A8

GPS Time & Frequency Standard

OPERATION MANUAL

Contents

1 Safety Considerations

1.1 General

This product and related documentation must be reviewed for familiarisation before operation. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the instrument may be impaired.

1.1.1 Before Applying Power

Verify that the product is set to match the available line voltage and the correct fuse is installed.

1.1.2 Before Cleaning

Disconnect the product from operating power before cleaning.

WARNING

Bodily injury or death may result from failure to heed a warning. Do not proceed beyond a warning until the indicated conditions are fully understood and met.

CAUTION

Damage to equipment, or incorrect measurement data, may result from failure to heed a caution. Do not proceed beyond a caution until the indicated conditions are fully understood and met.

1.1.3 This equipment must be earthed

An uninterruptible safety earth ground must be maintained from the mains power source to the product’s ground circuitry.

WARNING

When measuring power line signals, be extremely careful and use a step down isolation transformer whose output is compatible with the input measurement capabilities of this product. The product’s front and rear panels are typically at earth ground. Thus, never try to measure AC power line signals without an isolation transformer.

WARNING

Instructions for adjustments when covers are removed and for servicing are for use by service-trained personnel only. To avoid dangerous electrical shock, do not perform such adjustments or servicing unless qualified to do so.

WARNING

Any interruption of the protective grounding conductor (inside or outside the instrument) or disconnecting of the protective earth terminal will cause a potential shock hazard that could result in personal injury. Grounding one conductor of a two conductor out-let is not sufficient protection.

Whenever it is likely that the protection has been impaired, the instrument must be made inoperative and be secured against any unintended operation.

If the instrument is to be energised via an autotransformer (for voltage reduction) make sure the common terminal is connected to the earthed pole terminal (neutral) of the power source.

Instructions for adjustments while the covers are removed and for servicing are for use by service-trained personnel only. To avoid dangerous electrical shock, do not perform such adjustments or servicing unless qualified to do so.

For continued protections against fire, replace the line fuse(s) with fuses of the same current rating and type (for example, normal blow time delay). Do not use repaired fuses of short-circuited fuse holders.

1.2 Voltage, Frequency and Power Characteristics

Voltage 220-240V AC

Frequency 40-50Hz

Power characteristics 500mA Max

1.3 Environmental Conditions

1.3.1 Temperature

Operating (ambient)	-10°C to +55°C (-65 to +65 op)
Storage	-40°C to +85°C

1.3.2 Magnetic Field

Sensitivity	$\leq 2x10^{-11}$/ Gauss
Atmospheric Pressure	-60m to 4000m
	$<1x10^{-13}$/ mbar

1.4 Replaceable Fusing Characteristics

800mA time lag HBC

1.5 Cleaning Instructions

To ensure long and trouble operation, keep the unit free from dust and use care with liquids around the unit.

Be careful not to spill liquids onto the unit. If the unit does get wet, turn the power off immediately and let the unit dry completely before turning it on again.

Clean with a damp (with water) cloth.

Never spray cleaner directly onto the unit or let liquid run into any part of it. Never use harsh or caustic products to clean the unit.

1.6 Outdoor Antenna Mounting

Please ensure that all connections are sealed with self-amalgamating tape (as supplied).

2 GPS Time & Frequency Standard A8

2.1 Description

Quartzlock model 8 series GPS frequency standards are microwave, satellite controlled standard frequency sources, which use the emissions of the Navstar GPS satellites to control the frequency of a crystal oscillator, a low cost SC cut OCXO, a low drift SC cut OCXO or a Rubidium Atomic Standard. These satellites all have very high quality atomic clocks on board and their emissions are monitored by all the major time-keeping laboratories in the world, including the BIPM (the International Bureau of Weights and Measures). The accuracy of the Quartzlock model 8 series is thus traceable to the highest international level.

2.1.1 Features

- Software weighted average of all viewed satellite carriers
- Stability to < 1E-12
- High stability and disciplined Rubidium options
- 0.1, 1, 5 & 10 MHz outputs are standard
- 2048 kHz & 13 MHz options available
- Low distortion sine-wave and TTL compatible output Bench-top, Rack-mount, and Euro-cassette forms

2.1.2 Benefits

- International Reference BIPM / UTC Worldwide use (please notify of polar applications)
- High immunity to propagation errors and no ground-wave effects
- Portable and can advantageously replace Caesium, which has a limited tube life
- Much improved performance over other GPS standards

2.1.3 Applications

- Standards Labs; calibration of counters, timers, radio equipment and all quartz based instrumentation
- Telecoms synchronisation; Stratum I & IGSM, PCN base station commissioning
- Timescale correction to UTC, use with software clocks Time transfer Radio transmitter frequency referencing including quasi-sync systems.

2.2 Technology

For the extraction of stable and accurate frequency information from the complex signal format, this receiver uses an ultra high resolution carrier phase measurement in addition to the C/A code tracking used in all normal equipment. The high precision of this carrier gives a time and frequency resolution which is as much as 10,000 times better than that which can be resolved using C/A correlation alone. The resolution is so high that the frequency of the local oscillator can be measured to 1E-10 in < 0.1 second allowing ultra precise tracking of the reference signal.

2.3 Features & Benefits

Unlike most low cost GPS receivers the Quartzlock Model 8 series frequency standard receivers are able to perform extremely high-resolution carrier phase measurements for each satellite being tracked. This yields a frequency resolution, which is better than "code-only" detection by a factor of 10000. By performing carrier smoothed high-resolution code evaluation, the Model 8 is able to make range (or time) measurement of far superior precision to non-carrier, code-only detection receivers. This enables the Model 8 to detect almost instantaneously, any local oscillator frequency excursions and make fast corrections such that, even with a low cost crystal, the short-term stability is well controlled. The Model 8 is therefore unique in its price range and yields performance equal to multi-channel receivers that are unaffordable for many applications.

All satellites in view are tracked and a fast time and frequency averaging is performed, minimising any errors due to any single satellite. All satellites URA's (User Range Accuracy's) are taken into account in the course of the averaging process. Furthermore, significant errors may be eliminated from the averaging process by the use of special plausibility checks and the ability of the receiver to assume that it is stationary with respect to the earth. It will automatically determine its position with a repeatability of better than ±2m given sufficient time, i.e. >24hrs. Software clock techniques are used to minimise the effects of constellation changes. It is also possible by the use of DGPS techniques or non-SA (selective availability) satellites to achieve highly stable time information of greater precision than from code-only receivers. The averaging process also considerably reduces the deleterious effects of SA for as long as it is employed.

The Quartzlock Model 8 series frequency standard receivers are also unique in utilising entirely standard low-cost component parts, which are available worldwide. No application-specific parts are used (with the obvious exception of printed circuits, a few adjustable coils, mechanical piece parts and of course, the antenna). There is therefore no danger of the equipment becoming irreparable within a reasonably projected lifetime due to component unavailability.

In short the Quartzlock Model 8 series GPS receivers represent a significant advance in time-keeping and frequency reference technology, yielding an overall performance, which is comparable to instruments costing many times their price.

2.4 Technical Data

2.4.1 Equipment formats: -

- Model A8-B (Free standing for bench use)
- Model A8-RT (Special 19" x 1U Rack mounting)
- Model 8-EC (Euro-cassette 14HPx170mm, basic xtal only, 10MHz & interrupted 1pps only)

2.4.2 Stability options: -

- Model A8-B (Basic crystal) t ±100ns, f/f ±1x10-9 (95% certainty)
- Model A8-B (low cost OCXO) t ±30ns, f/f ±3x10-10

NB. The figures above are worst case, short term stability figures and include the variations error over a 24 hour period will be <1E-12 (df/f) and the mean time drift error will be < 5ns. The reference time for the unit imposed by Selective Availability (SA) where applied. In all cases, the frequency is GPS time as defined by USNO with correction for UTC applied as per USNO specifications. Further allowance must be made for small atmospheric perturbations.

