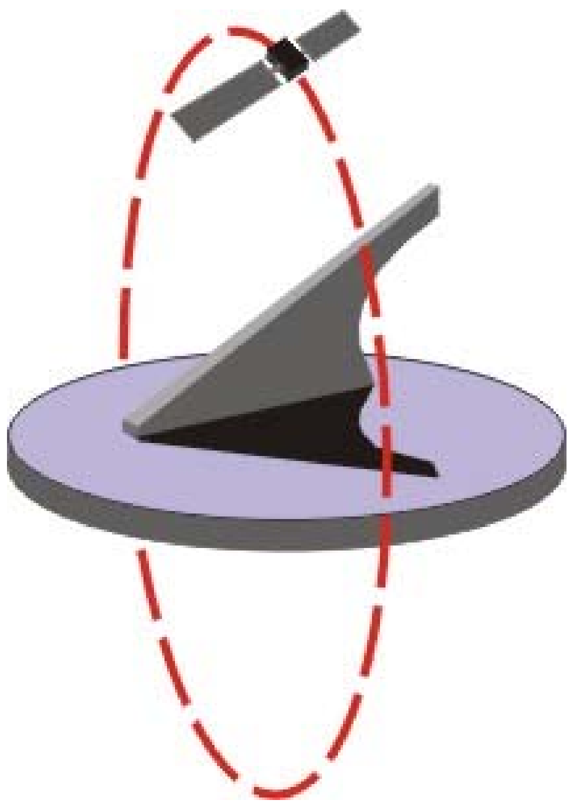
1756HP-GPS-IRIG-OUT

USER MANUAL



Rev 2.6 – March 2009

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CHAPTER 1 INTRODUCTION

The 1756HP-GPS-IRIG-OUT module provides accurate time and position information and services for the Allen-Bradley ControlLogix PLC system.

A 1756HP-GPS-IRIG-OUT makes use of Global Positioning System (GPS) technology to derive accurate time which is synchronized with the atomic clocks located on the GPS satellites.

The module supports IRIG B-122; the time is transmitted in an IRIG signal to IRIG devices via an external port.

This document serves to describe the functionality, installation, configuration and use of the module.

CHAPTER 2 MODULE ACCESSORIES

Each 1756HP-GPS-IRIG-OUT package includes the following components:

- **1756HP-GPS-IRIG-OUT module**
- **1756HP-GPS-IRIG-OUT user manual**
- **IRIG-Breakout and 500mm patch lead**
- **5m RG58 patch lead with a SMA male and TNC male connector on either end**
- **3.3V active 50Ω bullet antenna**

