

E8-1PPS Series

E8-X, E8-Y, E8000 & E8010

E8000-TT/E8000A

GPS Timing & Frequency Reference

USER'S HANDBOOK

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Safety Considerations

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.

Before Applying Power

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

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.

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.

Voltage, Frequency and Power Characteristics

AC Power Adaptor (Rack mount units excluding E8010)

Voltage 100-240V AC

Frequency 40-60Hz

Power characteristics 700mA Max

Voltage 15V DC 300mA – 1700mA

AC Plug Top Adaptor (Desk top units)

Voltage 100-240V AC

Frequency 50-60Hz

Power characteristics 600mA Max

Voltage 15V DC 1.2A

Environmental Conditions

Temperature

Operating (ambient) -10°C to +55°C (-65 to +65 option)

Storage -40°C to +85°C

Magnetic Field

Sensitivity $\leq 2 \times 10^{-11}$ / Gauss

Atmospheric Pressure -60m to 4000m

$< 1 \times 10^{-13}$ / mbar

Replaceable Fusing Characteristics

Rack mount units: - 800mA time-lag HBC

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.

E8-1PPS Series GPS Timing & Frequency Reference

Introduction

The GPS clock is shipped ready for operation. No adjustments are needed to have a 10MHz frequency reference and 1 pulse per second time reference within 20 minutes of initial switch on.

The status of the GPS lock is shown on four LEDs on the front panel.

For more information as to satellite signal strengths, etc, a computer with RS232 may be connected to the interface. A program such as NMEA Time may be used to display information from the GPS receiver.

Installation

The antenna should be installed, preferably with a 360 degree view of the sky. However the receiver is very sensitive and will give good results with the antenna on a window ledge, or even inside a building. The satellite signal strengths may be checked after installation using a computer with suitable software connected to the RS232 interface. The DC power supply should be connected. The unit will operate with any voltage between 12 and 18V DC. Current consumption for the E8-X is about 250mA max and the E8-Y/E8-1PPS about 300mA continuous, 600mA maximum warm up. A universal line power supply is provided.

Operation

The unit is fully programmed to operate without adjustment anywhere in the world. The GPS receiver will take about 1 minute to obtain a fix from a cold start with unknown location. The receiver then does a "site survey" for about 15 minutes, averaging the positions obtained. After the site survey is complete, the receiver switches to position hold mode, and uses all the satellites available to improve the accuracy of the time calculation. At this point the unit will lock its 20MHz reference oscillator to the GPS signal. This only takes a few seconds. Desk top: - when the PLL locks the red "lock" LED should go out, but may flash for a further minute as the PLL settles. The normal operating condition is with the red "lock" LED off. Rack mount: - when the PLL locks the "ON" LED will change from amber to green, but may flash amber for a further minute as the PLL settles. The normal operating condition is with the "ON" LED green.

The status of the satellite tracking is shown by the SATS USED LED. The normal situation is that the LED shows a long flash, followed by a number of short flashes. The number of short flashes shows the number of satellites being tracked, and included in the time solution. E8-X Only - the Lower LED may also flash. This shows the number of satellites being tracked, but not included in the timing solution. All other variants – the lower LED flashes once every time a 1PPS pulse is present.

If the red "lock" LED should start to flash at about 1Hz rate, this indicates that the phase error between the GPS signal and the internal 20MHz oscillator is greater than a pre programmed threshold. This does not indicate that the 10MHz output is unlocked. During normal operation the GPS receiver estimates the accuracy of the timing solution using the "TRAIM" algorithm (Time Receiver Autonomous Integrity Monitoring). If the predicted timing error is greater than the programmed limit, the receiver will switch into holdover, and the red lock LED will turn on. The 10MHz output and 1PPS output will then drift according to the ambient temperature and aging of the internal oscillator. The unit should never go into holdover during normal operation. The most likely reason for doing so is a major antenna fault.

GPS interface

The GPS receiver interface uses NMEA format. In order to use this, a freeware program such as Trimble Studio should be installed on the user's PC.

Connect the unit to the PC and start the program. It may be necessary to set the port and baud rate (9600).

The various windows available from the program should show current satellite data, etc.

GPS interface (E8-X NavSync Version Only)

The Internal GPS receiver interface uses Motorola binary format. In order to use this, a freeware program such as WinOncore should be installed on the user's PC.

Connect the unit to the PC and start the program. It may be necessary to set the port and baud rate (9600). The receiver is preset to output 3 sentences on a continuous basis. These are Ha, (position/status/data), Hn, (12 channel TRAIM status message) and Bb (Visible satellites).

The various windows available from the program should show current satellite data, etc.

It is important to note that some parameters shown by the program will not correctly indicate the actual state of the receiver. This is because the program does not automatically update its information when started. In particular, the TRAIM algorithm will be shown as off when in fact it is by default on in the receiver.

For the receiver to operate correctly, the site survey must be enabled, and the TRAIM must be on. If this is not the case, the receiver will track satellites and compute a fix, but the red lock LED will not go out, showing the 10MHz output is in the standby state.

If the receiver gets stuck in a state where it does not lock, the user may inadvertently disabled the TRAIM or the site survey. To get back to a known state, the following should be performed:

The messages can be sent using the message window in the WinOncore software.

Return to factory default state:

“@@Cf”

Enable Position Auto-survey; consult the CW12 user manual for further details.

“@@Gd03”

Enable T-RAIM algorithm; consult the CW12 user manual for further details.

“@@Ge01”

Enable 1PPS output when >1 satellite is being tracked; consult the CW12 user manual for further details.

“@@Gc02”

Set the alarm threshold for the T-RAIM algorithm (300ns). Consult the CW12 user manual for further details.

“@@Gf0003”

Request channel T-RAIM status message (sent every second).

“@@Hn01”

If required, the position/status/data message may be turned on:

“@@Ha01”

If required, the visible satellites message may be switched on:

“@@Bb01”

The GPS receiver stores the current status in non volatile memory when switched off.

Microcontroller Interface (E8-1PPS & E8000-TT/E8000A Only)

The microcontroller interface allows setup and debug of the digital phase lock loop which locks the 20MHz reference oscillator to the GPS receiver. The list of control codes is given in an appendix.

Network Time Protocol Time Server Output

The NTP Time server output provides a simple method of putting accurate time information onto a network. In order to use this, a freeware program such as Tardis 2000 should be installed on the user’s PC.

Connect the unit to the PC and start the program. It may be necessary to set the port and baud rate (9600).

NMEA Messages

There are two main types of sentence, ‘Approved’ and ‘Proprietary’. All sentences start with \$ delimited with commas and ending with <CR><LF>. Approved sentences are recognized by the first 5 characters after the \$, which define both the kind of talker providing the information (2 characters, GP in the case of a GPS), and the type of information (3 characters). Proprietary sentences are indicated by a P following the \$, as the first of the 5 characters, the next 3 indicating the manufacturer (from a listing of mnemonic codes), and the 5th character being selected by that manufacturer for the particular sentence structure. Proprietary sentences must conform to the general NMEA structures, but are otherwise undefined outside of the Manufacturers own documentation.

The following Approved messages are available from the receiver:

- GPGLL - Geographic Position - Latitude longitude
- GPGGA - Global Positioning System Fix Data
- GPGSA - GNSS DOP and Active Satellites
- GPGSV - GNSS Satellites in View
- GPRMC - Minimum required sentence

GPGLL - Geographic position, Lat/Lon

Latitude and longitude, with time of position fix and status.

*\$GPGLL, Latitude, N, Longitude, E, hhmss.sss, Status, Mode*cs*

\$GPGLL	NMEA sentence header (Position Data)
Latitude	User datum latitude degrees, minutes, decimal minutes format (ddmm.mmmmmm)
N	Hemisphere ‘N’ = North, or ‘S’ = South
Longitude	User datum longitude degrees, minutes, decimal minutes format (dddmm.mmmmmm)
E	Longitude Direction ‘E’ = East, or ‘W’ = West
hhmss.sss	UTC Time in hours, minutes, seconds and decimal seconds format.
Status	Status V = navigation receiver warning, A = data valid
Mode	Mode indicator: A = Valid, Autonomous, D = Valid, Differential, E = Invalid, Estimated, N = Invalid, Not valid
cs	Message checksum in hexadecimal

GPGGA - GPS fix data

Time and position, together with GPS fixing related data.