2.4.3 Outputs: -

- Square wave 2.5V into 50W:
- (TTL compatible, 50% duty cycle) -10 MHz & 5 MHz
- Rectangular sine wave 2.5V into 50W:
- (TTL compatible, 60% duty cycle) - 1 MHz &100 kHz
- 1pps 80% duty cycle (2.5V into 50W):
- +ve leading edge = UTC optional
- -ve leading edge = UTC

NB. The leading edge of the 1pps output may be set to ±500ms with respect to UTC with a resolution of 1ns.

2.4.4 Additional facilities with Model 8A

- Sinusoidal outputs (+13dBm into 50 W): 10 MHz, 5 MHz & 1 MHz
- Serial interface (RS232) 2400 or 9600 baud via 9 way 'D' type connector compatible with IBM® PC-AT.
- Includes NMEA capability.

2.4.5 Special options (all models)

- Square (TTL compatible) or sinusoidal (+13dBm into 50Ω): 2.048MHz & 13MHz
- Square wave only 16kHz, 1kHz
- Serial interface (Model A8-B only) 9600/19200 baud option

NB. At 9600 (and at 19200) baud, the equipment does not strictly conform to NMEA specification (0183) but the same information is available at the serial port, albeit at the higher speed.

- Multiple (4x) sinusoidal o/ps (internal distribution amplifier)
- Available in Model A8-M only: - any one of the above frequencies.

2.4.6 Additional Technical Data

2.4.6.1 **Output levels: (into 50Ω load)**

	Min	Typical	Max	Units
Square	2.25	2.5	2.75	V (pk)
Sine	+12	+13	+14	dBm
Sine accuracy		±0.25	±1	dB

2.4.6.2 Output Purity

Square	Min	Typical	Max	Units
Rise time	5	10	20	ns
Overshoot	-	2	0	%
Sine				
THD	-90	-70	-65	dBc
Noise		-80	-70	dBc

2.4.6.3 Output Frequency Stability

Model				
Interval	A8-B Crystal	A8-B OCXO	A8-B OCXO +	A8-Rb
100ms	1E-10	1E-11	1E-12	TBA*
1s	8E-10	2. 5E-11	2E-11	TBA*
100s	2.8E-10	7E-11	2E-12	TBA*
300s	1.5E-10	4E-11	5E-12	TBA*
10000s	5E-12	5E-12	5E-12	TBA*
1 day	1E-12	1E-12	1E-12	1E-12
1 week	1E-12	1E-12	1E-12	2E-13

RMS interval df/f (estimated)

TBA*: contact Quartzlock

2.5 Power Supply Requirements

Model A8-B/A8-M:

- 90-260v AC, 47-440 Hz or 120-370v DC, 8-10W typical (via in line power adapter as supplied)

12-14v DC via XLR plug on rear

Model 8-EC:

- 11.5 - 14v DC via DIN41612 64a/c plug on rear

Model 8-RT:

- 105-125v & 210-250v AC (user selectable), 47-63Hz (Via IEC type connector)

NB. Down Converter power is included in the total power consumption quoted above and fed by means of the co-axial signal cable as "phantom power".

2.6 Physical Sizes:

- Bench Standing: - W: 222mm, H: 57mm, D: 220mm (excluding feet and connectors)
- Rack Mounting: - 19" x 1U (44.5mm) x 312mm deep (excl connectors)
- Euro Cassette: - 3U high x 14 HP (71mm) wide x 175mm deep (ex handle)
- Antenna: - 40mm dia x 113mm length (excluding "N" connector)
- Down Converter: - 50 x 74 x 30mm max. (Ex connectors and mountings)

Quartzlock policy is of continuous product improvement and whilst the above specifications are correct at the time of going to press, they may be changed without prior notice.

3 Getting Started

1. Connect the antenna to the down-converter and the down converter, via the cable supplied, to the TNC socket on the rear panel of the Model 8.
2. Connect the Model 8 to a suitable mains power source and switch on. If the system includes an external local reference oscillator such as Quartzlock model A10-M Rubidium oscillator, this must be switched on simultaneously or before the model 8.
3. Check that the display is illuminated and that no fault warnings are displayed after a few minutes.
4. Check that the yellow "GPS Lock" LED is illuminated within half an hour or so.
5. When the yellow LED lights, the red LED will begin flashing thereby indicating a previously unlocked condition. This is the indicator that will warn the user in the event of future problems such as power failures or certain problems resulting in timing errors (even if the problems are temporary). This "Past Unlock" indicator should be manually acknowledged (or reset) by means of the adjacent button.

Once the yellow LED comes on there is no need to worry about anything unless it goes off again. If it does go off for any reason (except that given under warning 13 described later), the red LED will come on and stay on as an indication of excessive time and/or frequency error. If the oscillator loses time completely and has to be re-synchronised, the red LED will flash as an indication of total loss of synchronisation (such as a power failure).

The following notes are to answer the most **frequently asked questions** relating to steps 1-5.

1. The down-converter is not just a signal pre-amplifier; it is a vital part of the receiver and is therefore essential. Whilst the converter is fully weatherproofed, it is as well that it should be additionally protected wherever possible from the worst excesses of the weather, *particularly driven rain* and strong sunlight. If a cable is fitted between the antenna and the down-converter it should be as short as practicable and in any event should not have a theoretical loss in excess of 3dB at 1.5 GHz which includes an allowance of 1dB for each connector. This means that the maximum length of (for example) RG213 (similar to UR67) must be approximately 2.5m whilst the maximum length of RG58 (similar to UR76) must be <1m and is not recommended.

The cable from the down-converter to the receiver not only carries the 2nd IF signal (of 10.23 MHz) to the receiver but also supplies DC power as well as the receiver's second local oscillator reference frequency (of 92.07 MHz) to the down-converter.

The antenna should be mounted on a reasonably stable structure, which should not be moved permanently once the receiver has been switched on. Acceleration of the antenna should never exceed 1g. This should not be a serious restriction.

The antenna needs as complete as possible a view of the whole of the sky which is >5 ° above the horizon. If the position of the antenna is known to an accuracy of better than ±2m in position terms and the altitude is known to within ±4m, then reasonable (but degraded) performance may be obtained with approximately half the sky visible (e.g. with the sky obscured up to 30-40° above the horizon). If the position is not accurately known it will be necessary to allow the receiver to measure the position for itself (see notes to 5 below). As a single position estimate is likely to be considerably in error, the receiver has the ability to average its estimates over a very long period (>24hr). In fact, the receiver will stop averaging after 86400 estimates that it can make at a maximum rate of one per second. Note that at least four satellites need to be visible for a single estimate to be made. Thus if part of the sky is obscured, the total time during which insufficient satellites are visible (normally an insignificantly small percentage of the time) will increase. If the horizon is raised to 30-40° then the number of visible satellites will drop to <4 quite often, significantly lengthening the time required for an accurate position to be obtained. A raised horizon will also worsen the geometry of the constellation, detracting from the accuracy in ways that can be difficult to accurately predict. It can also worsen the time taken for the yellow "Lock indicator" LED to light.

