 1.5A unit. The supply can be unregulated, but must have low ripple - regulated will be best. The supply is internally isolated from the case, electrical 0V (pins B65, C65, D65), the GPS antenna and the output signals.

The safest method of connecting the power supply in a stand-alone application is to use an internal connector. Both units have suitable connectors, but the adaptation is not covered in this manual.

Because the GPS antenna connector is an unusual one, it is simpler to add a short length of 50 Ohm coaxial cable to the rear of the antenna connector, and mount an appropriate BNC or SMA connector on the other end. The accompanying photograph (Fig. 4) shows how the coax can be secured to the board. Run the cable through the adjacent circuit board hole and secure it with hot-melt glue or a cable tie.

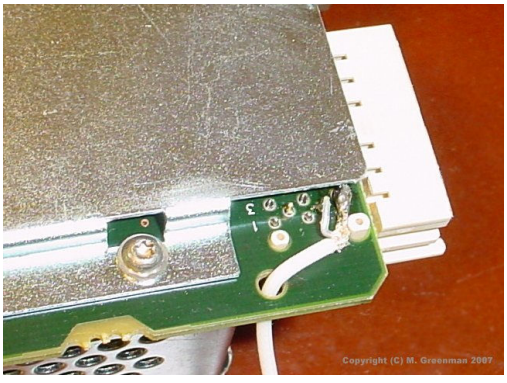


Fig. 4. Antenna connection detail

Alternatively, a special antenna patch cable can be made to connect directly to the GPS module within the unit. The HP (Furuno)

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receiver requires a miniature Hirose S-FLP-LP connector; the CIC (Motorola) requires a conventional SMB connector.

Use a 5V active patch or quadrifilar antenna. The antenna must be mounted well clear of other structures, and above any surrounding trees and metal objects. If the receiver cannot see most of the sky clearly, the quality of the fix and reference stability may suffer, the time to attain a fix may be extended, or the incidence of holdover events may be excessive.

The front panel RS232 socket can be connected to a PC via a null-modem cable (normally such cables have two DB9 female connectors) and a male – male DB9 adaptor. A special cable can be made with one DB9-M and one DB9-F connector, cable mount style, connected via a screened cable wired pin 2 to pin 3, pin 3 to pin 2, pin 5 to pin 5, and screen to frame at each end. See Section 4 for a drawing of a suitable cable.

Connect the GPS antenna, but do not run any software before starting the unit. Without the GPS antenna, startup may be considerably delayed, even once the antenna is connected. If software is running,and polling the unit when power is applied, communications can be confused. The CIC unit may stay in boot mode if powered up while being actively polled.

Powering Up

Apply power and check for LEDs illuminated on the front panel. Check that the power supply does not run hot, and check for no excessive heat from the unit. Check the antenna voltage at the white block connector – it should drop a few mV when the antenna is connected, but remain close to +5V.

The front panel LEDs should indicate Power On and Status Unlock. Since there is no battery backup to the GPS module, each time power is applied, the unit must newly acquire the satellites, the almanac and the ephemeris. This can take up to 20 minutes, as first the receiver must:

- Scan the available frequency band in order to locate a first satellite (the frequencies differ, and besides the satellite signals have Doppler and the receiver synthesizer reference is not accurate).
- Tune to and track the first satellite found, long enough to obtain the current almanac information, which includes the current date and time, and information about which satellites are currently out of service or inaccurate.
- Then download the ephemeris, which tells the receiver how to predict where each satellite is, and therefore which ones are above the horizon and should be searched for and tracked.
- Scan for each subsequent satellite which should be in view. Once each one is found, the frequency data for that satellite (at the current receiver temperature!) can be stored for future reference. Start decoding information from these additional satellites (up to eight satellites at once).
- Use preliminary data from the satellites to derive a tentative ‘fix’, in order to derive a position for short-term timing use and a starting point for the subsequent survey.

Once the GPS position is acquired, the GPS Available LED is illuminated, and the GPS receiver moves into Site Survey mode. Many hours later (about one hour from warm start, at least eight hours from cold start) the GPS module moves into Position Hold mode, all the while providing timing information to the GPSR with increasing accuracy.

While this process is occurring, it is worthwhile monitoring the process with a simple software program using the :SYST:STAT? Query. See Section 3 for more information.

Before the fix is acquired, the GPSR control system holds the reference oscillator mid-range, or at the last known useful EFC value. Once the fix is acquired, the GPSR attempts to lock the reference oscillator. Initially there will be relatively large excursions in the EFC value in order to attain syntonicity (frequency lock). Once the frequency is correct, the Status Active LED is illuminated. The control system continues to make small adjustments to the reference

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oscillator phase in order to achieve synchronism (time difference from GPS approaching zero).

Achieving frequency lock can take 20 minutes to 30 minutes, and best phase accuracy may take several hours. Best performance and the ability to maintain accurate holdover is not attained for several days, during which the Smart Clock learns the operating characteristics of the Reference Oscillator.

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3. Software

GPSR Firmware

The GPSR uses a command and query language known as SCPI (named after the organization which fosters and monitors its development). This language is a general purpose instrument language, and not especially suited to use with devices such as the GPSR. The protocol makes manual query and command ponderous at best, and also makes life difficult for the software writer, since the syntax is not fully defined.

The Symmetricom 58503B User Manual[3] is a good reference to the SCPI protocol, although it contains many commands not applicable to the GPSR.

Specific commands and queries are covered in detail in the Section 6.

Recommended Software

In this section we must clearly differentiate between software for the HP Z3815A and the CIC GPSR-A. The ***only*** software which currently works with ***both*** units are two development tools by Murray Greenman and a suite of programs by Con Wassilieff. These are:

GPSRTERM	A simple manual DOS terminal program with function keys
GPSRSPY	A version of GPSRTERM used to capture responses from the GPSR to file in binary and ASCII. Great for programmers.
GPSR Terminal	A suite of three Windows™ programs for Z3801A, Z3815A and CIC GPSR-A. Very comprehensive!

Conventional terminal programs will operate correctly with the HP (including Windows Terminal function keys, if set up correctly). Provided commands are hand typed, a conventional terminal program can also be used with the CIC GPSR-A.

The reason for the paucity of software which supports both units is the combination of a completely different method of sending commands to the CIC unit, and a need for different received data decoding rules.