*\$GPGGA, hhhmmss.sss, Latitude, N, Longitude, E, FS, NoSV, HDOP, Altref, M, msl, M, DiffAge, DiffStation*cs*

\$GPGGA	NMEA sentence header (Position Data)
hhmmss.sss	UTC Time in hours, minutes, seconds and decimal seconds format.
Latitude	User datum latitude degrees, minutes, decimal minutes format (ddmm.mmmmmm)
N	Hemisphere 'N' = North, or 'S' = South
Longitude	User datum longitude degrees, minutes, decimal minutes format (dddmm.mmmmmm)
E	Longitude Direction: 'E' = East, 'W' = West
FS	Fix Status: 0 No fix 1 Standard GPS 2 Differential GPS
NoSV	Number of satellites used in the position solution
HDOP	2-D Horizontal Dilution of Precision (0.00 to 99.99)
AltRef	Altitude (metres) above user datum ellipsoid
M	Units of height (metres)
msl	Mean Sea Level
M	Units of Mean Sea Level (meters)
DiffAge	Age of differential correction
DiffStation	Differential base station ID
cs	Message checksum in hexadecimal

GPGSA - GPS DOP and Active satellites

GPS receiver operating mode, satellites used for navigation and DOP values.

*\$GPGSA, Smode, FS, sv, sv, sv, sv,sv,,,,,, PDOP, HDOP, VDOP*cs*

\$GPGSA	NMEA sentence header (Satellite Data)
Smode	A = Automatic switching 2D/3D M = Manually fixed 2D/3D
FS	Fix Status: 1 No fix 2 2D GPS Fix 3 3D GPS Fix
sv	Satellites in use, null for unused fields (12 available fields)
PDOP	3-D Position Dilution of Precision (0.00 to 99.99)
HDOP	2-D Horizontal Dilution of Precision (0.00 to 99.99)
VDOP	Vertical Dilution of Precision (0.00 to 99.99)
cs	Message checksum in hexadecimal

GPGSV - GPS Satellites in View

The number of satellites in view, together with each PRN, elevation and azimuth, and C/No value. Up to four satellite details are transmitted in one message, with up to three messages used as indicated in the first field.

*\$GPGSV, NoMsg, MsgNo, NoSv{ ,sv, elv, az, cno}{, sv, elv, az, cno....}*cs*

Note: {} designate optional sections that appear only if there is satellite data.

\$GPGSV	NMEA sentence header (Satellite Data)
NoMsg	Total number of GPGSV messages being output
MsgNo	Number of this messages
NoSv	Number of satellites in view
sv	Satellites ID
elv	Satellite elevation angle (degrees)
az	Satellite azimuth angle (degrees)
cno	Satellite signal/Noise ratio (dB/Hz)
cs	Message checksum in hexadecimal

GPRMC - Recommended Minimum data

The 'Recommended Minimum' sentence is defined by NMEA for GPS/Transit system data.

*\$GPRMC, hhhmmss.sss, status, latitude, N, Hemisphere, longitude, E, spd, cmg, ddmmyy, mv, mvd, Mode*cs*

\$GPRMC	NMEA sentence header (Recommended Minimum Sentence)
hhmmss.sss	UTC Time in hours, minutes, seconds.
status	Status: V = navigation receiver warning, A = data valid
Latitude	User datum latitude degrees, minutes, decimal minutes format (ddmm.mmmmmm)

N	Hemisphere: 'N'= North, or 'S' = South
Longitude	User datum longitude degrees, minutes, decimal minutes format (dddmm.mmmmmmm)
E	Longitude Direction: 'E' = East, 'W' = West
spd	Speed over ground (knots).
cmg	Course made good
ddmmyy	Date in Day, Month Year format
mv	Magnetic variation
mvd	Magnetic variation direction
Mode	Mode Indicator: D = Valid, Differential, A = Valid, Autonomous, E = Invalid, Estimated, N = Invalid, Not Valid
cs	Message checksum in hexadecimal

GPS and Windows Serial Mouse Issue

Problem: It is possible for windows to incorrectly interpret the data output from the Quartzlock GPS interface as the output of a Microsoft Serial BallPoint Mouse. When that happens, Windows loads drivers for the Serial BallPoint Mouse. This causes the cursor to move erratically about the display, clicking, right clicking, double clicking, dragging and dropping display items as it goes. On Windows 2000, XP and Vista, you may not experience the problem if you wait until after the computer is booted before connecting the Quartzlock GPS to the serial communications port. This problem is not specific to Quartzlock GPS. Any NMEA/Binary output device connected to a Windows computer's serial port is likely to cause this problem. Below are several possible solutions to this problem.

Solution 1:

The easiest solution is to disable the Serial BallPoint mouse in the Device Manager. Of course, this solution assumes that you do not need to use a Serial BallPoint mouse with your computer. When the wild mouse problem occurs follow the steps below.

1. Unplug the DB9 connector.
2. Right click the **My Computer** icon on your desktop and select **Properties** to open the Device Manager.
3. Go to the hardware tab of the resulting pop up window and click on the **Device Manager** button.
4. Right click on **Serial BallPoint Mouse** and choose the option to **Disable** (NOT uninstall) this device.

Solution 2:

Do not plug the DB9 connector into the computer until the computer is turned on and the operating system is completely booted and running. Every time you use the Quartzlock GPS, you will need to start the computer and operating system before making the connection between the Quartzlock GPS and the computer. This solution normally works on Windows 2000, XP and Vista computers.

Specifications

OUTPUTS:

Sine wave, 10MHz, 12dBm ± 2dBm into 50ohms

Harmonics < -50dBc

Spurii < -75dBc

TTL, 3.3V CMOS, 1 Pulse Per Second

POWER SUPPLY:

100 to 240 AC 700mA (Rack Mount)

12 to 15V DC 250mA – 1500mA (Desk Top)

DPLL tracking bandwidths

5mHz to 500mHz typical in 8 binary increments

Default 20mHz

LOCK INDICATOR (Desk Top)

On	not locked
Off	locked, low phase error
Short flash every second:	locked, high phase error

ON INDICATOR (Rack Mount)

Amber	not locked
Green	locked, low phase error
Short amber flash every second:	locked, high phase error

GPS INDICATOR (Desk Top)

SATS USED	indicates no of satellites used in time solution
1PPS	Flashes when 1PPS signal is present

GPS INDICATOR (Rack Mount)

Green	indicates no of satellites used in time solution
Red	Flashes when 1PPS signal is present

INTERFACE

The E8-1PPS has 3 RS232 interfaces

1. NMEA output JP4 9.6k baud, RS232, 8 bits no parity, no handshake
2. GPS TSIP JP3 9.6k baud, RS232, 8 bits odd parity, no handshake
3. Microprocessor JP3 9.6k baud, RS232, 8 bits no parity, no handshake

The E8-X & E8-Y has 1 RS232 interface

1. NMEA output JP4 9.6k baud, RS232, 8 bits no parity, no handshake

The E8000 has 3 Optional RS232 interfaces

1. NMEA output JP4 9.6k baud, RS232, 8 bits no parity, no handshake

- 2. GPS TSIP JP3 9.6k baud, RS232, 8 bits odd parity, no handshake
- 3. Microprocessor JP3 9.6k baud, RS232, 8 bits no parity, no handshake

The E8000-TT/E8000A has 3 RS232 interfaces

- 1. NMEA output 9W D Pins 2 & 4 9.6k baud, RS232, 8 bits no parity, no handshake
- 2. GPS TSIP 9W D Pins 4 & 9 9.6k baud, RS232, 8 bits odd parity, no handshake
- 3. Microprocessor 9W D Pins 7 & 8 9.6k baud, RS232, 8 bits no parity, no handshake

INTERFACE CODES

Micro processor codes See [Appendix B](#)

Appendix A Board Variation/Configuration

TCXO Version

The following components are not fitted: -

C42
GPS1
R24, R25, R29
TCXO2
U8, U13, U17, U24, U25, U27, U29, U30, U33, U34, U38, U39
VCXO1, VCXO2, VCXO3

Note: - GPS2 WITH internal clock omit U40
GPS2 WITHOUT internal clock fit U40

Link configuration: -

Link1 position 2
Link2 position 1
Link3 position 2
Link4 position 2
Link5 not used
Link6 position 1
Link7 open
Link8 position 1

OCXO Version without 1PPS holdover and user adjustable 1PPS

The following components are not fitted: -

C51, C52, C53, C54, C55, C56, C57, C58
GPS2
L2, L3, L4, L5
R39, R40, R41
TCXO1, TCXO2
U13, U17, U24, U25 U27, U28, U29, U30, U33, U38, U39, U40, U41

Link configuration: -

Link1 position 2
Link2 position 1
Link3 position 1
Link4 position 1
Link5 position 2
Link6 position 1
Link7 short (8V tuning)

OCXO Version with 1PPS holdover and user adjustable 1PPS

The following components are not fitted: -

C51, C52, C53, C54, C55, C56, C57, C58
GPS2
L2, L3, L4, L5
R39, R40, R41

TCXO1, TCXO2
U13, U17, U24, U28, U38, U39, U40, U41

Link configuration: -

Link1 position 2
Link2 position 2
Link3 position 1
Link4 position 1
Link5 position 2
Link6 position 1
Link7 short (8V tuning)