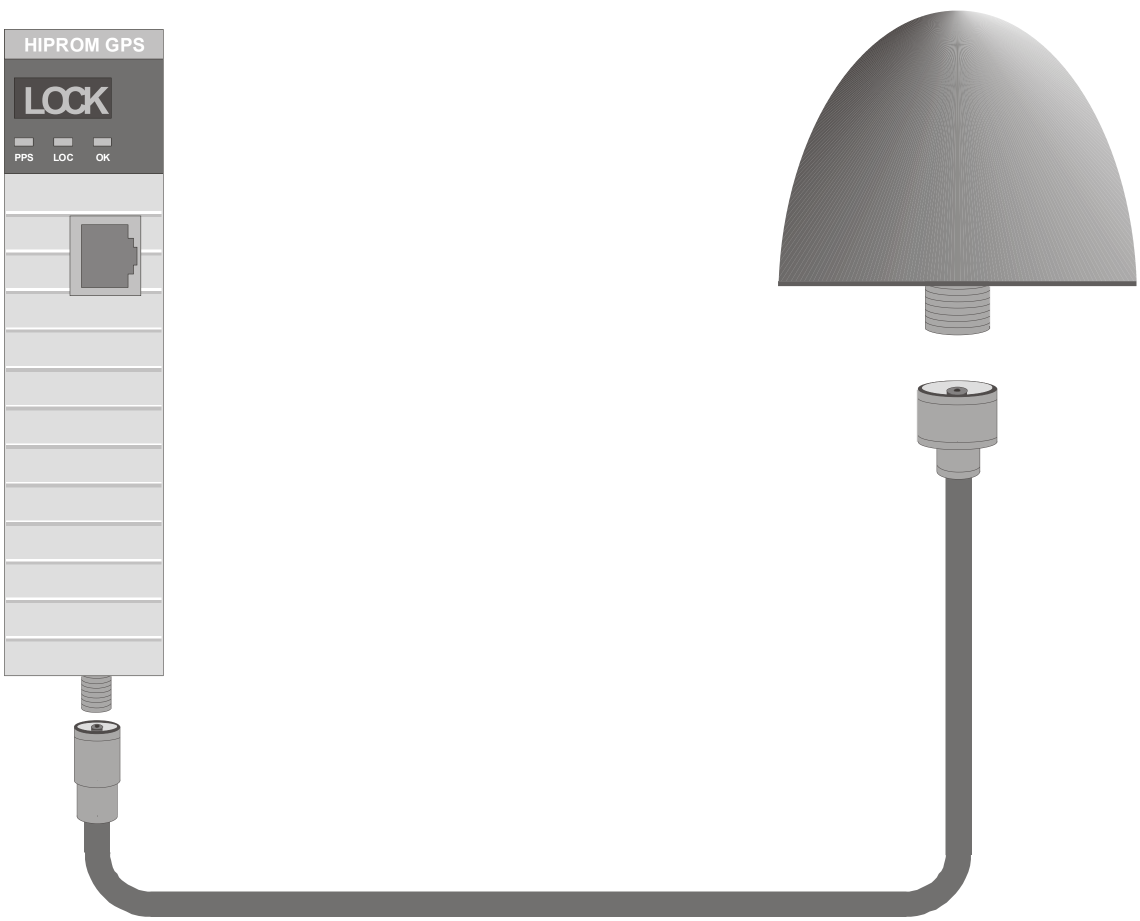


Figure 2.1 : 1756HP-GPS-IRIG-OUT module with antenna and patch-lead

CHAPTER 3 MODULE OPERATION

The 1756HP-GPS-IRIG-OUT module is designed to operate within the Allen-Bradley ControlLogix PLC system. All power required for the module's operation is derived from the 1756 backplane.