2. A suitable mains power source is specified in the handbook in terms of voltage and frequency but no consideration has been given to reliability. In cases where reliability is important, it is likely that the local mains supply will require augmentation for the purpose of enhancing reliability. As the power requirements of the Model 8 are reasonably modest, a standard UPS is recommended with whatever batteries are necessary depending on the required duration. It is also possible to feed the Model 8 with DC power but the unit is not able to act as a charger for external batteries.

3. If any faults exist at the time of power on, it is likely that the unit will detect a problem and issue (by means of its display) an appropriate warning. Some possible faults, such as a missing antenna or down-converter, will not be noticed until the internal temperature controlled crystal oven (OCXO) or atomic clock (if fitted) has reached its normal operating temperature. (This will normally take between one and ten minutes and is dependent on the type of oscillator used.) In normal circumstances, the GPS receiver will achieve lock within a few minutes but initially, if the position, local time or up-to-date almanac information are not known, a full search has to be undertaken by the receiver and the process could take as long as an hour. It is worth stressing, however, that it is not vital to actually do anything to the receiver in terms of information provision to allow it to work. There is no possible information, the lack of which will prevent it from working.
4. Once the yellow LED is illuminated, the receiver requires very little additional attention unless a fault is encountered. Note that it is possible to cause the yellow LED to go off by the execution of certain commands from the front panel. In particular, manually changing the delay or the assumed position may cause temporary loss of lock. It is recommended that the delay be set to the required figure as soon as possible after switch-on and before the yellow LED illuminates. (See **CONFIG MEN**U)

There are three discrete position memories that may be inspected by the user. They are entered, averaged and initial; any of which the user may cause to be used by the receiver. (See notes on the **USE** screen under the **CONFIG** menu.) The entered position is the only one that may be edited by the user. This can be used either to indicate the approximate position (within - say - a few hundred km) to the receiver or to provide a precise position where such a position is known to greater accuracy than may be expected to be obtained by averaging. An approximate position (in conjunction with the correct approximate time) will enable the receiver to minimise its time to first fix **(TTFF**) by searching first for satellites that should be visible according to the stored almanac. A precise position should enable the receiver to provide greater time accuracy within the first hour or so after switch-on than may be obtained by means of the averaged (self determined) position. The averaged position will not be readable until the receiver has observed sufficient satellites after switch-on. Initially, it is likely to be several tens of metres in error due to Selective Availability (SA) but as long as SA does not include errors in (or truncation of) broadcast ephemeredes, it may reasonably be expected to have a repeatability within 2m horizontally and within 4m in terms of altitude (with 95% certainty) after a period >24hr averaging.

The initial position will always be that position which was last in use before power off and is the default position for use by the receiver from power on. If it is found by the receiver to be in error by an amount in excess of normal errors such as SA, then the receiver will automatically switch to using the averaged position. This will then, of course, become the initial position after the supply is removed. If an entered position is used, the receiver will check it automatically. It may be close enough to be plausible but sufficiently wrong to cause undue timing errors. It is therefore strongly suggested that such a position should be checked against the receiver's own averaged estimate. Any disagreement in excess of 10m (position) after an hour or so or 3m after 24hr should be investigated. Vertical errors may be 2 or 3 times greater than those quoted. Once the receiver has tracked sufficient satellites to make a position estimate, it will not accept a significantly inaccurate entered position for use. All positions are referenced to the World Geodetic System 1984 co-ordinates known as WGS84 with altitude given as relative to the geoid as distinct from the ellipsoid. (For most of the globe, the geoid is much closer to sea level than the ellipsoid and is a more complex shape, details of which are stored within the receiver.)

5. The red LED will not light unless a problem causes time or frequency errors above a certain threshold. If a problem such as obscuration of the antenna is sufficiently short lived as not to seriously affect the overall time synchronisation, the red LED will remain off. It may be, however, that such a problem is reported to the user via a warning on the display but such a warning does not, of itself, indicate loss of lock. Some problems may cause the time or frequency error to exceed a certain threshold for a brief period without overall loss of time coherence; in other words, time accuracy may later be restored without any loss or gain of cycles at a frequency output with respect to the 1pps output. In this case the red LED is illuminated but without flashing. This is a condition, which is distinct from that where a total loss of synchronisation occurs. Total loss of synchronisation will occur during a power failure or such a long period without signals that such a great error is allowed to build up before signals are restored that re-synchronisation cannot be accomplished without resetting the time counters. In this case the red LED will flash rather than light continuously. (See page **LED INDICATIONS**).

If the receiver is allowed to ascertain its own position by averaging, it is possible that a severely erroneous "**first fix**" (position estimate) will inevitably cause considerable slewing of the average position during the first few minutes and to a lesser extent, during the first few hours. With certain types of local oscillator, the control time constant will be increased so quickly that lock detection criteria may be violated by fast slewing of the averaged position as it tends towards a more accurate estimate over time, causing the red LED to be lit. This can only happen if position averaging is relied upon and if the local oscillator control time constant is allowed to increment to its maximum at the earliest possible time (the default condition). A few hours of position averaging should prevent further occurrences of such a condition. If the actual position is initially unknown, it is possible to limit the maximum control time constant to allow fast response to time errors, thereby avoiding the red **"lock los**t" LED illuminating. Certain local oscillator types may also require some hours (such as temperature stabilised quartz) or days (such as Rubidium) to initially stabilise.

3.1.1 RS232 INTERFACE

The Model 8A, 8A+ and A8-Rb are equipped with a serial interface to RS232 standard. The RS232 interface is configured as Data Terminal Equipment (DTE) according to the following table and utilising a 9 pin "D" type male connector. It therefore resembles a "PC-AT compatible" implementation and use with such a PC will require a "crossover" or "Laplink"™ cable.

3.2 Pin Numbering, Signal Names And Signal

Notes: -

1. The pins corresponding to signals indicated thus are connected only to each other within the instrument.
2. The pins with direction indicated thus are not connected within the instrument.

The Baud rate of the RS232 interface is user selectable between two rates [2400 and 9600] by means of the "+" or "-" buttons with the speed indicator screen selected from the "CONFIG" menu (with diagnosis turned on). Higher speeds are possible if required by means of internal hardware configuration. The higher rates of 4800 and 19k2 are indicated in parenthesis (in the speed indicator screen selected from the "CONFIG" menu) and are achieved by moving the internal speed selection link (on the OCXO board, between the OCXO and the HD6350P integrated circuit) labelled "bps" from LO to HI.

Details of the information available at this interface are given in the section **REMOTE SIGNALLING** later in this handbook.

3.3 Display & Menus

3.3.1 Main Menu

When the instrument is first switched on, the display screen shows a model identifier. The main menu may then be obtained by pressing the "Mode" button. If, when this button is pressed, a waiting message is displayed, it signifies that the internal reference oscillator is not sufficiently stable to be used for satellite reception and a short time must be allowed before the receiver section will be activated however, all inputs/changes desired may be entered and will be processed.

E.g. "Mode" button is pressed, display reads: -

... waiting for

OCXO warm up

for a few seconds and then the normal: -

POS STATUS

TIME CONFIG

is displayed. This will happen whenever the display would normally return to the main menu until the internal reference oscillator has reached its normal operating temperature. The time taken for this will depend on the type of internal reference oscillator and the ambient temperature. This could be anything from a few seconds to several minutes. When the waiting message is displayed, the familiar user may ignore it in terms of button function indication, as the four buttons will have the same effect as they would have if the waiting message were not displayed.

As indicated by the front panel legend, the four buttons each have a different function once a lower level menu is accessed.