HP Z3815A Software

Three commercial packages should operate correctly with the Z3815A, at least insofar as the commands are relevant. These are:

SATSTAT	A terminal program by HP and Symmetricom used to send manual commands and queries, and to display status and time. No graphics features are provided. Known to work well with the Z3815A.[4]
GPSCON	A fully featured Windows program with graphics and many advanced features such as network and internet operation. Designed for the Z3801A and the Z3816A.[5]
BDSYSTEMS	A fully featured Windows program for the Z3801A and Z3816A.[6]

[3] See http://www.symmetricom.com/support/ttm-manuals-product.aspx?pType=GPS
[4] Download from http://www.symmetricom.com/Support/knowledge_base/software_download.aspx?prodtype=TTM&file=58503_SatStat50.zip
[5] Contact Graham Baxter [graham@delphe.co.uk]
[6] Contact BD Systems Inc. [bdsysco@yahoo.com]

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Two simple DOS program by Murray Greenman[7] also provides functionality for older computers:

Z3815A1	Simple status display for the Z3815A.
Z3815A5	Graphical monitor program for the Z3815A. Logs data to file in CSV format.

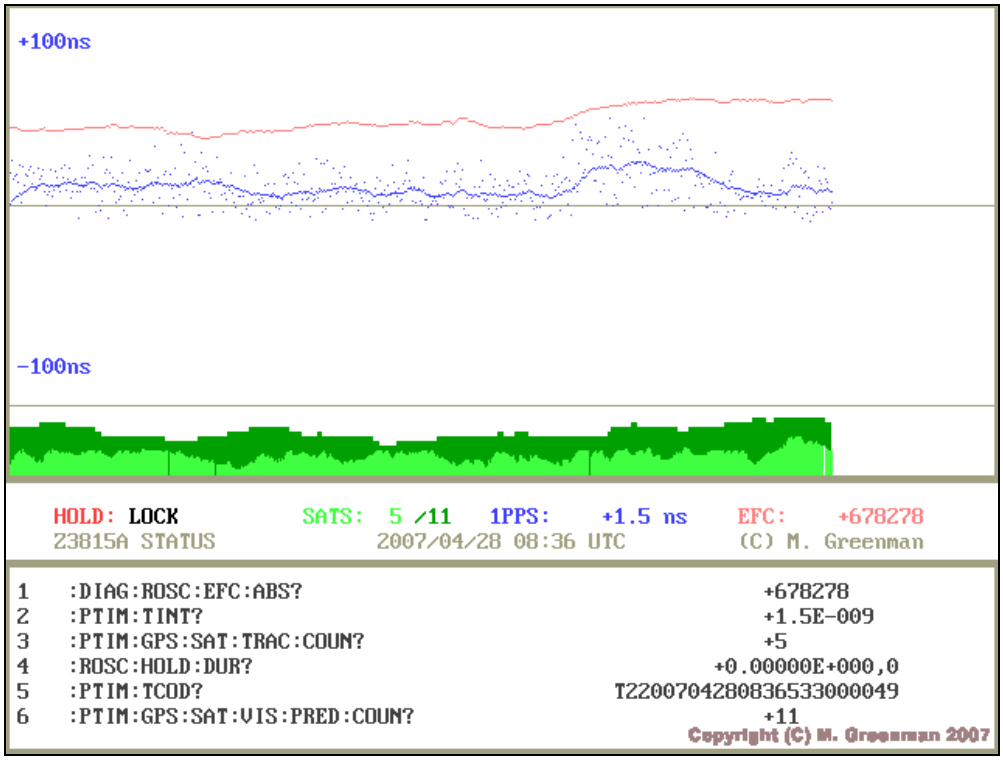


Fig. 5. Screenshot of the Z3815A5 software

Another DOS program by Murray Greenman[8] allows direct monitoring of the Z3815A Furuno GPS module (modifications must be made to the GPSR):

FURUNO	Simple DOS NMEA monitor and display program

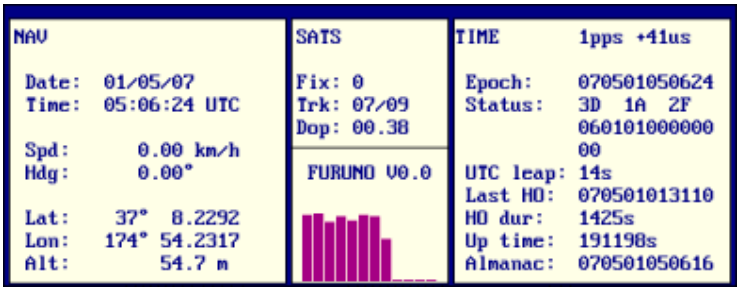


Fig. 6. Screenshot of the FURUNO software

[7] Download from http://www.qsl.net/zl1bpu/PRECISION/Z3815A/z3815a.zip
[8] Download from http://www.qsl.net/zl1bpu/PRECISION/Z3815A/Furuno/FURUNO.zip

Provided that the modification has been made to provide direct RS232 output from the GPS module, many of the NMEA messages from the Furuno GPS module can also be monitored by the free-ware program VISUALGPS[9].

A graphical Windows program specifically for the Z3815A is currently under development by Con Wassilieff. It currently also has limited support the CIC GPSR-A.

Z3815Aterminal Graphical program with status window, satellite monitor and pre-defined message query (to be released)

CIC GPSR-A Software

The only program currently known to operate with this unit was specifically written for the CIC by Murray Greenman:

GPSRVIEW A graphical monitor program for the CIC, complete with satellite histogram and constellation display. This is a DOS program and requires a 300MHz computer running Windows 98SE or earlier.