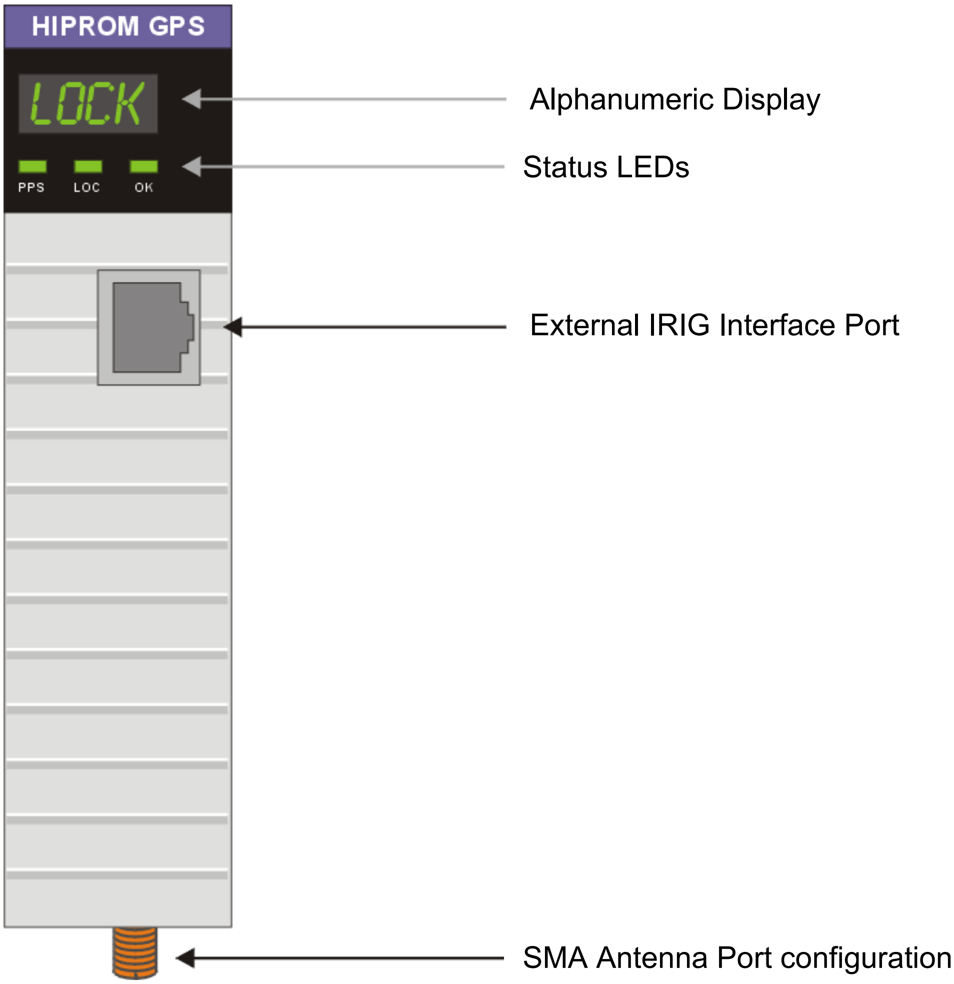


Figure 3.1 : 1756HP-GPS-IRIG-OUT Layout

The 1756HP-GPS-IRIG-OUT on-board GPS receiver is connected via the external SMA antenna port and external antenna patch-lead to the active GPS antenna. As soon as the module is powered-up it will begin searching for available GPS satellites. Soon after lock on at least 4 satellites has been achieved the module's internal time will become valid.

The current status of the module is conveyed to the user by means of the 3 bi-color Status LED's and the alphanumeric LED display.

The following information is available to the user directly across the backplane by means of a scheduled connection:

- Date and Time in Gregorian Format (year, month, day, hour, minute etc.)
- Universal Coordinate Time (UTC)
- GPS Receiver Status
- Number of satellites being tracking
- Position in Polar Coordinates (latitude, longitude and altitude)
- Position in Cartesian Coordinates (Earth-centered-earth-fixed X,Y,Z axis)
- Velocity in Polar Coordinates (Northerly, Easterly and Upward)
- Velocity in Cartesian Coordinates (Earth-centered-earth-fixed X,Y,Z axis)

The module requires regular updates of the ControlLogix Controller's CST (Coordinate System Time) value to enable accurate CST conversion and wall-clock offset functions.

All time and date information can be adjusted to the local time-zone by configuring the Time-Zone offset, in the scheduled output image.

Detailed GPS satellite information can also be requested by means of an unconnected message, responding with the following for each of the 8 GPS receiver channels:

- Satellite Identifier (PRN)
- Current Satellite Azimuth
- Current Satellite Elevation
- Signal Strength

The 1756HP-GPS-IRIG-OUT module supports two unconnected time conversion services, namely:

- CST → UTC and Gregorian
- UTC → Gregorian

This allows the user by means of a custom message service to convert between different time formats. The conversion is valid only for time data that is less than 1 hour old.

CHAPTER 4 INSTALLING THE MODULE

GPS utilizes a spread spectrum signal in the 1.5GHz range, and thus cannot penetrate conductive or opaque surfaces. Thus the antenna should be mounted in a horizontal position with an unobstructed view of the sky.

Attach the antenna patch lead to the antenna. It is recommended that waterproofing tape be used to seal the connection.

NOTE: Should a longer patch lead be required it is recommended that a GPS signal booster is used. Contact your local Hiprom distributor for assistance.

The module is equipped with a RIUP (Removal and Insertion Under Power) circuitry enabling the module to be installed or removed from the chassis while power is applied.

Attach the patch lead SMA (male) to the module's SMA (female) connector. It is not recommended that the antenna patch lead exceed a total loss of 10dB at 1.5GHz, as this may increase the time to GPS lock, or in extreme cases, prevent GPS lock from being achieved at all.