I.e. POS: - - (or minus), decrement etc.;

STATUS: - + (or plus), increment etc.;

TIME: - or cursor left;

CONFIG: - or cursor right.

Where appropriate, the "+" and "-" buttons will either cause numeric increment / decrement or allow selection of a short series of predetermined options depending on the item to which the cursor is applied.

The cursor will be provided automatically in any screen that contains editable information and may be moved, if appropriate, using the " " or " " buttons. Only editable data can be selected by means of the cursor. The " " or " " buttons also select the previous or next screen respectively when within the STATUS or CONFIG menus (not within the POS or TIME menus which effectively only have one screen). The top-level menu may be reached at any time by one or more presses of the "Mode" button.

3.3.2 Time Menu

There is only one screen under the TIME menu. It appears like this: -

1997-JAN-13 MON

10:04:32 UTC+0h

Note that this illustration indicates the display with the receiver having received at least one satellite. The cursor is under the offset value (relative to UTC) and may be changed (edited) using the "+" & "-" buttons in increments of one hour. As the offset value is changed, the time indication (and if necessary, the date) changes automatically to reflect local time. This offset will be stored in non-volatile memory if power is removed. There is also an internal battery powered clock to enable the receiver to re-acquire satellites more quickly when power is restored by reference to the stored almanac data. When the receiver is first powered, the second's display will be suppressed e.g.: -

1997-JAN-13 MON

09:54 UTC+0h

which indicates the uncertainty resulting from only having the internal back-up clock as a reference. At this time the cursor may be moved round the display by means of the " " or " " buttons and the date and time may be edited using the "+" & "-" buttons. This is because the internal master clock is not "set" until confirmed by a satellite. (Note here that the "day of week" display is not directly editable but is calculated immediately from the date value.) The reason that editing is allowed in this condition is to correct, if necessary, the internal battery powered clock thereby reducing the time to first fix **(TTF**F). Once the position has been verified by acquisition of sufficient satellites, the second's display is restored and editing of the displayed time or date will no longer be possible. If the stored almanac information is too old it may be that the receiver is unable to calculate UTC from GPS time until it has received updated information from the space sector, which it will normally do within 15-20 minutes. In this circumstance, the warning **"UTC/GPS data too ol**d" will be displayed.

NB. The 1pps output will not be active until various criteria have been met. Most importantly, the position (if entered) must have been verified and the normal lock criteria (sufficient to allow the yellow LED indicator to be illuminated) must have been met.

3.3.3 Position (Pos) Menu

The position menu selection yields access to three screens each giving a separately stored position. All three may be inspected by selecting them using the "+" or "-" buttons. Note that the cursor will be located under the name of the position displayed. The initial ("init'l") position is that used by default from power on and will be the position last used by the receiver (whether or not it had been verified by estimation with reference to the space segment at that time) e.g.: -

initl: 52N21.069

0034m 00W12.270

The averaged position will not be available until the end of TTFF but when visible, indicates the minimum time that could have been taken to build up the data that are averaged. If 20 minutes worth of position estimates (i.e. approx. 1200 seconds or more) have been averaged the display will appear thus: -

20'av: 52N21.045

-011m 00W12.282

and may be considerably in error due to the use of Selective Availability (SA) by the space segment. After more than 24 hours, the averaging will stop after 86400 estimates have been made. The display will appear thus: -

24hav: 52N21.069

0034m 00W12.270

At this stage, provided that SA consists only of timing errors which are near-Gaussian in their distribution and does not employ corruption or truncation of broadcast ephemeris, the averaged position has >90% certainty of being repeatable to within 2m horizontally and 4m vertically. This should mean that timing errors due to positioning errors should not exceed approx. ±10-20ns. It is perfectly possible to manually re-start the averaging process several times and manually average a few weeks worth of data to achieve a greater level of repeatability (accuracy?). The entered ("entr'd") position is the only position that is user editable. This is for two reasons; firstly it can enable a reduced TTFF when the receiver has been moved over international distances; secondly it may be used to achieve a higher precision than is available by use of the averaged position where the precise position is known to a greater accuracy.

entrd: 52N21.068

0036m 00W12.272.18

It will be evident that this is the only position display that enables movement of the cursor for this reason. If the position is changed, it must be confirmed by changing the "enter? NO" prompt to "enter? YES" using either the "+" or "-" button after pressing the "Mode" button and then once more pressing the "Mode" button. As mentioned over page, the initial position will be the one used by the receiver during its initial search following power on. It will also continue to be used following acquisition of satellites provided it passes the plausibility checks when the first position estimate is made. If the plausibility checks suggest that the initial position may be in error, the receiver automatically uses the averaged position instead. If the entered position is changed (edited),

the receiver will automatically use it provided it meets the plausibility requirements. If it is preferred to force the receiver to use the averaged position, see the details given under the "USE" screen in the **CONFIG MENU** section following.

3.3.4 CONFIGURATION (CONFIG) MENU

The configuration menu allows access to a number of screens depending on whether diagnosis is enabled or not. When it is off there are four screens available but when it is on there are nine.

The **USE screen** looks like this: -

use initial pos!

-- ok --

and enables the user to select one of three possible positions to use for time estimation by means of the "+" or "-" buttons followed by the "Mode" button and confirmation at the prompt. If either the initial or the entered position is used and fails the receiver's automatic plausibility check, the receiver will override the selection and switch to using the averaged position, giving an appropriate warning. Note that changing the position used once the "locked" condition has been achieved may result in loss of lock and will almost certainly cause transient timing and frequency errors. As mentioned under the POS screen, if the entered position is changed from its initial value (same as the initial position at power on) the receiver will automatically use it, subject to plausibility.

The **delay selection screen** looks like this: -

1pps delay:

+000000000ns

and enables the user to select the delay to be applied to the 1pps output with a maximum of ±500ms thus effectively providing any required time offset with 1ns resolution. Note that changing the delay once the "locked" condition has been achieved may result in loss of lock and will almost certainly cause transient timing and frequency errors.

The **max URA selection screen** looks like this: -

max. URA: all in

view 5(8)sats

and enables the user to select the maximum useable User Range Accuracy (URA as reported by and for each satellite) of any satellite which will be used to estimate the receiver timing errors. The permissible values are all those which are capable of being reported by virtue of the restrictions imposed by the signal coding. (See Navstar Standard Positioning Service; Signal Specification for details). An additional selection (the default) is "all in view" which reads all the currently visible satellites. If a small maximum URA is selected and no suitable satellites are in view, the receiver will automatically revert to the "all in view" setting to avoid loss of lock. It is worth noting that most satellites in the constellation are (at the time of writing with one exception) reporting a URA of 32m. This has been the case in recent years and the exceptions appear to be those with SA reduced to zero that reports a URA of 4m or less. Occasionally a satellite may report a URA of >32m and it is assumed that such satellites are suffering from clock or signalling errors or other uncertainties.

The **diagnosis selection screen** looks like this: -

diagnosis: OFF

and enables the user to set the state of the diagnosis reporting as ON or OFF by using the "+" or "-" buttons. If it is set to ON, the following additional screens will be accessible as well as additional screens under the STATUS menu. ADDITIONAL SCREENS AVAILABLE UNDER THE CONFIG MENU WITH DIAGNOSIS ON.

The **speed selection screen** looks like this: -

RS232: 9k6(19k2)

AUX: 19k2 baud

and enables the user to set and/or inspect the speed (Baud rate) of both the RS232 and the auxiliary (TX only, CMOS 5v logic level) ports. The figure in parenthesis after the RS232 speed is that which is available with the internal "bps" selection link in the "HI" position. Note that changing either one of the port speeds will cause both registers to be up-dated. This may cause a small disruption in the data stream or a framing error from the RS232 port even though only the speed setting for the AUX port has been changed.