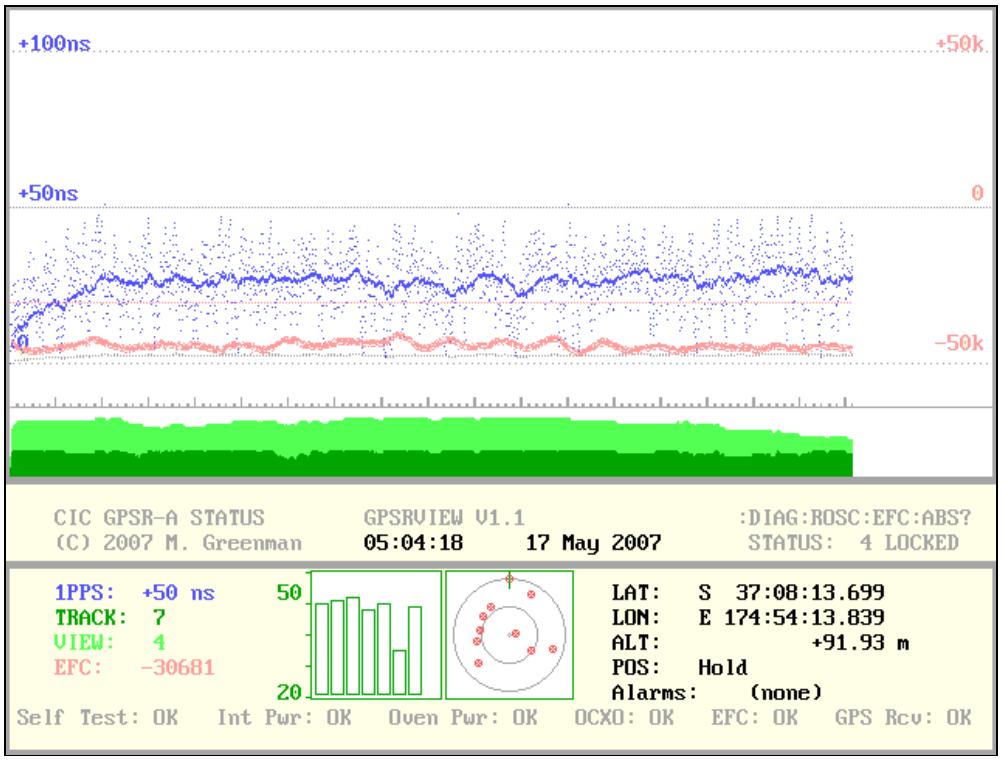


Fig. 7. Screenshot of the GPSRVIEW software

The CIC GPS module is a Motorola Oncore 12-ch, which operates in Motorola Binary mode at 9600-N-8-1. An external PC program (such as WinOncore) can be used to monitor the communications, provided a suitable RS232 adaptor is added. A clock or other application could be made to follow this data, which consists (only) of the '@@Ea' date/time/navigation and status message.

[9] http://www.visualgps.net/VisualGPS/default.htm

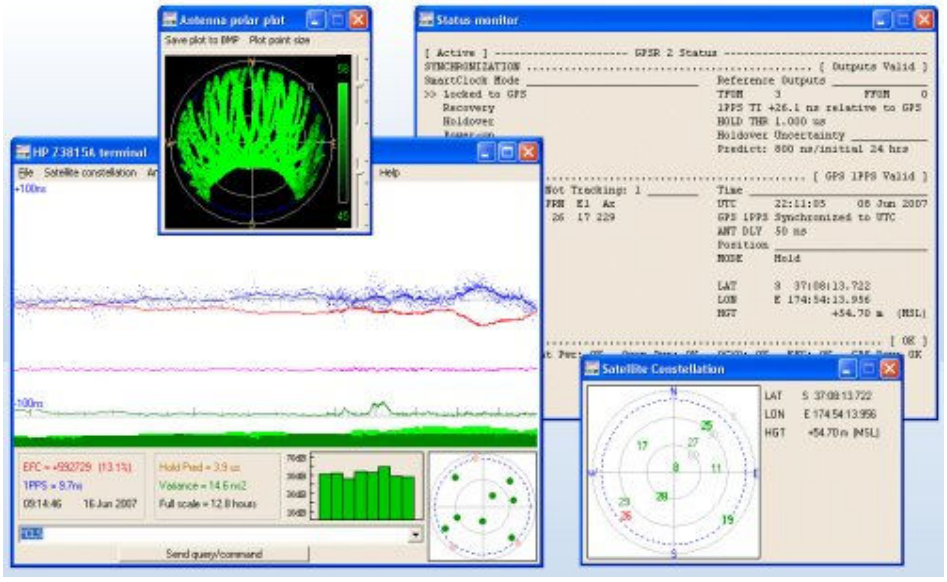
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Windows Software

The software suite GPSR Terminal by Con Wassilieff[10] provides a separate but similar program for the HP Z3801A, the HP Z3815A, and the CIC GPSR-A. In appearance and functional respects the programs are the same, but the commands and responses are different. The features of this software are very comprehensive.

As well as a scrolling graph showing 1pps TI, EFC, Holdover, TI variance and satellite fix information, the program includes a satellite signal strength histogram and constellation diagram, separate status display window, and pop-up windows for detailed satellite constellation diagram, an antenna performance plot, and manually requested information. The programs are compatible with Windows™ 95, 98, 2000, and XP, and will even operate on a 100MHz laptop. The software:

- Plots 1pps TI, TI average, TI/10, EFC LSBs, TI variance, Holdover Prediction and mean satellite C/N
- Makes no registry or system modifications - simply delete files to uninstall
- Has a free-form manual message capability, with pop-up window
- Has low memory and disc footprint, low processor requirements
- Has pop-ups for satellite constellation and antenna polar plot
- Includes versions for Z3801A, Z3815A and CIC GPSR-A
- Plots satellites in fix, satellites in view, holdover status
- Displays satellite constellation and signal histogram
- Has a separate refreshed status message window
- Displays correct UTC time and date



GPSR Terminal Software in action with an HP Z3815A

[10] Download from www.qsl.net/zl1bpu/PRECISION/Z3815A/GPSR Terminal.zip

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Using Manual Commands

As outlined in a previous section, manual control of the units is somewhat tedious, due to the clumsiness of messages and the absolute intolerance of typing mistakes. The best way to operate the units manually is to use a terminal program.

For the HP Z3815A, use the SATSTAT program, Windows TERMINAL[11] or Murray Greenman's GPSRTERM DOS program. TERMINAL can be set to send a whole range of pre-defined commands, which considerably eases the pain. GPSRTERM includes 10 favourite predefined commands using function keys. Set the programs for 9600-N-8-1 operation. The Z3815A is believed to use XON/XOFF control.

For the CIC, if you wish to use pre-defined commands, you can only use GPSRTERM. Edit the setup file for 19200 baud (19200-N-8-1). Control is via a pacing mechanism for transmitted requests, and the use of a huge receiving buffer for the high speed response.

There is no substitute for experimentation. Try the commands listed in Section 6 (avoiding the system reset command which wipes all the learned parameters!) and observe their action. An invalid or incorrectly typed will result in the prompt changing to '-E113>'. This can be cleared using the *CLS command.

[11] TERMINAL was supplied with Windows 3.1! It is better suited to this situation than Hyperterminal, and in addition it has programmable function keys.

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4. Features and Functions

Antenna Input

The GPS antenna is connected to the topmost white coax connector block A4. The connector is an unusual one (type unknown), and is best replaced using one of the techniques discussed under 'Getting Started'.

The antenna input is 50 Ohm, but carries +5V power for an active antenna. The maximum current that can be drawn by the antenna is 50mA (short circuit current 270mA). Clearly the user should guard against shorting the antenna connector or cable.

The antenna is connected to +5V via a 20 Ohm resistor, used to sense the presence of the antenna. If a passive antenna is used (not recommended), a resistor should be added in parallel to simulate preamp current of say 50mA. An alarm is generated when the antenna current is too low or too high. Disconnecting the antenna will force the unit into holdover.