Attach the patch lead of the IRIG-BREAKOUT to the module's RJ45 connector.

Once the module has been powered up for the first time, it will search for satellites from a cold start (i.e. no almanac). The module will take approximately 5 minutes to acquire Lock. Once a complete almanac has been downloaded, the time to achieve fix will be reduced to around 45 seconds.

An IRIG signal will only be transmitted once GPS lock has been acquired.

CHAPTER 5 CONFIGURING THE MODULE

A direct connection between the controller and the 1756HP-GPS-IRIG-OUT module is required to transfer I/O data to and from the module. In addition the module supports various unconnected messages that can be used to retrieve particular information.

5.1. Establishing the Direct Connection

This section describes the procedures necessary to configure the 1756HP-GPS-IRIG-OUT module within the ControlLogix system. Each 1756HP-GPS-IRIG-OUT module must be owned by a single ControlLogix controller.

The 1756 Generic Module is used in RSLogix5000 to configure the module. The configuration of the module is detailed in the table below.

<table>
<tr><th colspan="4">Data Format</th></tr>
<tr><td>CommFormat</td><td colspan="3">Data – DINT</td></tr>
<tr><th colspan="4">Connection parameters</th></tr>
<tr><td>Description</td><td>Instance</td><td colspan="2">Size</td></tr>
<tr><td>Input</td><td>1</td><td colspan="2">29</td></tr>
<tr><td>Output</td><td>2</td><td colspan="2">3</td></tr>
<tr><td>Configuration</td><td>4</td><td colspan="2">2</td></tr>
<tr><th colspan="4">RPI</th></tr>
<tr><td>Min</td><td>1.0 msec</td><td>Max</td><td>750.0 msec</td></tr>
</table>

Table 5.1 : 1756HP-GPS-IRIG-OUT connection parameters.

The steps required to add a new 1756HP-GPS-IRIG-OUT module are detailed below.