Appendix B μ P RS232 control codes

RS232 control codes (all values following command or returned from the microcontroller are hexadecimal unless stated)

* = backed up in EEPROM

OS Overall Status

OS? returns overall status bytes:

aa bb cc dd eeee ffff

aa is test status byte: bits set:

<i>bit0</i>	50PPS output (default 1PPS)
<i>bit1</i>	50PPS input (default 1PPS)
<i>bit2</i>	disable auto cal
<i>bit3</i>	disable 1PPS output
<i>bit4</i>	disable 1PPS input time tag
<i>bit5</i>	disable frequency correction (Kalman filter updated)
<i>bit6</i>	disable Kalman filter update
<i>bit7</i>	disable state control

bb is lock status byte: bits set:

<i>bit0, 1, 2</i>	state (0 to 7)
<i>bit3</i>	normalise DACs (cleared automatically)
<i>bit4</i>	OCXO warmed up
<i>bit5</i>	loop locked
<i>bit6</i>	Disable 1PPS quantization correction
<i>bit7</i>	zero clock on next 1PPS capture

* *cc* is output status byte: bits set:

<i>bit0</i>	1PPS base = last input time tag
<i>bit1</i>	1PPS base = Kalman phase estimate otherwise 1PPS base is zero
<i>bit2</i>	Disable user 1PPS offset calculation(enables PO command)
<i>bit3, 7</i>	NU

* *dd* is auto cal byte

(set to FF on loading new firmware)

<i>bit0</i>	set loads EEPROM default 0, then cleared
<i>bit1</i>	set initiates auto OCXO calibration, then cleared
<i>bit2</i>	set when OCXO cal is in progress
<i>bit3</i>	NU
<i>bit4, 7</i>	last EEPROM default number

eeee is OCXO current 0000 to FFFF 0 to 500mA

* *ffff* is running time 0000 to FFFF unit 18.2 hours

OSTaa write new test status byte

OSLbb write new lock status byte

OSPcc write new output 1PPS status byte

OSAdd write new autocal byte

PO 1PPS OUT

PO? returns current status of 1PPS output

aa bbbb cc dd

aa modulo50 counter (20ms) range 0 to 49

bbbb main counter (400ns) range 0 to 49999 (C34Fh)

cc delay setting (50ns) range 0 to 8 (delay 50 to 450ns)

dd vernier (0.25ns) range 0 to 255

POAaa write new modulo50 counter

POBbbbb write new main counter

POCcc write new delay setting

PODdd write new vernier

PD 1PPS OUT

PD? returns current user 1PPS offset in decimal ns

(-)aaaaaaaa

* (-)aaaaaaaa last user 1PPS offset, -500,000,000 to 499,999,999 ns

PD(space)(string)(carriage return) inputs new user 1PPS offset in floating point format e.g. to set the offset to 500ns delay "PD 000000500"

TO TIMETAG

TO? returns last time tag parameters
aaaaaaaa bbbb cccc dddd ee f(fp string)

aaaaaaaa Last time tag (32 bit)
bbbb first capture
cccc second capture
dddd second capture-first capture
ee Modulo50 capture
f (floating point) last 1PPS quantization correction

TO+ write TO? to command repeat stack

PM PERFORMANCE MEASURE

PM? returns last time tag in decimal ns, and other performance indicators
a (fp string) b (fp string) ccccccc dddd eeee f (fp string) g (fp string)

a (floating point) Corrected time tag
b (floating point) Last Kalman phase estimate
ccccccc Mean square measurement error (ns squared) (decimal integer)
dddd Filtered performance indicator 0 to 32768 (decimal integer)
eeee S1 multiplier (decimal integer)
f (floating point) Frequency estimate and correction
g (floating point) Mean of frequency estimate

PM+ write PM? to command repeat stack

Notes:

The performance indicator is the square of the current fractional frequency estimate divided by the P22 element of the error covariance matrix multiplied by 2048. The normal running value is 0 to 100

The mean square measurement error is the (Kalman phase estimate minus the current time tag) ^2 and filtered in an 8th order exponential filter. Units are ns^2.

The S1 multiplier is the constant used to multiply the S1 system noise parameter (random walk FM). This results in a recalculation of the Q matrix (system covariance matrix). This adjusts the filter for expected increased drift rate of the controlled oscillator.

The mean of the frequency estimate is the Kalman frequency estimate filtered by a 5th order exponential filter

KP Kalman filter error covariance matrix

* KP? returns current error covariance matrix

<i>P11</i>	<i>P12</i>	<i>P13</i>	
	<i>P22</i>	<i>P23</i>	
		<i>P33</i>	<i>in floating point format</i>

KPxx (space) (string) (carriage return) inputs a new floating point value, where xx identifies matrix element

KP+ write KP? to command repeat stack

KQ System covariance matrix

KQ? returns current system covariance matrix

<i>Q11</i>	<i>Q12</i>	<i>Q13</i>
	<i>Q22</i>	<i>Q23</i>
		<i>Q33</i>

Note Q matrix is calculated from system noise parameters on reset, and also in states 2, 3 and 5

KX System state vector

* KX? returns current system state vector

<i>X1</i>	<i>X2</i>	<i>X3</i>
-----------	-----------	-----------

Note X1 is current phase estimate, X2 is current frequency estimate, and X3 is current drift estimate

KX+ write KX? to command repeat stack

KS System noise parameters

* KS? returns current system noise parameters

<i>S1</i>	<i>S2</i>
-----------	-----------

Note S1 is the level of random walk FM noise, and S2 the level of white FM noise. These are fixed parameters that describe the oscillator being modelled.

KSx (space) (string) (carriage return) inputs a new floating point value where x is the matrix element

KZ Measurement parameters

* KZ? returns the latest measurement, and the current measurement noise parameter

<i>aa</i>	<i>8 bit command repeat interval multiplier. Range 1 to 255. Command repeat interval is 40ms x aa</i>
RI0aa	write new command repeat interval
RID	cancel command repeat and clear command repeat stack

Appendix C NMEA 0183 Protocol

This appendix provides a brief overview of the NMEA 0183 protocol, and describes both the standard and optional messages offered.

Introduction

NMEA 0183 is a simple, yet comprehensive ASCII protocol which defines both the communication interface and the data format. The NMEA 0183 protocol was originally established to allow marine navigation equipment to share information. Since it is a well established industry standard, NMEA 0183 has also gained popularity for use in applications other than marine electronics.

For those applications requiring output only from the GPS receiver, NMEA 0183 is a popular choice since, in many cases, an NMEA 0183 software application code already exists. The E8-1PPS is available with firmware that supports a subset of the NMEA 0183 messages: GGA, GLL, GSA, GSV, RMC, VTC, and ZDA.

NMEA 0183 communication interface

NMEA 0183 allows a single source (talker) to transmit serial data over a single twisted wire pair to one or more receivers (listeners). The table below lists the standard characteristics of the NMEA 0183 data transmissions.

Signal NMEA Standard

Baud rate 9600

Data bits 8

Parity None (Disabled)

Stop bits 1

NMEA 0183 message structure

The NMEA 0183 protocol covers a broad array of navigation data. This broad array of information is separated into discrete messages which convey a specific set of information. The entire protocol encompasses over 50 messages, but only a sub-set of these messages apply to the E8-1PPS GPS receiver. The NMEA message structure is described below.

\$IDMSG,D1,D2,D3,D4,.....,Dn*CS[CR][LF]

- \$ Signifies the start of a message
 - ID The talker identification is a two letter mnemonic which describes the source of the navigation information. The GP identification signifies a GPS source.
 - MSG The message identification is a three letter mnemonic which describes the message content and the number and order of the data fields.
 - ,
 - Dn Each message contains multiple data fields (Dn) which are delimited by commas.
 - *
 - The asterisk serves as a checksum delimiter.
 - CS The checksum field contains two ASCII characters which indicate the hexadecimal value of the checksum.
- [CR][LF] The carriage return [CR] and line feed [LF] combination terminate the message.

NMEA 0183 messages vary in length, but each message is limited to 79 characters or less. This length limitation excludes the "\$" and the [CR][LF]. The data field block, including delimiters, is limited to 74 characters or less.