The **switches screen** looks like this: - (earlier versions:-)

PLL1023=on PLL1023=on

Ctl=on: DA=$7AFC Rgl=on: DA=$7AFC

and allows two internal switches to be controlled for testing purposes. The PLL1023 switch is not implemented in hardware and therefore has no effect except to force Ctl (Rgl) to the off state when it is turned off. The Ctl switch may be used to inhibit automatic disciplining of the local reference oscillator. When it is switched off it is possible to set the local reference oscillator control DAC to any desired value for test purposes. Note that the DA value is unsigned and in hexadecimal format (as signified by the "$" prefix) where 7FFF corresponds to zero on the ADC offset display screen (under STATUS) where the value is displayed as a signed decimal number.

The **flag state indicators screen** looks like this: -

DA=-1284 4 -1ns

+0000ns 0E-10

and allows simultaneous observation of the D-A converter controlling the local oscillator as well as the number of currently observed satellites and the apparent errors in the local clock (reference oscillator) with respect to apparent GPS time. The editable digits in the lower left corner allow the introduction of a deliberate (time error) step into the control loop for test purposes, details of which are beyond the scope of this handbook.

The **time constant selection screen** looks like this: -

OSC control time

300:/3000s

when a Rubidium or OCXO local oscillator is used and allows the upper limit of the local reference oscillator control time constant to be set using the "+" or "-" buttons, thus preventing that value from being exceeded. The limit is indicated by the right-hand figure whilst the left-hand figure shows the actual value being used by the receiver. The actual indicator will start at a much smaller value at power on and will slowly increment, as it is safe to do so. In the example shown, the limit is set to 3000 but as the instrument has not been powered for very long, the time constant has only reached 300s. With certain types of local reference oscillator, the setting for optimum accuracy in frequency terms is higher than that for time. The relevant appendix for the actual oscillator used will provide further details and illustrations of the different screen used for simple quartz oscillators.

The **PRN control and indicator screen** looks like this: -

PRN: off

ID=00, Fre= +0

and its functions are for test purposes only. Switching PRN on makes the receiver operate its hardware as if it were tracking a single (possibly unavailable or non-existent) satellite at a Doppler shift, which is selectable by setting the right hand value. NB. This will prevent normal operation of the receiver and should never be required in normal use.

3.3.5 Status Menu

The status menu also allows access to a number of screens depending on whether diagnosis is enabled or not. With diagnosis off there are three screens available but with diagnosis on there are eight.

The **constellation display screen** looks like this: -

0000270-0F---000

F00-0F0DF0007F0-

It provides a single screen overview of the entire constellation where each character represents a different possible PRN number with Nos. 1-16 on the top row and Nos. 17-32 on the bottom. For a PRN code not currently in use by any satellite, the displayed character is a dash: "-". Other characters (with the exception of a space which has a special meaning) should be read as a hexadecimal representation of four status flags with the following meanings:

Bit	Meaning
1	This satellite should be visible at an elevation of >5 according to the stored almanac provided that the correct time is known.
2	Up-to-date ephemeredes are stored in memory for this satellite (having been read since the last observed horizontal occultation).
4	Sufficient data for this satellite has been stored locally to theoretically enable it to be precisely located by the receiver in time and position.
8	A successful carrier phase measurement has been made from this satellite within the last 3 seconds.

Thus the character "F" signifies that all the above meanings are true whilst a zero signifies that all the above meanings are false.

The special significance of a space in place of a character is that whilst the last attempt to measure the carrier phase of this satellite was successful, it was not within the last three seconds because the receiver has since been busy reading data from another satellite.

It sometimes happens that many of the displayed characters are momentarily replaced by dashes; this is a transient phenomenon due to the premature updating of the display whilst the stored almanac is being updated. This condition rarely lasts for >>1 sec.

The **receiver status display** screen looks like this: -

ACC: POS=initial

URA 32m 5(7)

and indicates the position being used (the default is initial), the max URA in use, the number of satellites tracked in the last three seconds and (in parenthesis) the number of satellites with an elevation of >5 according to the almanac.

The **individual satellite display** screen looks like this: -

SV: 01 14 113

TE 23 65 32m

As indicated by the cursor under the SV number, any satellite in the almanac may be selected by means of the "+" or "-" buttons. The top line indicates SV number (same as PRN) as well as elevation and azimuth if visible. The last figure on the bottom line indicates the satellite's currently reported URA in metres. The number under the SV number is a noise level figure for the receiver (and down-converter etc.) in arbitrary units which is indicative of the amount of noise present at the detector and is used to calculate signal to noise figure. The number under the elevation figure indicates the signal to noise ratio in arbitrary units. The two possible characters on the left end of the bottom line are only visible with diagnosis set to on and indicate firstly; either a successfully tracked satellite with the letter "T" or a valid PRN code (but without data) by the letter "b" and secondly; either that the satellite is being used and evaluated by the receiver by the letter "E" or the letter "p" indicating that the information has been discarded due to lack of plausibility.

3.3.6 Additional Status Menu Screens With Diagnosis On

The **ADC offset display** screen looks like this: -

ADC offset:

sin= +7 cos= +7

It is only relevant for test purposes and indicates the offset correction applied to the A-D converter to balance the sine and cosine amplifiers on the receiver's synchronous carrier detector.

The **DAC value display** screen looks like this: -

DAC value:

-1279

and indicates the correction currently applied to the local reference oscillator in the range –32767 to +32768. Note that zero corresponds to a true D-A converter value of $7FFF (hexadecimal).

The **MAX/MIN value display** screen looks like this: -

465 -52..-21ns

-52...+59E-11

and indicates the max and min t and f/f (as indicated by the next screen) over intervals of 1000s. The current seconds count for the current interval is displayed in the top left. Results for the previous interval may be shown by pressing "+" or "-".

The **control loop error display** screen looks like this: -

t: 13ns

f/f: -17 E-11

and indicates errors in the local reference oscillator with respect to apparent GPS time. This is because there is no direct access to true GPS time. It should be noted that (for the model 8A and the model 8A+), as the local oscillator control time constant is increased (normally automatically) the apparent errors would possibly worsen. This is because a short time constant will allow the receiver to track the perturbations caused by SA whereas a longer time constant will increasingly remove the effects of SA from the local oscillator thereby increasing the RMS difference between apparent GPS time and local oscillator time.

The **final screen** will normally look like this: -

no fatal error

since power on!

and its purpose is to store an error message in the event of a fatal run-time error causing the micro- processor to be reset. This is to allow the receiver to restart and function normally without masking errors and to enable this particular possible cause of "Past Unlock" indications (flashing red LED) to be traced.

3.4 Remote Signalling

In normal operation, the RS232 interface provides three NMEA compatible data strings each second as in the following example.

$PUTC: 13:45:55,97-03-02,+574E-12,-4ns,1234s, -1648,00,0F,V30970224As

$GPGGA, 195309,5221.069,N, 00012.270,W, 1,06,01,0034,M, 075,M,

$PLST: 1000F70-62---F7F001-F0000000F00-

The format of the first line is a proprietary format (as indicated by the letter "P" as the second character) with fixed field lengths (comma separated) and with fields starting at the following character positions with the following contents:

Pos'n	Contents
3	The timescale of the following time reference (either GPS or UTC
8	The nominal time of day . . . . ..
17	…And date (if UTC; of the next rising edge of the 1pps output).
26*	The apparent frequency difference between the local clock and the average of the currently evaluated satellites
39*	The difference between locally established GPS time and apparent GPS time
53*	The current local oscillator control time constant
56*	The current correction being applied to the local oscillator (in the range –32767 to +32768).
63	A diagnostic indication of current warnings. (See note 1 below)
66	A diagnostic indication of current lock (tracking) state. (See note 2 below)
69	A software identifier.