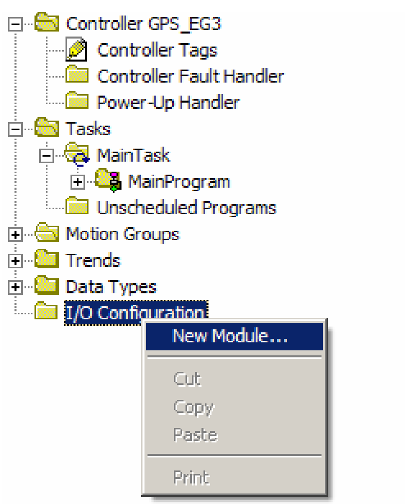


Figure 5.1 : Right-click on I/O Configuration and select New Module

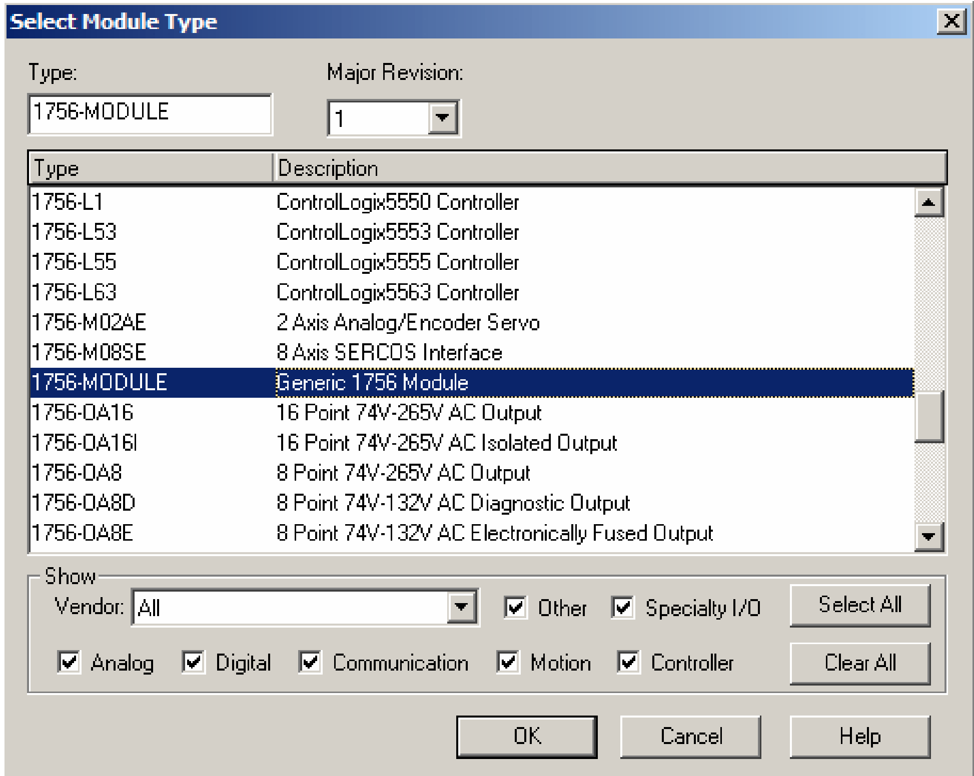


Figure 5.2 : Select Generic 1756 Module (1756-MODULE)