Field definitions

Many of the NMEA date fields are of variable length, and the user should always use the comma delineators to parse the NMEA message date field. The following table specifies the definitions of all field types in the NMEA messages supported by the E8-1PPS:

Status A Single character field: A=Yes, data valid, warning flag clear V=No, data invalid, warning flag set

Special Format Fields

Latitude	lll.lll	Fixed/variable length field: Degreesminutes.decimal-2 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal- fraction are optional if full resolution is not required.
Longitude	yyyyy.yyy	Fixed/Variable length field: Degreesminutes.decimal-3 fixed digits of degrees, 2 fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Leading zeros always included for degrees and minutes to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Time	hhmmss.ss	Fixed/Variable length field: hoursminutesseconds.decimal-2 fixed digits of minutes, 2 fixed digits of seconds and a variable number of digits for decimal-fraction of seconds. Leading zeros always included for hours, minutes, and seconds to maintain fixed length. The decimal point and associated decimal-fraction are optional if full resolution is not required.
Defined		Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in this standard by the presence of one or more valid characters. Excluded from the list of allowable characters are the following that are used to indicated field types within this standard: "A", "a", "c", "hh", "hhmmss.ss", "lll.ll", "x", "yyyyy.yy"

Numeric Value Fields

Variable	x.x	Variable length integer or floating numeric field. Optional leading and trailing zeros. The decimal point and associated decimal fraction are optional if full resolution is not required (example: 73.10=73.1=073.1=73).
Fixed HEX	hh	Fixed length HEX numbers only, MSB on the left

Information Fields

Fixed Alpha	aa	Fixed length field of upper-case or lower-case alpha characters.
Fixed Number	xx	Fixed length field of numeric characters

NMEA 0183 message options

The E8-1PPS can output any or all of the messages listed in the table below. Typically NMEA messages are output at a 1 second interval with the "GP" talker ID and checksums. These messages are output at all times during operation, with or without a fix.

GGA	GPS fix data
GLL	Geographic position Latitude/Longitude
GSA	GPS DOP and active satellites
GSV	GPS satellites in view
RMC	Recommended minimum specific GPS/Transit data
VTG	Track made good and ground speed
ZDA	Time and date

Appendix D TSIP Protocol

Please refer to the Trimble Website

[Resolution SMT GG - User Guide](#)

[Trimble VTS Software](#)

Appendix E Connector, Jumper and Link References

CONN1

External 1PPS Input (MCX)

CONN2

GPS Antenna Input (BNC) (Optional TNC)

CONN3

GPS Antenna Input (SMA) (not fitted if CONN3 fitted)

CONN4

1PPS Output (BNC)

CONN5

1PPS Output (MCX) (not fitted if CONN4 fitted)

CONN6

10MHz RF Output Sine/Square (MCX/SMA) (not fitted if CONN7 fitted)

CONN7

10MHz RF Output Sine/Square (BNC)

CONN8

External 10MHz RF Input (MCX/SMA)

J1

Lumberg 1613 14
15Vdc Input

JP2

Samtek TSM-103-01-S-DV

Pin 1 – External reference tune output
Pin 2 – External reference lock input
Pin 3 – Ground

Pin 4 – Ground
Pin 5 – Not Connected
Pin 6 – Not Connected

JP3

Samtek TSM-104-01-S-DV

Pin 1 – Ground
Pin 2 – Ground
Pin 3 – GPS Port A RS232 RX
Pin 4 – uP RS232 RX

Pin 5 – GPS Port A RS232 TX
Pin 6 – uP RS232 TX
Pin 7 – Loopback
Pin 8 – 1PPS Output (Holdover Option)

JP4

TE Connectivity 5747840-6

Pin 1 – Not Connected
Pin 2 – GPS Port B RS232 RX
Pin 3 – GPS Port B RS232 TX
Pin 4 – Not Connected
Pin 5 – Ground

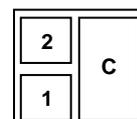
Pin 6 – Not Connected
Pin 7 – Not Connected
Pin 8 – Not Connected
Pin 9 – Not Connected

JP5

Eeprom programming connection

Link1

Select 1PPS input: -
Link Position 1 – External 1PPS input via CONN1
Link Position 2 – Onboard GPS 1PPS input



Link2

Select 1PPS Output (CONN4 / CONN5): -
Link Position 1 – Onboard GPS 1PPS Direct Output (No Holdover)
Link Position 2 – 1PPS smoothed output (Holdover)

Link3

Select controlled oscillator type: -
Link Position 1 – OCXO / EXT
Link Position 2 – TCXO

Link4

Select controlled oscillator type: -
Link Position 1 – OCXO / EXT
Link Position 2 – TCXO

Link5

Select controlled oscillator input: -
Link Position 1 – External input via CONN8
Link Position 2 – Onboard oscillator

Link6

Select 10MHz output (CONN6 / CONN7): -
Link Position 1 – Sine wave output
Link Position 2 – Square wave output

Link7

Open for 5V oscillator tuning link for 8V oscillator tuning voltage

Link8

Select TCXO supply voltage: -
Link Position 1 – 3.3Vdc
Link Position 2 – 5Vdc

TP1

1PPS Input

TP2

OCXO tuning control voltage output

TP3

1PPS Output

TP4

TBC

TP5

Test Out

TP6

Capture

TP7

TBC

TP8

OCXO current monitor

TP9

+15Vdc

TP10

Ground

TP11

External Reference Oscillator Lock Input (High +5Vdc = Not Locked. Low 0Vdc = Locked)

TP12

Lock LED

TP13

1PPS (GPS1 fitted) or SATS Unused LED (GPS2 fitted)

TP14

SATS Used LED

TP15

ON LED

TP16

+5Vdc

TP17

+5Vdc Ref

TP18

+10Vdc

TP19

+3.3Vdc

TP20

GPS2 site survey finished

Appendix F EEPROM defaults

DEFAULT 0 OCXO medium performance with 0 to 5V tuning

Automatically loaded after programming firmware

S1 = 2E-12
S2 = 3E-11
Rmeas = 225E-18
OSCcontrolconstant = 2E-7
OSCtunespan = 5.0
maxphasedrift0 = 20000 (in nanoseconds)

DEFAULT 1 OCXO medium performance with 0 to 8V tuning

S1 = 2E-12
S2 = 3E-11
Rmeas = 225E-18
OSCcontrolconstant = 2E-7
OSCtunespan = 8.0
maxphasedrift0 = 20000 (in nanoseconds)

DEFAULT 2 TCXO low performance with 0 to 3.3V tuning, NavSync receiver

S1 = 2E-11
S2 = 3E-10
Rmeas = 2.5E-15
OSCcontrolconstant = 5E-6
OSCtunespan = 3.3
maxphasedrift0 = 200000 (in nanoseconds)

DEFAULT 3 Rubidium high performance with 0 to 5V tuning

S1 = 2E-14
S2 = 5E-12
Rmeas = 225E-18
OSCcontrolconstant = 0.4E-9
OSCtunespan = 5.0
maxphasedrift0 = 5000 (in nanoseconds)

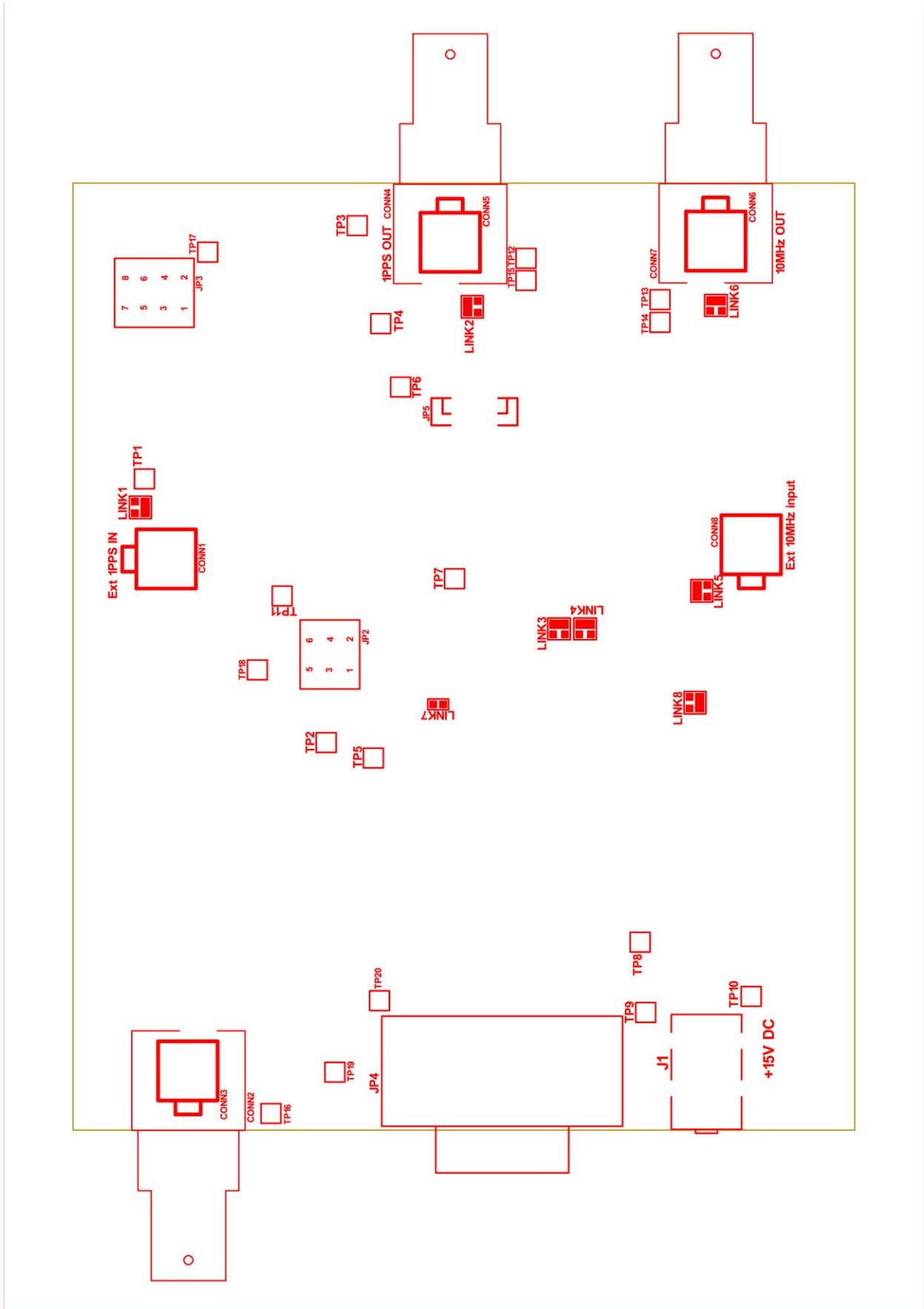
DEFAULT 4 TCXO low performance with 0 to 3.3V tuning, Trimble receiver