DC Power

Power connections are independent of supply polarity, although an AC supply is not permitted. The power supply should be connected between backplane pins A59 – A63 (DC In A) and pins A54 – A58 (DC In B), using PCB strip connector pins with 2.54mm spacing.

Note:
Under no circumstances connect power to any other pins on the backplane, or serious damage will occur.

It is recommended that the nearby holes in the backplane be blocked in some way (piece of tape?) or the connector be fastened permanently in place. The unit will run off nominal 24 to 50V DC supplies. Unless the power supply is adequately rated (40W) the unit may not start correctly. Current is maximum during the first 10 minutes as the oven warms up.

A backup power supply is highly recommended. This needs to be of the 'no break' or uninterruptable variety. While a UPS used to power the DC power supply is an obvious option, a very simple approach is to use a pair of 7AH gel-cell sealed lead-acid batteries in conjunction with a DC supply. See the drawing below.

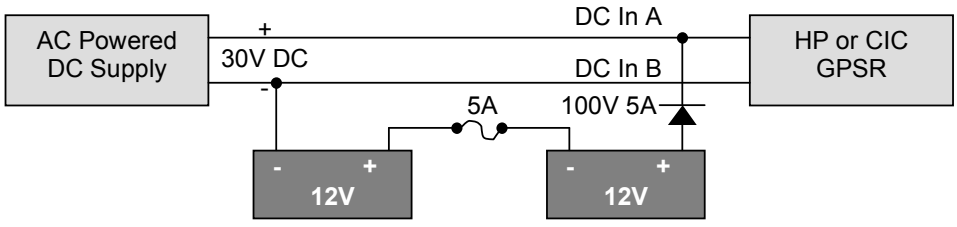


Fig. 8. A suitable battery backup arrangement

The batteries are series connected to the output of the AC powered DC supply via a 100V 5A diode arranged so that the battery supplies current only when the AC powered DC supply has failed. (Diode anode to battery +, diode cathode to DC supply +, battery – to DC supply -).

The AC powered DC supply must provide at least 30V under load in order to prevent the diode from conducting and flattening the battery. Separate arrangements will need to be made for charging the batteries correctly. The unit will continue to operate as the batteries go flat (down to below 16V), but clearly damage to the batteries will result if this occurs.

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10MHz Outputs

Three sine wave 10MHz outputs are provided on the white coax block, B1, B2 and B3. These outputs provide 5V p-p open circuit, 2.5V into 75 Ohm, and 2V p-p into 50 Ohm. The output impedance is 75 Ohm. These outputs are enabled only when the GPSR is locked.

Other Outputs

Three further digital (square wave) frequency outputs are provided on the backplane connector. These are all at pseudo-ECL levels, balanced outputs capable of driving into 50 Ohm, or driving a current driven line receiver such as an RS422 receiver over very long cables.

These frequencies are derived very accurately from the 10MHz signal via a phase-locked loop process. They share the precision of the main reference. The frequencies are 19.6608MHz (300×2^{16}), 4.096MHz (1000×2^{12}) and 1.544MHz. These outputs are enabled only when the GPSR is locked.

8kHz (125us period pulses) and 50Hz square wave outputs are also provided.

Serial Port

The front panel serial port is wired as a DCE, and fitted with a female DB9 connector. Only three pins are wired – RXD, TXD and GND. There is no hardware handshake. The HP Z3815A is believed to respond to XON/XOFF, but the CIC unit does not.

In the HP, the default settings are 9600-N-8-1, but are adjustable from 1200 to 19200 bps and a range or parity settings,. The serial port settings for the CIC are not adjustable, and are at 19200-N-8-1 with 10ms pacing required.

A suitable connection cable to a PC serial port would be a 'Null Modem' cable (usually these have a DB9 female connector at each end), in conjunction with a DB9 male – male adaptor. The adaptor can be used at either end of the cable (but not both).

A suitable cable can also be made as follows:

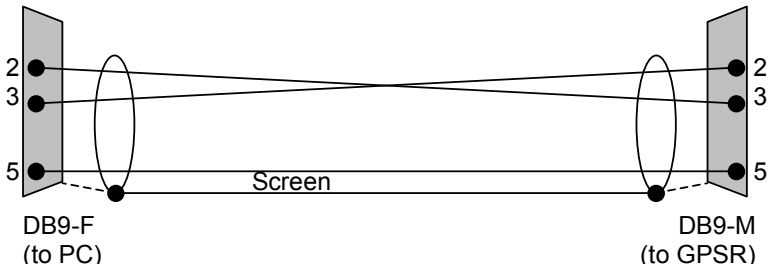


Fig. 9. Connections for the PC cable

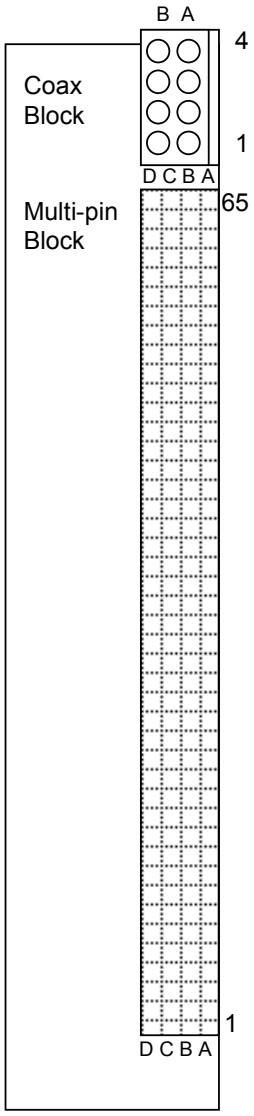
The cable should be 2m long and should preferably be screened and use metal shielded connectors to minimize radio interference – not just serial data noise, but to prevent leakage of the reference signals. The shield should connect to the connector covers. One connector is both DB9 male (connects to GPSR), while the other is DB9 female (connects to PC). The cable is therefore not reversible.

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Rear Connectors

Table 1 -
View of rear panel (scale about 1:2)





Notes:

DC in (A) is 20 – 56V DC with respect to DC In (B).