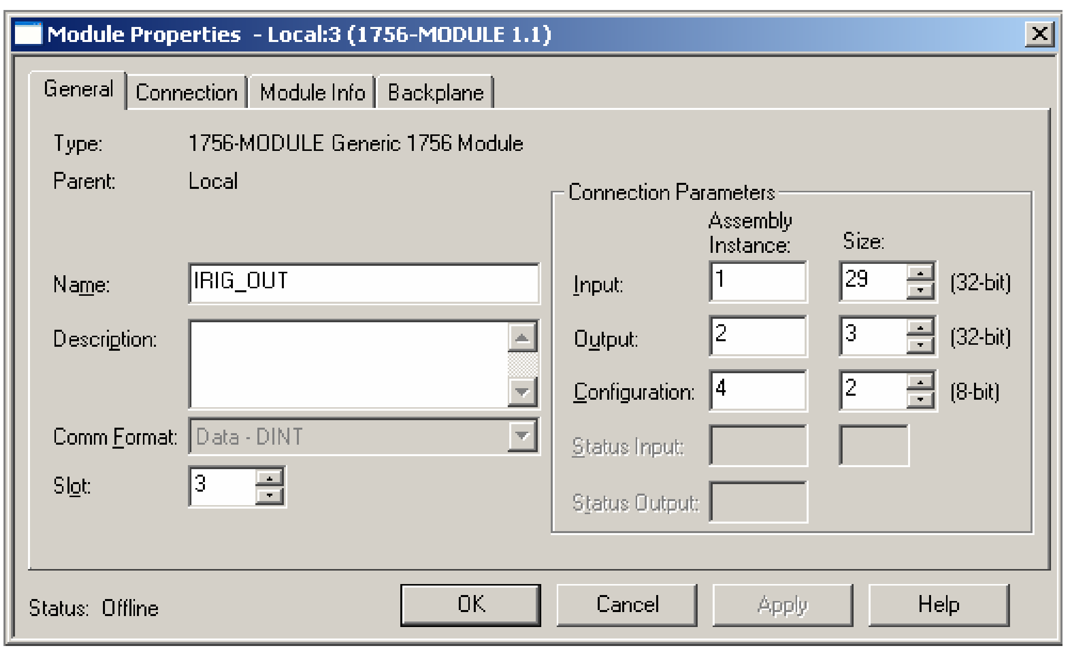


Figure 5.3 : Configure module's parameters

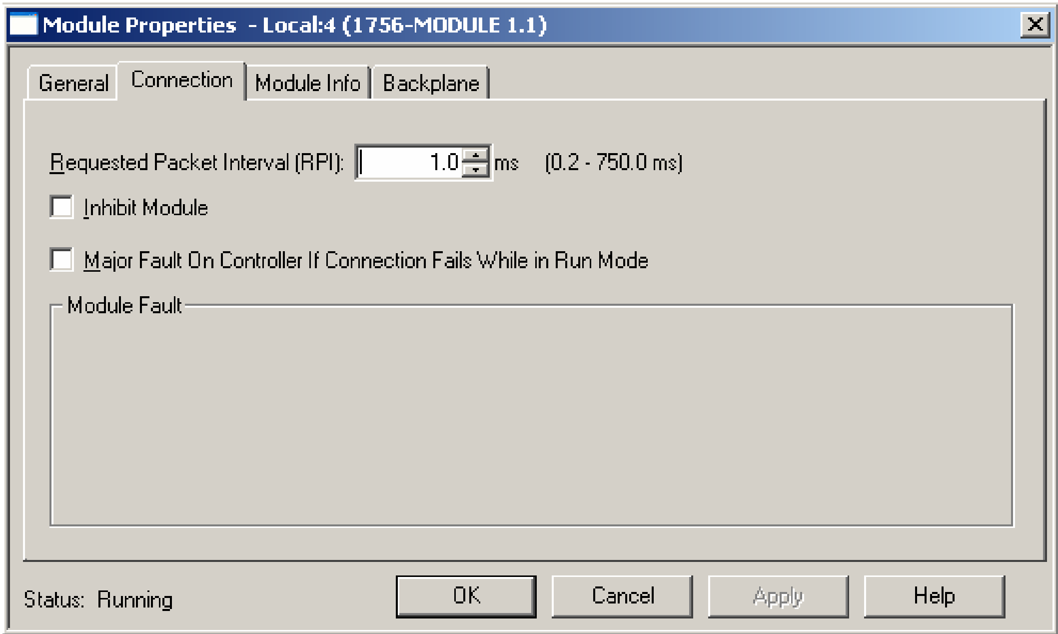


Figure 5.4 : Configure module's RPI (Requested Packet Interval)

The first word of the Configuration Image configures the module as a 1756HP-GPS-IRIG-OUT. Set the first word of the image to 0x01. If the user is using RSLogix 5000 v16 the UTC time base is different from previous versions of RSLogix. To ensure that ControlLogix PLC's running different versions can be time synced using the 1756HP-GPS-IRIG-OUT module the user must select if v16 is used or not. The last bit (least significant bit) of the second byte of the configuration image configures the module to use or not use v16 UTC time. By setting the bit, the module will use v16 UTC time. The highest bit (most significant bit) of the second byte of the configuration image configures the module to be the CST master. By setting this bit, the module will attempt to become the CST master. If a CST master is present, it will not become the CST master and indicate that a duplicate master was detected.

Configuration Image

BYTE	VALUE
0	**0x01**
1	**0x??**

Byte 1 = X000 000Y (binary) where 'X' will make the module a CST master if set to 1 and 'Y' will make the module use v16 UTC time if set to 1.

Once a modules configuration data has been downloaded to the controller, it will attempt to establish a connection with the module. A connection will fail if there is inappropriate configuration data.

5.2. Coordinate System Time Master

It is important that at least one controller or 1756HP-GPS-IRIG-OUT module in the ControlLogix rack be configured as the Coordinate System Time master. This can be configured in RSLogix5000 by right-clicking on the Controller and selecting Properties. Ensure that the checkbox as indicated below is checked to make the controller the CST master; otherwise the procedure in section 5.1 above may be followed to make the 1756HP-GPS-IRIG-OUT module the CST master.