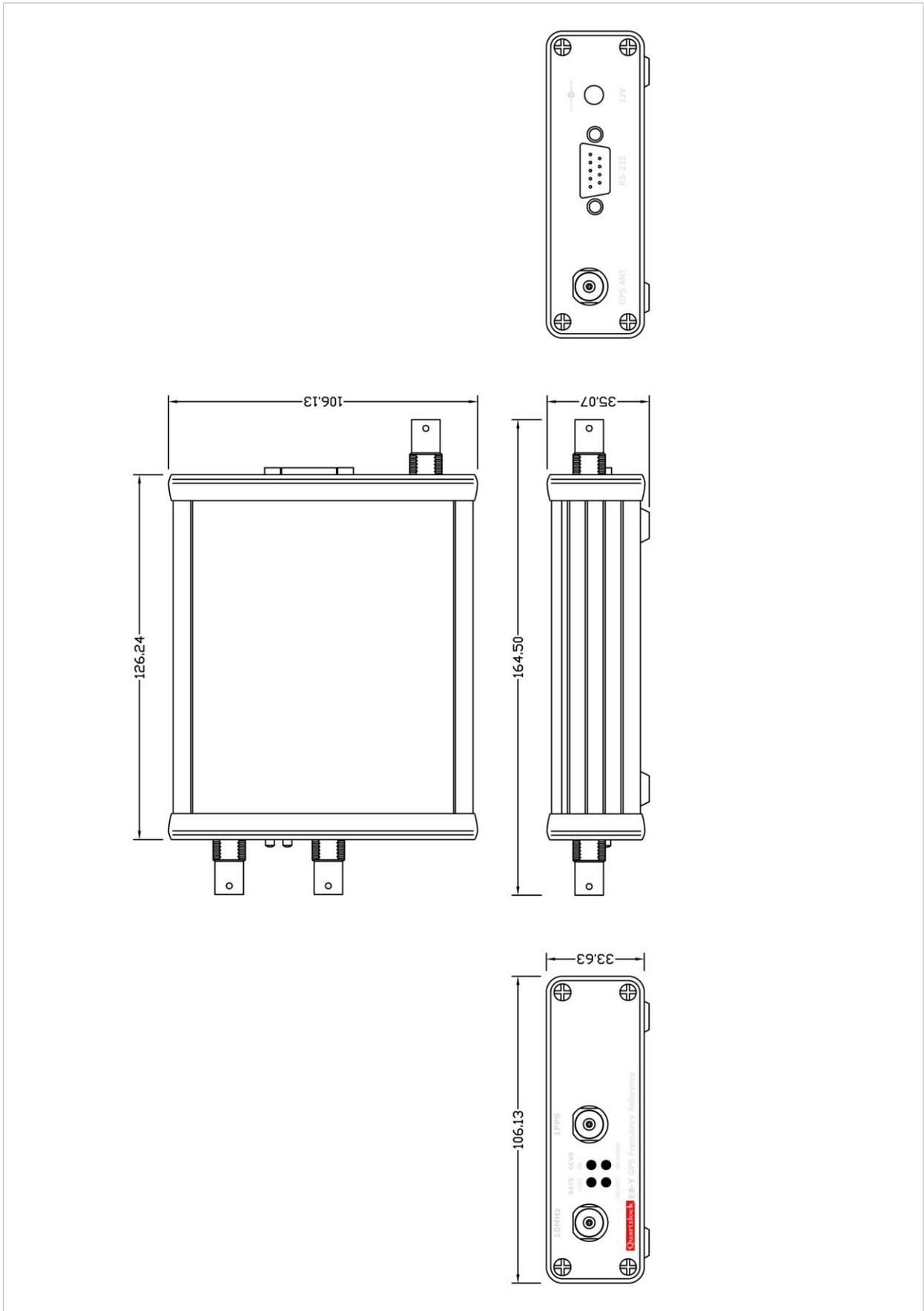
S1 = 2E-11
S2 = 3E-10
Rmeas = 2.5E-15
OSCcontrolconstant = 5E-6
OSCtunespan = 3.3
maxphasedrift0 = 200000 (in nanoseconds)

Notes: - default is loaded using EDx command, where x is default number.

After loading a default, software will attempt to calibrate the actual tuning slope (control constant) of the oscillator. Lock state must be 4 for this to occur.

Appendix G Board Layout





Appendix H Instrument RS232 Connections 9 Way Male Connector

E8-X, E8-Y, E8000, E8010

Pin

1. N/C
2. RS232 RX NMEA Data
3. RS232 TX NMEA Data
4. N/C
5. Ground
6. N/C
7. N/C
8. N/C
9. N/C

E8-X, E8-Y, E8000, E8010 TSIP Option

Pin

1. N/C
2. RS232 RX TSIP
3. RS232 TX TSIP
4. N/C
5. Ground
6. N/C
7. N/C
8. N/C
9. N/C

E8000-TT/E8000A

Pin

1. N/C
2. RS232 RX GPS NMEA Data
3. RS232 TX GPS NMEA Data
4. RS232 RX Data Trimble TSIP
5. Ground
6. N/C
7. RS232 RX E8-Series Micro Controller
8. RS232 TX E8-Series Micro Controller
9. RS232 TX Data Trimble TSIP

Appendix I Board Test

Introduction

This board locks an oscillator (TCXO, OCXO or rubidium oscillator) to a 1PPS pulse stream from an integrated GPS receiver. The hardware comprises a number of more or less independent sections which require testing on each new board.

The circuit sections are:

- a) 1PPS output circuit
- b) 1PPS time tag circuit
- c) Controlled oscillator tuning supply
- d) GPS module and interfaces
- e) Controlled oscillator
- f) Options

The design uses a PIC 18F65K22 microcontroller which is clocked at 10MHz from the controlled oscillator. This ensures the microcontroller internal clock is synchronous with the controlled oscillator. By time tagging the incoming 1PPS using the internal clock, the frequency difference between the 1PPS input and the controlled oscillator can be measured. Frequency corrections are then made to the controlled oscillator.

The board test uses special test routines that are a permanent part of the operating software.

General purpose test equipment is used to make manual measurements.

Circuit Descriptions

1PPS output circuit

This part of the circuit is only fitted if an E8-1PPS is built with optional 1PPS holdover

The microcontroller generates a rising edge on pin 3(ECCP3). This is generated using an internal peripheral (capture/compare module) when the internal clock equals the setting of the 1PPS output delay register. The delay register is settable by the PD command.