Character positions with an asterisk will probably be one of several leading spaces that are inserted to ensure that the least significant digits remain in the same place.

The second line is in accordance with NMEA-0183 (but with a small non-prescribed extension to the position characterisation digit. See note 3 below.) The data in this line is comma separated as follows: -

string identifier, date, lat, long, position characterisation digit (see note 3 below), number of satellites evaluated, HDOP, altitude above geoid, "M" for metres, altitude of geoid above ellipsoid, "M" for metres,

The third line is effectively a duplication of the information provided by the LCD under the STATUS menu as the constellation display screen and is fully described under "STATUS".

NOTES

Note 1: - The diagnostic indication of current warnings (given at positions 63/64) in the proprietary data string indicates either the warning currently displayed or zero if no warning is displayed.

The correspondence is as follows: -

1 " offset large: service!"

2 "entered pos bad >averagd"

3 "subhoriz sat found-> pos?"

4 "no noise check antenna!"

5 "Xtl offs large: check pos"

6 "Xtl offs large: adjust!"

7 " can't find any sat's!"

8 " can't find enough sat's"

9 "buffered mem/clock lost!"

10 "sat lost -> all in view"

11 " control voltage large! "

12 " UTC/GPS data too old!"

13 "entered pos not verified"

14 "pos bad! true pos unknown"

15 "too much noise: service!"

17 "reducing osc control time"

Note 1 For further details see the section entitled DON'T PANIC! later in this handbook.

Note 2 The diagnostic indication of current lock (tracking) state (given at positions 64/65 in the proprietary data string) indicates, by means of two hexadecimal digits, the states of eight flags.

The correspondence is as follows: -

LSBit 0 control has started (will not return to zero)

1 f low (control of t has started)

2 locked; yellow "GPS Lock" indicator LED illuminated

3 t<±20ns and f/f<±2-9 (integrators activated)

4 control has started (will return to zero when locked)

5 red "Past Unlock" indicator LED continuously illuminated

6 hold-over mode (yellow LED flashing)

MSBit 7 red "Past Unlock" indicator LED flashing

All the above meanings are true when the flag is set (=1), thus, in normal operation the two characters will be "0F".

Note 3 The position characterisation digit has a fourth possibility ("3") which is not specified in NMEA- 0183 as follows:-

"0": no position estimate available

"1": 3D position estimate available

"2": DGPS-improved position estimate available.

And finally, the Quartzlock (non-standard) addition: -

"3": no position estimate available due to receiver reading slow data from a particular satellite

4 Warnings and Messages

4.1 What should I do when this happens?

As the performance of the model 8 GPS receiver is thoroughly self-monitored, almost anything that can possibly affect normal operation will be detected. This applies to faults (which will be rare) and to influences external to the instrument. When a problem is detected, regardless of how serious, a warning message will be displayed. If the problem adversely affects (or may affect) the output precision, the red LED on the front panel may be illuminated. Many of the warning messages are necessarily (due to the size of the display) somewhat cryptic. This section is therefore dedicated to fuller explanations of the meanings and implications of these warnings.

Warnings are explained below in numerical order where the numbers are those used to indicate the same warnings via the serial interface. Any displayed warning may be cleared (acknowledged) either by pressing the "Mode" button on the front panel or by the appropriate command sent via the serial interface. (See the section headed **REMOTE CONTROL** for details.) Note that warnings may be "stacked" internally and if a subsequent warning is waiting, it will immediately replace, in the display, an earlier warning, which was acknowledged. The "Past Unlock" indicator (red LED) may be cancelled (acknowledged) either by pressing the "Reset" button on the front panel or by the appropriate command sent via the serial interface. (As before, see the section headed **REMOTE CONTROL** for details.) The precise meanings of the indicator LEDs on the front panel are also given at the end of this section.

4.1.1 WARNINGS

4.1.1.1 " offset large: service!"

This indicates that either or both the normal offsets applied to correct the outputs of the sine and cosine detector amplifiers are larger than their design limits (±28). It does not necessarily mean that the instrument's output precision is affected but it should not be ignored indefinitely. Before seeking further advice, set diagnosis on and use the ADC offset display screen under the CONFIG menu to note the offset values for sin and cos.

4.1.1.2 "entered pos bad >averagd" (or "initial pos bad >averagd")

This warning is inevitable in normal operation if a rough position was entered for the purpose of minimising TTFF. It indicates that the entered position has failed the plausibility check (i.e. >±500m in any co-ordinate) and the receiver has automatically switched to using the averaged position which it has calculated for itself and which will improve in certainty over.28 the succeeding >24hrs. There is a very small chance that this could occur due to unusual measurement or stored almanac errors but the ill effects of such an occurrence will be automatically remedied within a few minutes.

4.1.1.3 "subhorizsat found-> pos?"

This may occur if the initial or entered position at power on was significantly in error. It means that a satellite has been received that (according to the stored almanac) should be below the horizon at the initial or entered position. The full word coined here to describe such a satellite is "sub-horizontal". This warning may also be observed if the stored almanac is significantly out of date (the receiver having been out of use for some time) such that the satellite is not located where the almanac indicates that it should be. The almanac will normally be updated within 20-30 minutes of operation.

4.1.1.4 "no noise check antenna!"

Indicates that the normally received noise is not detectable and its absence may be due to a faulty or missing antenna, down-converter or cable. This noise is partly due to the fundamental properties and design limitations of a radio receiver and partly due to natural noise, which exists throughout the universe. Nevertheless, the noise level is a good indication of the health of a receiver. The noise level should be >10 in the receiver's own arbitrary units (See the individual satellite display screens). See also warning #15.

4.1.1.5 "Xtl offslarge: check pos"

This warning will only be issued prior to an internally computed position estimate having been made and indicates that the Doppler correction, applied to the receiver to compensate for the expected Doppler shift of the signal from a particular satellite, is significantly different from the expected value. This could be due either to the initial or entered position at power on being significantly in error or the stored almanac being considerably out of date. Another possibility is that the local reference oscillator requires adjustment but this will only apply if the position used is actually correct. If this latter possibility is actually the case, it will be reported correctly (by means of warning #6) once sufficient satellites have been found to enable a reliable position estimate to confirm the entered or initial position.

4.1.1.6 "Xtl offs large: adjust!"

This warning indicates that the local reference oscillator is in error by more than 1.5-6 prior to any correction being applied and that an internal adjustment may be required. This warning will only be issued after a position estimate has been made. Note that this warning actually refers to the internal 10.23 MHz oscillator which is normally phase locked to the master reference of 5 or 10 MHz. If this phase locking has failed for any reason, the receiver will still be able to track satellites and calculate its position provided the error is <5E-6 but frequency control will be impossible..29

4.1.1.7 " can't find any sat's!"

This is normally indicative of a faulty or missing antenna or antenna cable or an obscured antenna. It is possible that a faulty down-converter could cause this problem but most such faults would also result in too little or too much noise being detected, causing warning 4 or 15 to be issued. Ingress of water into the antenna cable will almost certainly cause this problem.