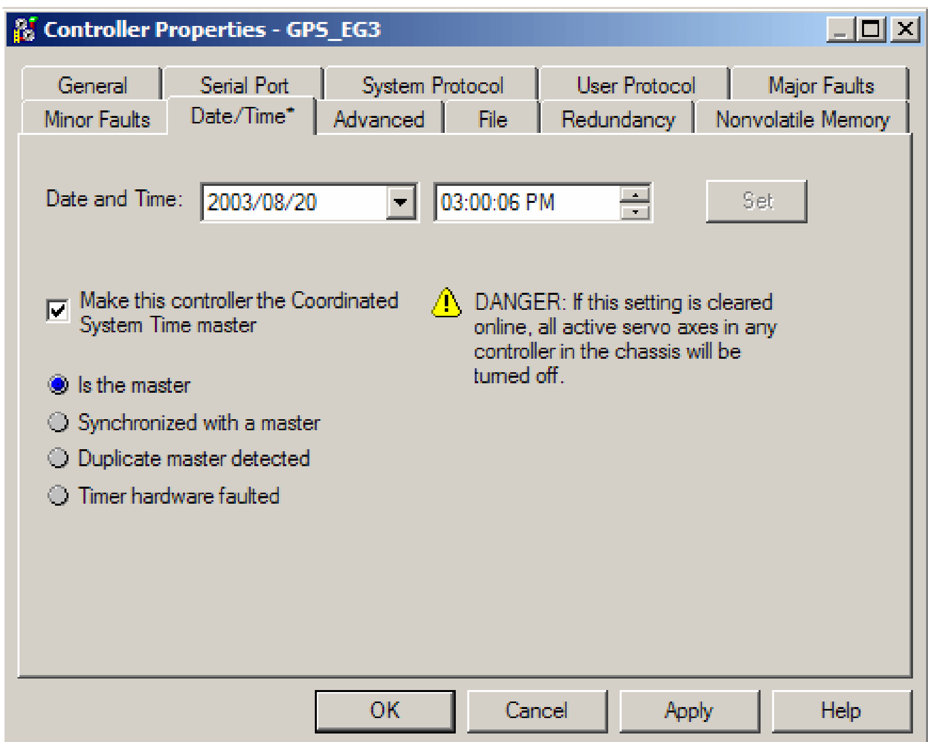


Figure 5.5 : Configure CST Master

CHAPTER 6 I/O ADDRESS MAP

The input and output image of the 1756HP-GPS-IRIG-OUT module is defined in the following sections. Appendix A and B provide example code and recommended structures that can be used to extract and view the data.

6.1. Input Image

<table>
<tr><th>WORD</th><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>0</td><td colspan="2">Reserved</td><td>CST Master</td><td>Dup Master</td><td>Reserved</td><td>IRIG-OUT</td><td>South</td><td>West</td><td>PDOP Ok</td><td>Ant Ok</td><td>Batt Ok</td><td>PPS</td><td>Time Valid</td><td>CST Ok</td><td>GPS Locked</td><td>Module Ok</td><td colspan="16">Reserved</td></tr>
<tr><td>1</td><td colspan="32">SV Count</td></tr>
<tr><td>2</td><td colspan="32">Year</td></tr>
<tr><td>3</td><td colspan="32">Month</td></tr>
<tr><td>4</td><td colspan="32">Day</td></tr>
<tr><td>5</td><td colspan="32">Hour</td></tr>
<tr><td>6</td><td colspan="32">Minute</td></tr>
<tr><td>7</td><td colspan="32">Second</td></tr>
<tr><td>8</td><td colspan="32">Microsecond</td></tr>
<tr><td>9</td><td colspan="32">UTC[0]</td></tr>
<tr><td>10</td><td colspan="32">UTC[1]</td></tr>
<tr><td>11</td><td colspan="32">CST[0]</td></tr>
<tr><td>12</td><td colspan="32">CST[1]</td></tr>
<tr><td>13</td><td colspan="32">CST Offset[0]</td></tr>
<tr><td>14</td><td colspan="32">CST Offset[1]</td></tr>
<tr><td>15</td><td colspan="16">Latitude - Minutes</td><td colspan="16">Latitude - Degrees</td></tr>
<tr><td>16</td><td colspan="32">Latitude - Seconds</td></tr>
<tr><td>17</td><td colspan="16">Longitude - Minutes</td><td colspan="16">Longitude - Degrees</td></tr>
<tr><td>18</td><td colspan="32">Longitude - Seconds</td></tr>
<tr><td>19</td><td colspan="32">Altitude</td></tr>
<tr><td>20</td><td colspan="32">Velocity North - (m/s)</td></tr>
<tr><td>21</td><td colspan="32">Velocity East - (m/s)</td></tr>
<tr><td>22</td><td colspan="32">Velocity Up - (m/s)</td></tr>
<tr><td>23</td><td colspan="32">ECEF Position X</td></tr>
<tr><td>24</td><td colspan="32">ECEF Position Y</td></tr>
<tr><td>25</td><td colspan="32">ECEF Position Z</td></tr>
<tr><td>26</td><td colspan="32">ECEF Velocity X - (m/s)</td></tr>
<tr><td>27</td><td colspan="32">ECEF Velocity Y - (m/s)</td></tr>
<tr><td>28</td><td colspan="32">ECEF Velocity Z - (m/s)</td></tr>
</table>