The internal resolution of this edge is 400ns (One processor cycle at a clock frequency of 10MHz). In order to provide 1ns delay resolution, the rising edge is further delayed by the shift register U25 and the analogue delay chip U30. U25 shifts the rising edge into the shift register on each selectable rising or falling edge of the processor clock (exclusive OR gate U29 provides the clock inversion). Each output of the shift register provides a delayed and re-clocked rising edge with successive delays of 100ns. Inversion of the clock shifts all the delayed outputs by 50ns. U27 is a 16 to 1 multiplexer that selects one of the edges under control of the 4 bit address provided by the microcontroller. Bit 0 of the address is used to invert the clock. Bits 1 to 3 are used to select the delayed edge. The minimum delay is 50ns, and the maximum used is 450ns.

The output on pin 5 of U27 is then applied to U30. U30 is a standalone delay chip that provides delay increments of approximately 0.25ns steps from 0 to 63ns. There is a fixed delay of about 20ns.

Using the three delay mechanisms, the processor can calculate appropriate settings to delay the 1PPS output -500000000 to +499999999 ns in 1ns steps.

An internal timer terminates the 1PPS pulse after 10ms.

1PPS time tag circuit

This is the most complicated of the three circuit blocks.

It can time tag the incoming 1PPS rising edge to a resolution of 1ns. It does this by a combination of an internal capture module, (ECCP2) and a pulse width expander. After the first 1PPS, the processor has a near exact knowledge of when the next and subsequent 1PPS edges will arrive. It prepares for a new edge by setting the ready line (pin 48) high. This will occur between 20 and 40ms before the next 1PPS edge.

Initially D types U4A, U4B, U9A, and U9B are reset. Multiplexer U3 is configured to pass the incoming 1PPS to the clock input of U4A, so the 1PPS edge will set U4A. The processor pin 40 (CLKO) has a square wave at 2.5MHz, synchronized to the processor internal cycle clock. The first falling edge of CLKO will set U4B (clock is inverted by U11). The next rising edge of the 10MHz clock will then set U9A.

When U9A Q goes high, an internal capture is generated in the processor via OR gate U12 and the ECCP2 input pin. This capture provides an internal hardware read of the internal clock register.

As the 1PPS input is asynchronous, the time between the setting of U4A and U4B will vary between 0ns and 400ns depending on the phase of the 1PPS relative to the processor internal cycle clock. U9A is always set 100ns after U4B. And gate U15 generates a pulse between 100ns and 500ns by ANDing the Q output of U4A, and the ~Q output of U9A. This is applied to the gate of TR1 which charges the integrator an amount which depends on the pulse width.

In the resting state the integrator U14 is stabilised by feedback through U10. A bias voltage of 2.0 volts is applied to pin 4 of U10. The integrator positive input (pin 3, U14) is connected to 2.5V derived from a potential divider from the +5V reference. Current flows to the negative input through R10, and then to the output of U10 through D2 and R11. The positive input of U10 is connected to the integrator output through R12. The effect is to stabilise the integrator output voltage at 2.0 volts.

When a 1PPS pulse arrives, U9B is set. This applies a higher positive voltage to U10 positive input via R15 and D3. The output of U10 goes high, and reverse biases D2, effectively disconnecting the stabilisation circuit from the integrator. The pulse to be expanded, length 100 to 500ns, turns on TR1. The integrator charges due to current in R13 to an output voltage between 3V and 8V depending upon the pulse width. After TR1 turns off, the integrator discharges due to current in R14. This discharge is about 2000 times slower than the charge rate, which expands the input pulse to a time between 200us and 1ms.

The positive input of the fast comparator U5 is biased at 1.9V. When the integrator output voltage falls to this level, the output of U5 goes high, generating a second capture via OR gate U12. The processor can measure the time between the 2 captures with a resolution of 400ns. Because of the 2000 times expansion of the integrator, the basic resolution is 200ps.

When the comparator output goes high, U9B is reset via U7, reconnecting the stabilization circuit ready for the next expansion.

Calibration

The pulse expander is an analogue circuit which can drift. It needs calibration so the range of the expanded pulse can be exactly referred to the 100 to 500ns unexpanded pulse. The calibration operates by generating pulses of exactly 100ns wide and 500ns wide by gating the 10MHz clock. These calibration pulses are expanded and measured. The results can then be used to correct measurements of the 1PPS input.

The calibration operates every 20ms when the 1PPS input is not expected. Each calibration cycle generates a pulse of 100ns and 500ns which are measured. If the CAL_ON line on pin 47 of the processor is set high before the READY line is set high, gate U3 routes the clock input of U4A to the (inverted) CLKO line. This makes the D type chain generate the calibration pulse. The 500/100ns line and gate U18 controls the width of the calibration pulse. The processor averages the calibration readings in a long time constant filter. The filtered results are used to correct each 1PPS timetag.

Controlled oscillator tuning supply

The controlled oscillator supply is nearly identical to that used in the A6-CPS. A dual 16bit DAC is used to generate a tuning voltage in the range 0 to 5V. The fine tune DAC output is divided by 256 and added to the output of the coarse tune DAC. There is provision for two different dual DACs to be fitted. U23 is a lower cost option, and U24 is lower noise for use with the lowest phase noise OCXOs. U21 provides DC gain to increase the maximum tuning voltage to about 8V. Two tuning voltage ranges are provided, 0 to 5V with link7 open, and 0 to 8V with link7 closed.

GPS receiver and interfaces

Provision is made for either a Trimble Resolution-SMT or a NavSync CW25-TIM GPS receiver to be fitted. It is intended that the Resolution-SMT (GPS1) should be used in all builds of the E8-1PPS. The CW25-TIM (GPS2) can be used in builds of the E8(X)-1PPS. Two versions of the CW25 can be used, with or without internal TCXO clock.

Each GPS receiver has two serial ports. The default for GPS1 is that port A is TSIP binary. This must not be changed, as the microcontroller monitors packets on this interface. Port B can be set to either TSIP or NMEA as covered in the board setup described later. Port A is connected to header JP3 pins 3 (Rx) and pin 5 (Tx). Port B is connected to the 9 way D connector JP4 pins 2 (Rx) and pin 3 (Tx).

The default for GPS2 is Port 0 is Motorola binary protocol, and Port 1 is NMEA. Port 0 is connected to JP3, and Port1 to JP4.

The microcontroller interface is connected to JP3 pin 4 (Rx) and pin 6 (Tx)

LED Interface

When GPS1 is fitted, the microcontroller decodes packet 6D which contains the number of satellites currently used in the over determined time solution. LED1A is flashed to indicate this number. LED1B is flashed each time a 1PPS pulse is received by the microcontroller. LED2B is the lock indicator which has a number of flash codes, described later. LED2A is the power on LED

When GPS2 is fitted, R24 and R25 are omitted. R39 and R40 are fitted which connect LED1A and LED1B directly to the internal LED interface in GPS2. These LEDs then flash to show the number of satellites tracked, and the number used in the time solution.

Controlled oscillator

The controlled oscillator is intended to be an OCXO in E8-1PPS variants and a TCXO for the E8(X)-1PPS A rubidium oscillator may also be used.

For OCXO variants, link5 is set to position 2. The OCXO sine output is applied to comparator U31. The anti-phase square wave outputs are the processor clock, and the 1PPS output circuit clock. Links 3 and 4 are set to position 1.

For TCXO variants, link8 is set to position 1 for 3.3V supply, and position 2 for 5V supply to the TCXO. The TCXO frequency is 20MHz, and is applied to comparator U31. U28 divides the TCXO frequency by 2, and the anti-phase 10MHz signals are selected by links 3 and 4 set to position 2.

For rubidium versions, link 5 is set to external 10MHz (position 1). The rubidium output is applied to CONN8. The rubidium tuning voltage is at pin 1 of connector JP2. Pin 2 of JP2 is a rubidium locked signal to the processor (active low).

For OCXO variants, U8 is the 12V regulator for the OCXO. U34 provides a current monitor to the processor analogue input pin 27. OCXO warm-up is detected by a reduction in OCXO current below a threshold.

Options

Various hardware options are provided for future expansion

Low noise tuning DAC

U23 will normally be fitted. This is a low cost dual 16 bit DAC. For use with the lowest phase noise OCXOs, U24 may be fitted. This is the lowest noise dual 16bit DAC available.

Traceability memory

U13 is a 1Mbyte flash memory. This may be used to store status data to prove correct locking to GPS time over an extended period.

Temperature sensor

U39 is a temperature sensor. This is intended for implementation of a more elaborate OCXO holdover algorithm.

Required Equipment

- a) source 1 10MHz fixed frequency accuracy $\pm 1E-6$ level 1V RMS (EMF) adjustable
- b) DC voltmeter 5 digit resolution
- c) 2 channel oscilloscope, preferably digital storage
- d) Frequency counter, capable of time interval measurement with a resolution of at least 1ns.
- e) RF power meter, 50ohm.

Board Set Up.

A new board should be configured by setting various links. These are solder links. Refer to the build summary document for the various link connections.

It is assumed that a new board is first tested without the controlled oscillator fitted.