4.1.1.8 " can't find enough sat's"

This is normally indicative of a partially obscured antenna. If the position is known, the receiver may be made to work (by the user explicitly setting the use of the entered position) with reduced accuracy/certainty and it may be that even with significant antenna obscuration, the receiver will find sufficient satellites (4) occasionally to make position estimates. Local oscillator control will continue with as few as one satellite (or even none with severe limitations) but it should be remembered that the RMS errors in apparent GPS time would be greater than with the full constellation. Also the GDOP may be considerably increased, even when four or more may occasionally be received. At the time of writing, work is in hand to quantify the performance degradation suffered with specific examples of obscuration (contact Quartzlock for further details). It is also remotely possible that particularly unfortunate constellation geometry, possibly combined with an unforeseen failure of a satellite, could add to the basic problem of a normally minor obscuration to cause this warning to be issued. This warning will never be issued after sufficient satellites have been found to enable a position estimate to be computed.

4.1.1.9 "buffered mem/clock lost!"

This warning will only be issued at power on and indicates probable corruption of the internal, battery backed memory and/or clock and whilst not fatal, will probably increase TTFF because the receiver cannot make any assumptions about which satellites should be visible or where. An important point to note is that the 1pps

Delay setting, the serial interface Baud rates and the maximum control time constant setting may also be lost. The almanac problem may be partially alleviated very simply by editing the time and date indications on the "TIME" screen and editing the entered position screen under the "POS" menu. Accuracy within ½ hour in time and within a few degrees lat/long will be sufficient (altitude needs no entry here). The almanac used for the subsequent search will then be that which was permanently written into the software at the date of compilation. If no action is taken, the receiver should autonomously (assuming that there are no other problems) find enough satellites and receive an up-to-date version of the almanac within an hour. Terminally masochistic users may wish to know that this condition (clock and all memory cleared) may be forced by holding the -/POS & /CONFIG buttons as the power is switched on.

4.1.1.10 "sat lost -> all in view"

Only issued when no satellite is found by reason of a user-imposed restriction on the maximum acceptable URA. When all such satellites are lost from view, the receiver will automatically revert to the "all in view" option to prevent loss of GPS time tracking.

4.1.1.11 " control voltage large! "

This indicates that the correction applied to the local reference oscillator is larger than approximately three quarters of the available amount either positive or negative. By itself, this does not mean that the output precision is affected but it should be taken as an early warning of some drift (such as ageing) which may require correction before the limit of range is reached. It may also be due to operation in extreme ambient temperature conditions. If it occurs after several years of normal operation of a quartz local oscillator, it is probable that several more years of normal operation might be obtained but this would be at greater (and growing) risk of limiting. In the case of a Rubidium based local oscillator, the condition may be more serious as it could indicate imminent failure of the physics package. Note that this warning is inhibited until the control loop has settled to avoid false alarms due to the very small adjustment range available with certain (such as Rubidium) local oscillators. Note the DAC value given in the display screen under the STATUS menu before seeking further advice.

4.1.1.12 " UTC/GPS data too old!"

This will normally only occur when the receiver has not been used for some time. It signifies that the stored correction data, which give the difference between GPS time and UTC, are out of date and may not therefore be relied upon. It may also occur if the time was entered incorrectly (or correctly following warning #9). No special action may be taken to correct this problem but the routine reception (normally within 30 minutes) of up-to-date correction data will enable normal operation to resume.

4.1.1.13 "entered pos not verified"

This warning is issued where a position has been entered and where insufficient satellites (<4) have been received to allow the entered position to be verified. Note that the act of entering a position will cause the receiver to assume that position to be correct (even if there are insufficient satellites to verify it) and to begin to control the local oscillator. If there is subsequently cause to issue warning #3 or warning #14 (see below), control will cease and the yellow LED (if on) will be extinguished. In that case, only re-entering the position or the acquisition of sufficient satellites will enable another attempt to control the local oscillator.

4.1.1.14 "pos bad!true pos unknown".31

This warning is issued where sufficient satellites (typically 2) have been received to indicate both that the position used is obviously wrong and that insufficient satellites have been received to provide an averaged position.

4.1.1.15 "too much noise: service!"

Indicates that an abnormally high noise level is present at the detector and the cause should be investigated. The most likely reason for this is a faulty down-converter or cable but no other possibility should be ruled out without investigation. Another possibility that should not be ignored is that the receiver is detecting man-made interference although, due to the nature of GPS signals, most types of interference would need to be of an unusually high level to affect the receiver adversely. The noise level should be <35 in the receiver's own arbitrary units. Note the noise level from any of the individual satellite display screens before seeking help.

4.1.1.16 "hold-over mode enabled"

This mode is activated with certain types of local reference oscillator if no satellites are detected for >20s provided that the position used meets certain criteria. It is maintained for no longer than three times the current control time constant (t) at the time of the loss of signals.

4.1.1.17 "reducing osc control time"

Indicates that the error (dt) relative to apparent GPS time has exceeded a predetermined threshold for more than a predetermined time (currently >±50ns for >2 minutes). When this happens, the oscillator control time constant is automatically reduced by 1s/s until the error drops below 50ns. There is no cause for alarm when this warning is issued but it is indicative of the maximum control time constant being set too high with regard to the ambient temperature range being experienced by the receiver. In a stable ambient temperature environment, following a period of settling (possibly several days, or even weeks if the oscillator is relatively new) the maximum allowable time constant may be reached without this warning being issued. If this warning appears more than once or twice per week, it is advisable to either manually reduce the maximum control time constant or take steps to stabilise the ambient temperature. If the control time constant frequently drops significantly below approximately 500 seconds (5000 seconds for a Rubidium controlled local oscillator), it is probable that there will be high short-term errors in frequency as the time errors are corrected relatively quickly. The upper limit to the time constant should be manually reduced if the automatic reduction has to be applied to an extent that it is more than halved.

4.2 Indicator LEDs

4.2.1 YELLOW "GPS LOCK" LED

The yellow LED is used to indicate to the user that the receiver is working within reasonable limits and is able to estimate GPS time (and hence UTC) with reasonable accuracy even if UTC is not yet known. It will be illuminated when dt and df/f drop below certain levels and the signs of the two error figures are different. For a low-cost OCXO, dt must be < ±20ns and df/f must be < ±2E-9. The yellow LED will be extinguished whenever the red LED changes from off to on. If satellite signals are lost for any reason, provided the control time constant has reached at least 1000s (and the averaged position - if used - has reached 24hrs), the reference OCXO will maintain its current value and drift rate for a time of three times the control time constant. This "hold-over" mode is signalled by a rapid (approx. 4 Hz) flashing of the yellow LED. If GPS time is not re-established within that hold- over period, the OCXO control ceases and lock acquisition is started from scratch as if the receiver had just been powered on.

4.2.2 RED "PAST UNLOCK" LED

The red LED is used to indicate to the user that the receiver has suffered an operational disruption in the past even though it may since have recovered. It actually indicates two differing levels of severity of past problems by means of either lighting continuously for minor errors or alternatively blinking indefinitely to indicate a previous total loss of time coherence. Once on, it cannot turn off by itself and similarly, once flashing, it cannot turn off (or revert to continuous) unless commanded by means of the button on the front or a command via the serial interface. If it is flashing, it indicates a previous loss of time coherence or a total break in the 1pps output such as may have been due to a power failure. If it is on continuously, it indicates a possible temporary time inaccuracy but without long term frequency error or loss of time coherence; i.e. there were ten million cycles of the 10 MHz output between every adjacent pair of pulses on the 1pps output. Possible reasons for the red LED illuminating continuously are: -

Without operator intervention: -

- No satellite observed for >30s and inadequate criteria to enable hold-over mode
- df/f > ±5-9
- dt > ±200ns
- End of period in hold-over mode

Due to operator intervention: -

- Position used was changed in CONFIG
- Entered position was changed (not applicable to some software versions)
- Delay was changed by less than approximately 150ns. Note that with larger delay changes, the red LED may start to flash if the 1pps divider chain needs to be reset.