1.544 & 4.096 MHz clocks: 2v ppk square wave push-pull +A -B, +C -D
19.6608 MHz – 5v ppk sine wave

2s pulses: 75uS triangular -ve going ramp starting on a +3v DC pedestal, 2 sec apart

125uS pulses: 0.6uS wide
20mS pulses: 4mS wide

COAX BLOCK

B4		A4	GPS Antenna
B3	10MHz –3dBm	A3	
B2	10MHz –3dBm	A2	
B1	10MHz –3dBm	A1	

MULTI-PIN BLOCK

	D	C	B	A
65	0V	0V	0V	RF Gnd
64	+4.47V	+4.47V	0V	
63	+4.47V	+4.47V	0V	DC In (A)
62	+4.47V	+4.47V	0V	DC In (A)
61	+4.47V	+4.47V	0V	DC In (A)
60	+4.47V	+4.47V	0V	DC In (A)
59	+4.47V	+4.47V	0V	DC In (A)
58	+4.47V	+4.47V	0V	DC In (B)
57	+4.47V	+4.47V	0V	DC In (B)
56	+4.47V	+4.47V	0V	DC In (B)
55	+4.47V	+4.47V	0V	DC In (B)
54	+4.47V	+4.47V	0V	DC In (B)
53	+4.47V	+4.47V	0V	0V
52	+4.47V	+4.47V	0V	+5V
51	+4.47V	+4.47V	0V	0V
50	+4.47V	+4.47V	0V	+2V
49	+4.47V	+4.47V	0V	+2V
48	+4.47V	+4.47V	0V	0V
47	+4.47V	+4.47V	0V	19.6608 MHz
46	0V	0V	+4.47V	0V
45	20mS +ve	20mS -ve	20mS +ve	20mS -ve
44	0V	0V	0V	0V
43	125uS +ve	125uS -ve	125uS +ve	125uS -ve
42	0V	0V	0V	0V
41	1.544 MHz	1.544 MHz	1.544 MHz	1.544 MHz
40	0V	0V	0V	0V
39	4.096 MHz	4.096 MHz	4.096 MHz	4.096 MHz
38	0V	0V	0V	0V
37	+4.2V	2s pulse	0V	0V
36	+4.2V	2s pulse	0V	0V
35	+4.2V	2s pulse	0V	5V
34	+4.2V	2s pulse	0V	0V
33	+4.2V	2s pulse	0V	5V
32	+4.2V	2s pulse	0V	0V
31	+4.2V	2s pulse	0V	0V
30	+4.2V	2s pulse	0V	0V
29	+4.2V	2s pulse	0V	0V
28	+4.2V	2s pulse	0V	5V
27	+4.2V	2s pulse	0V	0V
26	+4.2V	2s pulse	0V	5V
25	+4.2V	2s pulse	0V	0V
24	+4.2V	2s pulse	0V	0V
23	+4.2V	2s pulse	0V	5V
22	+4.2V	2s pulse	0V	0V
21	+4.2V	2s pulse	0V	0V
20	+4.2V	2s pulse	0V	5V
19	0V	0V	0V	0V
18	+4.47V	+4.47V	0V	0V
17	+4.47V	+4.47V	0V	0V
16	+4.47V	+4.47V	0V	5V
15	+4.47V	+4.47V	0V	0V
14	+4.47V	+4.47V	0V	0V
13	+4.47V	+4.47V	0V	0V
12	+4.47V	+4.47V	0V	0V
11	+4.47V	+4.47V	0V	0V
10	+4.47V	+4.47V	0V	0V
9	+4.47V	+4.47V	0V	0V
8	+4.47V	+4.47V	0V	5V
7	+4.47V	+4.47V	0V	0V
6	+4.47V	+4.47V	0V	DTA –ve
5	+4.47V	+4.47V	0V	DTA +ve
4	+4.47V	+4.47V	0V	0V
3	+4.47V	+4.47V	0V	+2V
2	+4.47V	+4.47V	0V	+2V
1	+4.47V	+4.47V	0	0V

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5. The Status Screen

The HP and CIC units have a very similar status display. This message contains most of the information a user might need in one fixed-format response. The message is the response to the :SYST:STAT? query. It can be displayed on a dumb terminal, or a computer using just about any terminal software. Set the software to ignore CR, and use a fixed format font.

Note:
When using commercial terminal software with the CIC unit, the commands must be hand typed.

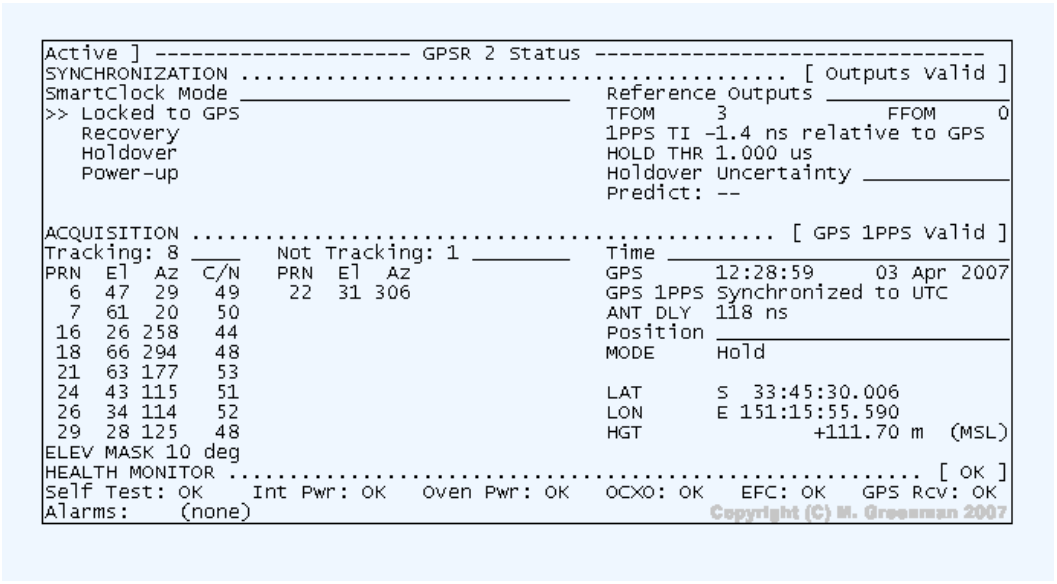


Fig. 10. The GPSR Status Message Response

The message is divided into several logical areas – Acquisition, Synchronization and Health.

Acquisition

The Acquisition area shows the GPS tracking and fix status, i.e. how well the GPSR is proceeding with the process of producing an accurate internal reference. It also shows the time and position information.