Power up the board from a regulated supply set to 15v. Supply current will depend upon build configuration.

Supply LED (LED1B green) should light.

Programming

Connect the programmer to JP5 and load the latest version firmware. Board power must be on. In case of problems, check the Vdd supply at C47 ($5V \pm 0.15V$)

Power Supplies

Check:

- a) $+10V \pm 0.3V$ at TP18
- b) $Vdd 5V \pm 0.15V$ at C47
- c) $+5V \pm 0.1V$ at TP16
- d) $+12V \pm 0.3V$ at U8 pin3
- e) 5V ref $+5V \pm 5mV$ at TP17

Board Functional Tests

Power down the board

Set the solder links as follows:

OCXO variants:

1. position 1 external 1PPS
2. position 1 1PPS holdover option NOT fitted
position 2 1PPS option fitted
3. position 1
4. position 1
5. position 1 external 10MHz
6. optional to suit build specification sine or square 10MHz output
7. To suit OCXO tuning range
8. Not Used

TCXO variants

1. position1 external 1PPS
2. position 1 note that 1PPS holdover option cannot be fitted to TCXO versions
3. position 2
4. position 2
5. position 1 external 10MHz
6. optional to suit build specification
7. open circuit 5V tuning
8. to suit TCXO supply voltage

Connect source 1 to CONN8 and set to 10MHz, 1VRMS (EMF) The processor should now be clocked from this source.

LED2B (red) should be continuously on. If it is flashing, the processor is not getting an external clock.

Check U31, U28 (TCXO version), Link3, 4.

Operation of the interface must first be checked. Connect a PC with RS232 to JP3. Only pins 6 (TXD) pin4 (RXD) and pin 2 (ground) need to be connected. Start a general terminal program, set the interface to 9600baud, 1start bit, no parity, and check that the microcontroller responds to commands by sending "OS?"

Connect a second RS232 port to JP3. Only pins 5(TXD) pin3 (RXD) and pin 1 (ground) need to be connected. Start the appropriate GPS control software (This is Trimble GPS Studio or NavSync WinOncore). The GPS receiver should start operating within a few seconds of power up, and should communicate with the control program.

The EEPROM must be set to default values using command "EDx" to match the controlled oscillator type fitted. See Appendix F for EEPROM defaults.

This only needs to be done after reloading the firmware.

If the 1PPS holdover option is not fitted, connect the external 1PPS source to CONN1 at this point. LED1B should flash at a 1Hz rate. The state should change to S1, and then S2. The board test

software should be started when in state 2. DO NOT allow the state to reach S4, and then commence the OCXO calibration. This cannot be done when an external 1PPS source is being driven from the E8-1PPS board 10MHz output. If the OCXO calibration does start, send SR (software reset) to stop it.

The special board test software is started by entering state7. The following command is used:

OSL07

The reply should be "BOARD TEST 0"

In this state all the normal interface commands are locked out except the keys "I" (increment) and "D" (decrement). In some tests the keys "H" (high) and "L" (low) can also be used.

I and D may be freely used to step from one test to another. The tests may be performed in any order. Test F will roll over to test 0 when incremented.

TEST 0 1PPS output delay control

THIS TEST CAN ONLY BE USED IF 1PPS HOLDOVER OPTION IS FITTED

Connect oscilloscope channel 1 to TP7 via a divide by ten probe.

Connect channel 2 to TP3 via a divide by 10 probe. Bandwidth of oscilloscope and probes should be at least 200MHz. Trigger on channel 1. Time base should be single shot sampling.

The rising edge on TP7 is the start marker (zero time) of the internal clock. The delay of the 1PPS output is checked relative to this marker.

The 1PPS output is switched to 50PPS for this test to provide a faster update rate.

Using the H and L keys, the delay may be stepped in 10ns increments. This should be observed on the oscilloscope.

The interface will show the current delay (signed decimal), the shift register delay in 50ns steps, and the delay vernier (hex). The delay vernier is the programming word applied to U30.

Linearity check

Transfer to probes to the counter (set to 1Mohm input impedance)

Set the delay to 0ns. The counter should read a delay close to 0ns. The residual delay can be up to ± 10 ns. This is unimportant, and is caused by loading effects on the 1PPS output. Change the delay in 10ns steps until the vernier setting reads a minimum hex value. The delay chip U30 is now set to its minimum delay. Step the delay in further 10ns steps. Each increment on the counter should be 10 ± 3 ns. When the vernier rolls over, the increment on the counter should be 10 ± 5 ns.

If there is a substantial jump at the vernier roll over points, the software constant DELAYLINEBITS_PER_NS can be adjusted. The software must be re-compiled if this is done.

TEST 1 1PPS output delay control

THIS TEST CAN ONLY BE USED IF 1PPS HOLDOVER OPTION IS FITTED

This test is exactly the same as TEST0, except the delay steps are 100ns. This may be useful in debugging the shift register circuit.

TEST 2 Calibrator check

For this test, a 1PPS source must be connected to CONN1 as otherwise the calibrator will not be operating. LED1B should be flashing to show that a 1PPS input is present.

The calibrator is enabled, and continuously displays the results over the interface. Four columns are displayed:

Averaged 100ns cal	Averaged 500ns cal	last 100ns cal	last 500ns cal
02AE	0B66	02AF	0B66 (typical values)

The averaged values will slowly approach the spot values due to the long time constant of the filter. A maximum jitter of ± 1 is normal on the spot values.

As a further check on the time expander, an oscilloscope with a divide by 10 probe should be connected to TP4. Groups of 2 saw tooth ramps should be observed, each group repeating every 20ms. One group should be expanded. The first ramp is the expansion of the 100ns calibration pulse, and the second is the expansion of the 500ns calibration pulse.

The following voltage measurements should be made using the oscilloscope cursor:

- Ramp start voltage: $2.0V \pm 0.1V$
- First ramp peak voltage: $3.0V \pm 0.2V$
- Second ramp peak voltage: $8.0V \pm 0.4V$

If the voltages are incorrect, there may be an incorrect component around the time expander circuit.

TEST 3 1PPS capture check

NOTE If 1PPS holdover option is not fitted, this test cannot be used directly as the internal 1PPS source is not available. An external 1PPS source must be used. This must be synchronous with the processor clock, and must have very low jitter. A spare A6-1PPS board can be used, with the 10MHz input connected to the 10MHz output of the E8-1PPS board under test. The 1PPS input should be connected to CONN1.

An A6 frequency converter digital board may also be used.

PROCEDURE IF 1PPS HOLDOVER OPTION IS FITTED:

The 1PPS output is used as a pulse generator to test the 1PPS capture. The 1PPS output should be connected to the 1PPS input. A link should be made between pins 7 and 8 of JP3. This connects the 1PPS output to the time expander input, overriding the 1PPS from the GPS module.

PROCEDURE IF 1PPS OPTION IS NOT FITTED:

Connect synchronous 1PPS input to CONN1

After each pulse the interface will display the 1PPS user delay (signed decimal in ns), followed by the 5 parameters output by the "TO" command. These are:

- Last time tag (decimal ns)
- First capture (hex)
- Second capture (hex)
- Capture difference (hex)
- Modulo50 counter (hex)

If channel 2 of the oscilloscope is transferred to TP4, the integrator output may be observed

The Capture difference should show a maximum jitter of ± 1 , which is $\pm 200ps$. The Last time tag is rounded to the nearest 1ns. The actual value of the Last time tag depends upon the reset point of the internal clock, and is not significant.

NOTE If 1PPS holdover option is not fitted, following procedure cannot be used as 1PPS source delay is not adjustable.

As the 1PPS output delay is stepped using the "H" and "L" keys, the time tag should step with the same 10ns increments. Note that any nonlinearity detected in TEST0 will also appear in this test.

The key point to look for is when the first capture changes by integer 1. This represents an overflow of the time expander, and is the point where a jump in the time tag might be expected if the calibration was not working correctly.

TEST 4

THIS TEST CAN ONLY BE USED IF 1PPS HOLDOVER OPTION IS FITTED

This test is similar to TEST3; however the rate of the 1PPS output is increased to 50PPS. This enables an estimate to be made of the jitter in the time expander. The interface shows the first capture, the second capture, and the capture difference. The jitter in the capture difference is normally ± 1 , which is ± 200 ps.

TEST 5 Coarse tune DAC

In this test the fine tune DAC is set to 0V and the coarse tune DAC is stepped.

Connect the DC voltmeter between TP5 and ground. By using the H and L keys, check that the voltage can be stepped between 0V and about 4.659V

TEST 6 Fine tune DAC

In this test the coarse tune DAC is set to midrange and the fine tune DAC is stepped.