Changing the position used or the delay by a very small amount will turn the red LED on as a matter of course by way of a warning (or possibly an event marker for remote logging) even though the error criteria may not be exceeded. It may therefore be reset (or acknowledged) immediately. The yellow LED will be turned off whenever the red LED is illuminated but even though the red LED may be immediately reset under these circumstances, the yellow LED may remain off until the next routine reset of the 1pps divider chain.

4.3 Remote Control

The Quartzlock model 8A may be remotely controlled by means of commands presented via the RS232 serial interface. It should be noted that any successfully received remote control command (or just a header) will immediately inhibit the changing or editing of any parameters by means of the front panel buttons. This is done primarily to avoid possible conflict or ambiguity in the setting of any parameter but also may serve to "lock" the receiver against unauthorised or inadvertent tampering. A special remote command; "#local< ><lf>" may be used to re-enable front panel control if desired. Unless and until this command is issued, all the functions of the front panel buttons remain available only for the purpose of inspecting any values or settings by means of the front panel LCD.

A remote command should be presented to the RS232 interface according to the following rules: -

Each command should begin with a hash character "#" (ASCII 35 ($23)) and end with a return ( ) followed by (lf) (ASCII 13, 10 ($0D,$0A)). In the remainder of this section this latter pair of characters will be indicated by the single symbol: < >.The second character (case insensitive) indicates the function of the command as follows:

a letter "s" for "setting" which will be followed by an underline (_),

a letter "c" for "clearing" any current warning which will also be followed by an underline (_),

a letter "L" being the first letter of the word "local" which re-enables front panel data entry.

In the case of commands beginning "#s_..." the following three characters denote the parameter to be set or read. e.g:

"#s_tim= +1,29-07-97,13:43< >"

will set the battery backed clock to 12.43 hrs UTC on 29 July 1997 with an offset of +1 hr displayed.

#s_tim= +1,29-07-97,13:43< >

will set the battery backed clock to 12.43 hrs UTC on 29 July 1997 with an offset of +1 hr displayed if no satellites have been received since power on.

If the time is already known from one or more satellites, the clock will not be remotely settable and the time and date setting part of the command will be discarded with a response of "time known"; only the shorter command giving the offset (e.g. "#s_tim=1< >") only will yield the normal "!ok" acknowledgement confirming that the displayed offset has been set according to the command.

5 GLOSSARY

Terms, acronyms and unusual words as used in this handbook

ADC	Analogue to Digital Converter (used in the model 8 to read the analogue outputs of the sine and cosine carrier detectors).
Almanac Orbital	Information broadcast by all Navstar satellites and stored locally by a GPS receiver to enable rapid location after power application.
Antenna Cable	Cable between antenna and down-converter, as distinct from down- converter cable.
Antenna Obscuration	Obstruction between antenna and (part of) sky, sufficient to hinder satellite reception from that part of the sky.
Apparent GPS	Time calculated realisation of GPS time and subject to errors, particularly SA, atmospheric aberrations and position used.
Azimuth	Direction of observed satellite relative to true North from position of receiver.
Baud Rate	Transmission rate of data and signalling overheads via aerial link expressed in bits per second.
Constellation	Group of satellites either currently observable by a receiver or currently included in the system; dependent on context.
Control Time	Constant integration time of negative feedback applied to local reference oscillator.
DAC	Digital to Analogue Converter (used in the model 8 to steer the frequency of the local reference oscillator under micro-processor control).
Delay	Nominal difference between UTC and time as signalled by the 1pps output of the receiver.
DGPS	Differential GPS; GPS with enhanced accuracy due to separate reception of pseudorange corrections determined nearby.
Doppler	Shift observed shift in frequency (in this context; of a radio carrier) caused by relative movement between transmitter and receiver.
Down-converter	Module used by model 8 to reduce the frequency of the signal; by reference to the receiver's local oscillator thereby considerably reducing cable loss and allowing the use of lighter cable.

Down-converter cable	Cable between down-converter and GPS receiver which carries a 92.07 MHz reference frequency and DC power from the receiver to the down-converter and also carries the 2nd IF signal from the down- converter to the receiver.
Elevation	Angle of a particular satellite above the horizontal as observed from the antenna.
Ellipsoid	Simple solid as an approximation to the shape of Earth, used in preference to the geoid to simplify certain calculations.
Ephemerides	Orbital data with limited currency due to high level of precision, may be superseded within one orbital period.
GDOP	Geometrical Dilution Of Precision; increased uncertainty of a position estimate due to non-ideal location of satellites.
Geoid	Approximation of true shape of Earth, closer (although more complex) than simple ellipsoid and very close to mean sea level.
GPS time	Timescale used by the Navstar GPS system; close to UTC but without the leap seconds, which are added to UTC to maintain approximation to sidereal time.
HDOP	Horizontal Dilution Of Precision.
Hexadecimal	Numbering system to base 16 (e.g. 0123456789ABCDEF). Hexadecimal numbers used in this handbook are prefixed with a "$" symbol to avoid ambiguity.
IF	Intermediate Frequency (used within a radio receiver); the 1st IF of the model 8 is 102.3 MHz and is confined to the down-converter
LED	Light Emitting Diode; primarily used as front panel indicator(s) and display illumination.
NMEA	National Maritime Engineering Association; body defining the interface protocol used by the serial interface (NMEA-0183) NVRAM or non-volatile memory with integrity preserved in the absence of power; used in the model 8 to save the almanac and certain user determined settings.
OCXO	Oven Controlled X (Crystal) Oscillator, sometimes referred to as temperature controlled; used as a considerably more stable alternative to a quartz crystal at ambient temperature.
PLL	Phase Locked Loop; method of controlling an oscillator to have a fixed phase (or frequency) relationship to another.

Position averaging	Calculation of an average of a number of separate position estimates intended to remove certain types of error.
PRN	Pseudo-Random Noise/Number (sequence); used by the satellites to distinguish the signals and to provide part of the timing signal.
RMS	Root Mean Square; means of expressing time-averaged energy content of varying signal, noise or error.
Rubidium	Chemical element with certain advantageous properties for use in an atomic clock.
Selective Availability (SA)	Deliberate errors imposed on the signals from the satellites to deny the full accuracy of the system to unauthorised users Sub-horizontal below the horizon; coined in this handbook to describe satellites, which the stored almanac suggests, should be below the horizon.
SV	Space Vehicle (satellite); one of the constellations of Navstar GPS satellites used by the model 8.
TTFF	Time To First Fix; the time between switching a receiver on and it making its first position estimate (for which four satellites are needed).
UPS	Uninterruptible Power Supply; power supply usually incorporating rechargeable batteries to mitigate the effects of mains power failures.
URA	User Range Accuracy; reasonable estimate of time and position (pseudorange) accuracy broadcast by and relating to each satellite.
UTC	Universal Co-ordinated Time (internationally agreed and maintained) referred to GPS time by USNO.
WGS84	World Geodetic System 1984; internationally agreed datum and co- ordinate system used by GPS system.