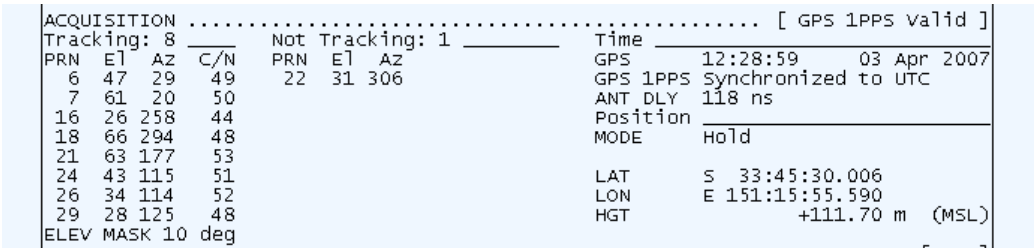


Fig. 11. Acquisition section of Status message

At the right of the line starting 'ACQUISITION…….' is an important indicator which shows the GPS engine timing status (the output of the T-RAIM feature which monitors the overall accuracy of the 1pps information supplied by the GPS module). This message can read:

[GPS 1PPS Valid]	(GPSR synchronized to GPS)
[GPS 1PPS Invalid]	(GPSR not yet synchronized to GPS)

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Beneath the 'ACQUISITION' title line to the left is the information regarding the current GPS satellite constellation. The number of satellites in view (above the horizon) is the total of those being tracked, and those not tracked. The CIC displays the numbers slightly differently, as it frequently shows all satellites tracked, whether or not they are above the horizon. In addition, the Azimuth and Elevation information is usually incorrect, and frequently zero.

Satellites

Referring back to Fig. 11, below the tracking information is a list of satellites which are being tracked (up to eight) and to the right a list of satellites not tracked. In each case the satellite identity (pseudo-random code, PRN), elevation (angle above the horizon from receiver, El), azimuth (bearing from true North from receiver, Az) and carrier to noise ratio (signal strength, C/N) are displayed.

The status of satellites[12] not being tracked can be:

Not OK	Reported unhealthy by GPS service, or not of sufficient elevation
Acq	Attempting to acquire the satellite signal
Acq.	Reading timing information from satellite
Acq..	Reading satellite orbital information

The final line in the Acquisition section reminds the user of the elevation mask (the elevation angle below which any satellite will be ignored). It is usual to be conservative when setting the elevation mask for GPS timing receivers, as propagation timing errors increase markedly at low elevations. 10° (as shown) or higher is usual.

Time and Position

The time and date indicated in the Status message (Fig. 11, right) is GPS time, i.e. that of the GPS system, which does NOT include leap seconds applied to UTC. In other words, the time shown will be ahead of UTC (and civil time) by the Leap Second offset, 14 sec at time of writing.

This can be changed (in the Z3815A) to display UTC time via the **:PTIM:TCOD:FORM F1** message.

In the position section, the GPS receiver survey mode is shown ('Hold' or 'Survey'). The position and height is either the current value (during survey) or the hold position (in hold).

A survey progress message is also shown in this area if the mode is 'Survey'.

Synchronization

The Synchronization section provides status information for the 10MHz Reference Oscillator, and about the process of synchronizing the 10MHz Reference to the 1pps from the GPS receiver. This is the section at the top of the message, starting with 'SYNCHRONIZATION…….'.

```
SYNCHRONIZATION ..................................... [ Outputs Valid ]
SmartClock Mode _____________________________  Reference Outputs _____________
>> Locked to GPS                              TFOM     3        FFOM     0
   Recovery                                   1PPS TI -1.4 ns relative to GPS
   Holdover                                   HOLD THR 1.000 us
   Power-up                                   Holdover Uncertainty ___________
                                              Predict: --
```

Fig. 12. Synchronization section of Status message

At the right of this first line (Fig. 12) is an important indicator which shows the validity of the 10MHz and other synchronized products (19.6608MHz, 4.096MHz, 1.544MHz, regenerated 1pps). This indicator can show:

[12] Marked differently in the CIC. An acquiring satellite has an asterisk '*' ahead of the PRN

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[Outputs Invalid]	(GPSR warming up)
[Outputs Valid/Reduced Accuracy]	(GPSR in holdover, or locked but not steady)
[Outputs Valid]	(GPSR in steady operational state)

Smart Clock

Beneath the 'SYNCHRONIZATION' title line (Fig. 12, to the left) is a list of four operating Smart Clock states:

>> Locked to GPS
Recovery
Holdover
Power-up

The currently active state is the one marked '>>' at the start of the line (in the above example, the 'Locked to GPS' state). When the unit is started up it passes through these states, which are also indicated via the front panel LEDs.

Reference Outputs

To the right (Fig. 12) is a section which gives indicator values for Smart Clock controlled parameters. The first of these are the 'TFOM' (Time Figure of Merit) and 'FFOM' (Frequency Figure of Merit).

TFOM	Time Error	TFOM	Time Error
0	<1ns	5	10-100us
1	1-10ns	6	100-1000us
2	10-100ns	7	1-10ms
3	100-1000ns	8	10-100ms
4	1-10us	9	>100ms

Essentially the TFOM is a logarithmic presentation of the Time Error in ns, so the smaller the better. TFOM lower than 3 may not be shown in these units due to lack of timing resolution.

FFOM	Status
0	Stabilized – within specification
1	Reference Oscillator is stabilizing
2	Unlocked (in holdover)
3	Unlocked (not in holdover) – do not use

The reference outputs are disabled when the FFOM is >2. Stabilizing is the process of achieving synchronization (phase agreement) once syntonization (frequency agreement) is complete.

1pps TI

Indicates the instantaneous timing difference between the GPS 1pps and the Smart Clock regenerated 1pps (the system time). During stable operation this difference mostly reflects propagation errors and resolution limitations in the GPS receiver. The CIC only displays TI with 50ns resolution.

HOLD THR

Is the user-set time error threshold.

Holdover Uncertainty

This item gives a prediction of the holdover performance after 24 hours without GPS. The prediction is not available until the Smart Clock has learned the Reference Oscillator performance. It is not indicated at all in the CIC GPSR-A.

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Health Monitor

At the very bottom of the Status screen is a three-line 'Health Monitor' for the system. The first line starts with 'HEALTH MONITOR….." and has an important indicator at the end of the line. This will normally read 'OK', if all the individual health flags are OK. If any of the flags indicates a problem, this will indicate 'Err'.

The individual health checks (next line) normally indicate 'OK', but will indicate 'Err' if the condition is in error, as follows:

Self Test	The last microprocessor system test of all components failed
Int Pwr	Internal power supply exceeds tolerance
Oven Pwr	Oscillator oven power supply exceeds tolerance
OCXO	Oscillator output failed
EFC	Oscillator control voltage at or near full scale
GPS Rcv	Satellite receiver communications or 1pps signal failed

The final line specifies the most recent (uncleared) alarm.