Connect the DC voltmeter between TP5 and ground. By using the H and L keys, check that the voltage may be stepped over a total range of about 18.2mV

TEST 7 OCXO current monitor

In this test the OCXO current is continuously displayed. The current monitor can be checked by connecting a known resistor from the OCXO supply pin to ground.

The OCXO current is displayed as a 2 byte hex number. Full scale is about 500mA. With no resistor,

i.e. an OCXO current of zero, the maximum offset should be 0600h.

Connect a 120ohm, 1W resistor from an OCXO supply pin (C40) to ground. The current monitor has a long time constant so at least 30 seconds should be allowed for the reading to stabilise. Note the reading, convert to decimal, divide by 65536 and multiply by 500. This should be the current in mA. A typical reading of 33CCh is a current of 101mA. The expected accuracy is only about 10%.

Test 7 is the last programmed test.

OCXO Output Buffer

The OCXO output buffer operates independently of the processor and can be tested as any linear amplifier. It has an input impedance of 500ohms, and a gain of 1 into a 50 ohm load. 1VRMS at the input should give 1VRMS (13dBm) into a 50ohm load.

To test set source 1 to 10MHz. Check that the input level at CONN8 is 1V RMS. Use a high impedance probe for this. Adjust the output level of source 1 if necessary. Connect an RF power meter to CONN4 or CONN5 and check for 13dBm \pm 1dB

The buffer 1dB bandwidth should be at least 2MHz to 40MHz. This can be checked using a spectrum analyser /tracking generator combination if desired.

This completes the board test.

To exit the board test software, a power on reset must be performed.

Final Board Configuration

The controlled oscillator should be fitted at this stage. Reset link 5 as follows:

OCXO position 2

TCXO open circuit

Reset link1 to position 2 (1PPS from GPS receiver)

Power up the board with a GPS antenna connected.

GPS Receiver Configuration

The default configuration needs only a few modifications:

Trimble Resolution-SMT: Adjust using GPS Studio:

1PPS output mode: set to 1PPS only output if 1 or more satellites tracked

Packet masks: Set Primary timing packet (8F-AB), Supplemental timing packet (8F-AC), and Auto event packets on

Port B: may be set to NMEA or TSIP as desired

NOTE: -

After changes the configuration **MUST** be saved otherwise the unit will return to the previous settings after power down.

NavSync CW-25-TIM: Adjust using WinOncore

Run E8.TXT

Send @@Gc02 1PPS on when tracking 1 or more satellites

The Trimble Resolution-SMT will do a self survey when first powered up at a new location. Further power ups at the same location will not result in a new self survey.

The NavSync CW25-TIM will always perform a self survey on power up.

Controlled Oscillator Auto Calibration

When new firmware is loaded, EEPROM default 0 is automatically loaded. This is an OCXO with 5V tuning. If an alternative controlled oscillator is fitted, then the appropriate EEPROM default must be loaded.

It is essential that the physical tuning voltage range, adjusted with Link 7, should match the tuning voltage range stored in the EEPROM, and loaded by the EEPROM default command. This can be checked using the "OC?" command.

When the EEPROM default is loaded, a flag is set to indicate that OCXO calibration is required. The software will attempt to get lock on the 1PPS from the GPS receiver in the normal way, going through states 0, 1 2 and 3. When the normal running state 4 is entered, the software will immediately enter the special OCXO calibration routine. This is shown by a message over the interface. The following actions then happen:

- a) The Kalman filter frequency correction is stopped
- b) The OCXO tuning is offset by about 10% of the total
- c) The Kalman frequency estimate is reset to enable rapid acquisition of the new frequency
- d) The command "PM?" is written to the command repeat stack to provide user monitoring

Over a period of about 5 minutes, the filter will acquire the new frequency. From knowledge of the voltage offset applied to the tuning voltage, and the frequency shift that this has produced, the tuning constant of the oscillator can be calculated as a fractional frequency/volt. This parameter is

then written to EEPROM to replace the default tuning constant. The new tuning constant may be viewed with the “OC?” command.

After the calibration is complete, the unit will go back to state 0 and should lock normally.

State Control

The following information has been copied from the software listing to provide more information on the state control:

STATE 0

State 0 is the first state after cold start. Red lock LED is permanently on. The state is exited only when:

- a) The rubidium is locked OR
- b) The OCXO has warmed up
- c) A 1PPS capture has been received

Test for oscillator type (eeprom default) using NavSync CW25 device. In this case state 0 is only exited; when CW25 has finished its site survey, and set its ready line high.

STATE 1

State 1 is waiting for the internal clock to be reset. A timeout is started. If no clock reset is acknowledged in 1 second, state 0; is re-entered. Red lock LED is permanently on.

STATE 2

The internal clock has been synchronized on the first 1PPS capture. Red lock LED is permanently on.

The Kalman filter should now be tracking the incoming 1PPS, although no frequency corrections are being made.

In this state, and state 3, the Kalman filter is made adaptable to the real behaviour of the system.

The performance measure `filteredfreqerror` is used to modify the random walk noise parameter which describes the controlled oscillator. This is `S1`.

The frequency error is high so the effective filter bandwidth is too narrow to track warm-up drift of the oscillator. The scaling parameter of `S1`, (`S1scale`) which is the random walk FM noise root variance, normally preset to 1, is increased according to the value of the filtered frequency error ratio. After each change to `S1scale`, the `Q` matrix is recalculated.

This state is exited after 100 successful 1PPS captures and if the frequency drift is less than a threshold

If captures stop, after a time out state 0 is entered

STATE 3

In this state the Red lock LED flashes rapidly. The error monitor parameter `filteredfreqerror` is compared with a threshold, when it is less than the threshold state 4 is entered and the lock light is switched off

If the 1PPS captures stop for more than 6 seconds, state 0 is entered, also if captures are more than `MAXTIMEOFFSET` (20us) from initial capture when clock was reset in this state the Kalman filter is made adaptive. The frequency error is high so the effective filter bandwidth is too narrow to track warm-up drift of the oscillator. The scaling parameter of `S1`, which is the random walk FM noise root variance, normally preset to 1, is increased according to the value of the filtered frequency error ratio. After each change to `S1scale`, the `Q` matrix is recalculated.

STATE 4

The normal running state. If the filtered frequency error rises above the high threshold loss of lock is assumed, and state 5 re-entered.

If the captures stop, the holdover state 6 is entered

STATE5

In this state the Red lock LED flashes rapidly. In this state the Kalman filter is made adaptive. The frequency error is high so the effective filter bandwidth is too narrow to track warm-up drift of the oscillator. The scaling parameter of S1, which is the random walk FM noise root variance, normally preset to 1, is increased according to the value of the filtered frequency error ratio. After each change to S1scale, the Q matrix is recalculated.

If captures stop, holdover state 6 is entered

STATE6

This is the holdover state. The 1PPS capture flag is tested to see if the GPS module has resumed fixes, and has restored the 1PPS. If so, state 5 is re-entered to restore tracking in the holdover state, frequency corrections are inhibited automatically as there are no 1PPS captures.

The red lock LED is flashed with 50% mark space ratio.

User Performance Test

THIS TEST CAN ONLY BE USED IF 1PPS HOLDOVER OPTION IS FITTED

A simple performance test may be made without any equipment. The loop back link must be connected to pins 7 and 8 of JP3. This will over ride the 1PPS from the GPS receiver, with the internally generated 1PPS. As the 1PPS output and the 1PPS time tag are using the same internal clock, the Kalman filter will see no frequency offset and no jitter on the 1PPS time tags. The performance measure and frequency offset displayed using the “PM” command should reach limiting low values after about 30 minutes.

In order to do this test, the base time of the 1PPS output should be set to “internal clock” using the command “OSP00”. If the base time is set to “Kalman estimate” or “Last input time tag” completely random results will occur.

After the command “OSP00”, the EEPROM should be updated with the command “EU”. “SR” may now be used to perform a software reset.

The quantization correction from the GPS receiver must now be switched off. This can be done by setting bit 6 of LOCKSTATUS.

“PM+” will then display the performance measures. The software will go through its start up procedure with the display of successive states ending in state 4. After 30 minutes the performance figures should be typically:

-1.2000E-08 -1.2017E-08 0000000 00000 00001 -5.8970E-13 -5.8973E-13

Note that the Kalman phase estimate is almost identical to the time tag, the mean square measurement error is zero, the filtered performance indicator is zero, the S1 multiplier is 1, the last frequency estimate and the mean frequency estimate is small. This last figure will further reduce with time.

If the user 1PPS offset is stepped 10ns, the effect on the performance parameters may be seen. A single phase step will be rapidly tracked out with minimum effect on the frequency.

After this test, reset the 1PPS base to the Kalman estimate by using the command “OSP02”, followed by “EU”.

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