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6. Commands and Queries

The GPSR uses an instrument command and query language called SCPI.[13]

The unique features of the SCPI protocol are its hierarchial structure, a lack of syntax precision in responses, and the use of a command prompt which changes with the mood of the device! There are also quite distinct differences in the way the HP and CIC devices have interpreted and deployed the protocol. This will be obvious from the different serial communications settings, but there are more subtle differences in the behavour, such as use of CR and LF characters, and differences in prompt, which make universal software a very complex proposition.

Fortunately the HP Z3815A does operate with commercial software intended for the HP Z3801A, Z3816A and the Symmetricom 58503B, so it is the CIC GPSR-A that might be considered the 'odd man out'.

Two general types of messages exist. These are by nature ***commands*** (instructions to change something) and ***queries*** (requests for information). These can be differentiated by the use of a '?' at the end of the query, but not at the end of the command.

The messages are generally made up of multiple words, subdivided through the hierachy by a colon ':', which precedes every message word (except for some single word examples). The messages are subdivided into functional groups through the use of specific primary key words. These are:

*	Precedes single word non-exemplary commands
:DIAG	Diagnostic group
:GPS	GPS related group
:PTIM	Time group
:ROSC	Oscillator group
:STAT	Status group
:SYNC	1pps timing group
:SYST	System group

As an example, the query which asks for the current absolute EFC value is:

:DIAG:ROSC:EFC:ABS?

Some message groups have as few as one working message, which makes little sense.
Some commands are accessable from multiple groups, or (in the CIC) only from a different group!

There are several messages that do not use the message hierachy. These are the '*' commands and queries. Examples are:

*CLS	Clear error condition and clear error prompt to 'SCPI>'
*IDN?	Query GPSR identity
*TST?	Perform self test and reset (a command, despite the '?'!)

Commands and queries can be sent in upper or lower case, and are echoed in upper case. The key words can be used in an approved shortened form or in full, but not anywhere in between. In this document, only the shortened form is shown. There is also no foolproof[14] mechanism for correcting errors in hand-typed messages – they have to be aborted (press ENTER) and started again.

[13] Standard Commands for Programmable Instrumentation. See http://www.scpiconsortium.org/

[14] It seems that 'backspace' works when used from Hyperterminal

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In the following tables, the commands are shown only in short form, and only brief details are given. Refer to the HP Z3801A manual or the Symmetricom 5350B manual for a more detailed description of their purpose and syntax. Those interested in developing software would be well advised to make use of the GPSRSPY program, and to consult the 5350B manual, which gives a good description of the SCPI protocol and syntax.

These command lists are by no means exhaustive. There are undoubtedly commands that have yet to be discovered!

HP Z3815A Messages

COMMAND	FUNCTION	TYPICAL RESPONSE
*CLS	Clear error prompt	scpi>
*ESR?	Returns and clears error status register	+0
*IDN?	Request ID	HEWLETT-PACKARD,Z3801A,3542A07543,3543-A
*TST? ¥	Perform self test, restart	+0 (if all OK)
:DIAG:GPS:UTC n	Set time/date to UTC (n=1) or GPS (n=0)	None, must subsequently perform *TST? for this command to work
:DIAG:GPS:UTC?	Request time/date format	0 = GPS, 1 = UTC
:DIAG:IDEN:GPS?	Request GPS unit information	"–","SFTW P/N # 4850113","SOFTWARE VER # 004","–"'"–"'"MODEL # FURUNO GT-74","–","–","–","–"
:DIAG:LOG:READ?	Request latest log item	Timestamp and latest error event described
:DIAG:LOG:READ:ALL?	Request error log	List of all errors since log cleared
:DIAG:LOG:CLE	Clear error log	Time stamp and clear event log entries
:DIAG:ROSC:EFC:REL?	Request Relative EFC voltage	+1.69286E+001
:DIAG:ROSC:EFC:ABS?	Request Absolute EFC voltage	-30684
:GPS:INIT:DATE yy,mm,dd	Set current date	
:GPS:INIT:TIME hh,mm,ss	Set current time	
:GPS:INIT:POS N|S,deg,min,sec,E|W,deg,min,sec,elev	Set current position (format as below - elevation is in metres)	
:GPS:POS?	Request current position	S,+37,+8,+1.39180E+001,E,+174,+54,+1.38200E+001,+8.74300E+001
:GPS:POS:HOLD:LAST?	Request last held position	As above
:GPS:POS:SURV ONCE	Forces position survey	
:GPS:POS:SURV:STAT :POW?	Request power-up survey behaviour	0 (will use last powerdown state) 1 (will survey on power up)
:GPS:REF:ADEL nn NS	Set antenna delay to nn ns	
:GPS:REF:ADEL?	Request antenna delay	+0.00000E+000
:GPS:SAT:TRAC :EMAN nn	Set elevation mask angle to nn degrees (0 – 89)	
:GPS:SAT:TRAC:EMAN?	Request elevation mask angle	+10
:GPS:SAT:TRAC:IGN nn,nn,...	List satellites to be ignored (can use :NONE or :ALL)	
:GPS:SAT:TRAC:IGN?	List ignores satellites	+0
:PTIM:LEAP:ACC?	Request UTC leap secs	+14
:PTIM:DATE?	Request GPS date	+year,+month,+day
:PTIM:DATE?	Request GPS time	+hour,+minute,+second
:PTIM:GPS:SAT:TRAC?	Request list of sats tracked	2,6,9,23,31
:PTIM:GPS:SAT:TRAC :COUNT?	Request number of satellites tracked	7
:PTIM:STR?	Request time in string form	"05:43:05" (includes quotes)
:PTIM:TCOD?	Returns time code	T1#H337EDF8530000BC (format 1, GPS hexadecimal) T2200705231051093000003C (format 2, UTC decimal)
:PTIM:TCOD:FORM?	Returns currrent time format	F2
:PTIM:TCOD:FORM Fn	Force time code to mode n	
:PTIM:TZON nn	Set system time offset	
:PTIM:TZON?	Request UTC time zone offset	+0,+0
:ROSC:HOLD:DUR?	Request duration of holdover, holdover status	+4.91000E+002,0
:SYNC:HOLD:INIT	Force receiver into holdover	No respose – goes into holdover
:SYNC:HOLD:REC:INIT	Recover receiver from holdover	No respose – comes out of holdover
:SYNC:IMM	Force fast sync if recovering	
:SYNC:TINT?	Request 1pps timing offset	-4.13E-008
:SYST:COMM:SER2 :BAUD?	Query diagnostic port baud rate	+9600
:SYST:COMM:SER2 :BAUD nn	Set diagnostic port baud rate	nn = 1200, 2400, 9600 or 19200

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:SYST:COMM:SER2 :FDUP?	Reports whether serial port is FDX or HDX	1 (FDX), 0(HDX)
:SYST:COMM:SER2:PARITY?	Query parity of diagnotic port	NONE, ODD or EVEN
:SYST:COMM:SER2:PARITY pppp	Set parity of diagnostic port	Pppp = NONE, ODD or EVEN
:SYST:ERR?	Describes syntax error, e.g.	- 113, Indefined header
:SYST:PRES §	Reset to factory settings	Reset message, plus string of HEX data repeated every few minutes
:SYST:STAT?	Request Status message	Full screen message (about 2000 characters)

¥ Note:
This command also resets the unit

§ Note:
Do not use :SYST:PRES unless absolutely necessary. You will lose all the system preset values, including the 'Smart Clock' parameters, with the result that the system will take some days to return to peak performance, and various alarms may appear. Cycling the power is ugly but preferable! If you need to reset, use *TST?. Some units may also respond to :SYST:PON, which simulates cold start.

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CIC GPSR-A Messages

COMMAND	FUNCTION	TYPICAL RESPONSE
*CLS	Clear error prompt	scpi>
*IDN?	Request ID	CHONGHO I&C Co,.LTD. GPSR-000000 ver3.03 2001/04/12
:DIAG:LOG:READ?	Request latest log item	Timestamp and latest error event described
:DIAG:LOG:READ:ALL?	Request error log	List of all errors since log cleared
:DIAG:LOG:CLE	Clear error log	Time stamp and clear event log entries
:DIAG:ROSC:EFC:REL?	Request Relative EFC voltage	+1.69286E+001
:DIAG:ROSC:EFC:ABS?	Request Absolute EFC voltage	-30684
:GPS:POS?	Request current position	S,+37,+8,+1.39180E+001,E,+174,+54,+1.38200E+001,+8.74300E+001
:GPS:POS:SURV ONCE	Forces position survey	
:GPS:REF:ADEL nn NS	Set antenna delay to nn ns	
:GPS:REF:ADEL?	Request antenna delay	+0.00000E+000
:GPS:SAT:TRAC :EMAN nn	Set elevation mask angle to nn degrees (0 – 89)	
:GPS:SAT:TRAC:EMAN?	Request elevation mask angle	+10
:PTIM:LEAP:ACC?	Request UTC leap secs	+14
:PTIM:DATE?	Request GPS date	+year,+month,+day
:PTIM:DATE?	Request GPS time	+hour,+minute,+second
:SYNC:HOLD:INIT	Force receiver into holdover	No respose – goes into holdover
:SYNC:HOLD:REC:INIT	Recover receiver from holdover	No respose – comes out of holdover
:SYNC:TINT?	Request 1pps timing offset	No response
:SYST:ERR?	Describes syntax error, e.g.	- 113, Indefined header
:SYST:PRES §	Reset to factory settings	Reset message, plus string of HEX data repeated every few minutes
:SYST:STAT?	Request Status message	Full screen message (about 2000 characters)

§ Note:
Do not use :SYST:PRES unless absolutely necessary. You will lose all the system preset values, including the 'Smart Clock' parameters, with the result that the system will take some days to return to peak performance, and various alarms may appear. Cycling the power is ugly but preferable!

There are four known bugs in the CIC :SYST:STAT? status message, and one other query bug.

1. The 1pps TI is displayed with only 50ns resolution (although clearly it is measured and used to much greater resolution).
2. The satellite azimuth and elevation information is frequently returned as zero, even though the satellite is tracked and the C/N value is returned correctly. This problem comes and goes, and clears on reset.
3. The satellite azimuth and elevation information is usually completely incorrect, even when displayed. Satellites stay in the ‘tracked’ list even when well below the horizon.
4. The satellite ‘tracked’ count is frequently incorrect (probably due to bug 3). The satellites in fix, their PRN and C/N values are correct.
5. Although the :SYNC:TINT? request is accepted without syntax error, nothing is returned.

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7. Specifications

Understandably, the specifications for these units are somewhat sketchy.

GPS Receiver

HPZ3815A – Furuno GT74, eight channel parallel, C/A code. L1 (1575MHz). Sensitivity – 133dBm. NMEA mode, 9600-N-8-1
CIC – Motorola Oncore ??, 12 channel parallel (8ch tracked) C/A code L1 (1575MHz) Motorola Binary mode (@@Ea), 9600,N-8-1

Smart Clock technology, T-RAIM, timing engine. Ephemeris and Almanac kept in EEPROM. Real time clock with battery backup.

Reference Oscillator

HP Z3815A - HP E1938, 10MHz. EFC range 0 – 5V (EFC 0 to 1048575)
CIC - C-MAC STP2145A, 10MHz. EFC range 0 – 10V (EFC –50,000 to +50,000)

10MHz Outputs

Three outputs, 5V p-p sine wave, 75 Ohm (2.5Vp-p into 75 Ohm, 2Vp-p into 50 Ohm)

Frequency accuracy (unlocked) < $1x10^{-9}$ /day

Phase Noise (locked)

100Hz	-120dBc
1000Hz	-130dBc
10kHz	-135dBc

1PPS Output

HP Z3815A - Internal SMB connector
CIC - Internal connection footprint, no connector 5V CMOS, 25us width.

Time accuracy better than 1us (locked to GPS). Jitter <200ns (typically 50ns).
Holdover 7us after 24 hours without GPS following three days with GPS (typically 3us predicted).

Other Outputs

19.6608MHz, 4.096MHz, 1.544MHz, square wave pseudo-ECL balanced output.
8kHz (125us) pulses, 50Hz square wave pseudo-ECL balanced output
Internal 10MHz square wave, 1pps (CMOS 5V), Even sec (1PPS2)
All outputs locked to 10MHz

RS232 Interface

Debug and monitoring using SCPI protocol
DB9F connector, wired as DTE

Antenna

Maximum cable length 50m.
5V preamp power 270mA short circuit protected. Expected current 50mA.

Operating Conditions

0°C to +50°C operating
-40°C to +80°C storage

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Power Supply

Absolute limits 20V DC to 56V DC, polarity independent

24V DC 2A warmup, 1.5A operating (50W)
48V DC 1A warmup, 0.8A operating (50W)

Warmup period is about 10 minutes from cold start
Time to first fix 30 minutes from cold start or when geographically confused or clock lost
Time to Hold 30 minutes from cold start, 10 minutes from reset or holdover

No performance changes noted between 16V DC and 56V DC, either on step change or after 30 minutes (thermal due to power supply efficiency change).

CIC and Z3815A versions without E1938 oscillator, power consumption is about 25% lower

Dimensions

Width	56mm
Height	234mm
Depth	292mm (including rear connectors but not handle)
Mass	~2kg

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