Figure 6.1 : Connected Input Image

6.2. Input Image Description

Field/Value	Description	Location	Type
Module OK	**Module Status** 0 = Module has faulted 1 = Module is operating properly	**Local:s:I.Data[0].16**	BIT
GPS Locked	**Satellite Lock** 0 = Not tracking sufficient satellites to provide positional fix 1 = Sufficient satellites being tracked to provide positional fix Typically, tracking 4 satellites is sufficient to provide lock.	**Local:s:I.Data[0].17**	BIT
CST Ok	**Valid CST** 1 = Module is receiving updates CST 0 = Module has not received updated CST for 1sec or more	**Local:s:I.Data[0].18**	BIT
Time Valid	**Date / Time Valid** 0 = Date Time Not Valid 1 = Date Time synchronized with GPS	**Local:s:I.Data[0].19**	BIT
PPS	**Pulse per Second** This bit transitions from 0 to 1 precisely every second. The pulse duty cycle is approximately 50%.	**Local:s:I.Data[0].20**	BIT
BATT Ok	**Battery Backup on Boot** 0 = No battery backup available on boot-up. 1 = Battery backup available on boot-up. With battery backup enabled the time taken for the GPS module to regain satellite lock is greatly reduced. It is recommended that if the module is not to be used for an extended period that the battery backup be disabled.	**Local:s:I.Data[0].21**	BIT
ANT Ok	**Antenna OK** 0 = Antenna Fault 1 = Antenna OK An Antenna fault will occur if the antenna is not present or has been damaged.	**Local:s:I.Data[0].22**	BIT
PDOP Ok	**PDOP OK** 0 = Position Dilution of Precision is unacceptable 1 = No Position Dilution of Precision present Position Dilution of Precision occurs when although there are sufficient satellites in lock, 2 or more of them appear to occupy similar positions in the sky and thus the number of effective satellites is decreased.	**Local:s:I.Data[0].23**	BIT
West	**Current East / West Hemisphere** 0 = Current position in East hemisphere 1 = Current position in West hemisphere	**Local:s:I.Data[0].24**	BIT
South	**Current North / South Hemisphere** 0 = Current position in North hemisphere 1 = Current position in South hemisphere	**Local:s:I.Data[0].25**	BIT

IRIG-OUT	**IRIG-OUT Module Configuration** 1 = Module has been configured as an IRIG-OUT module. 0 = Module not configured as IRIG-OUT	**Local:s:I.Data[0].26**	BIT
Reserved	**Reserved**	**Local:s:I.Data[0].27**	BIT
Dup Master	**A duplicate CST master has been detected** 0 = No duplicate CST master detected 1 = A duplicate CST master is detected	**Local:s:I.Data[0].28**	BIT
CST Master	**This module is the local rack CST master** 0 = This module is not the CST master 1 = This module is the CST master	**Local:s:I.Data[0].29**	BIT
Reserved	**Reserved**	**Local:s:I.Data[0].30..31**	BIT
SV Count	**Satellite count** Number of Satellites currently being tracked	**Local:s:I.Data[1]**	DINT
Year	**Calendar Year** Current Local Calendar Year This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[2]**	DINT
Month	**Calendar Month** Current Local Calendar Month (1 - 12) This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[3]**	DINT
Day	**Calendar Day of Month** Current Local Calendar Day (1 - 31) This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[4]**	DINT
Hours	**Real Time Hours** Current Local time Hours (0 - 23) This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[5]**	DINT
Minutes	**Real Time Minutes** Current Local time Minutes (0 - 59) This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[6]**	DINT
Seconds	**Real Time Seconds** Current real time Seconds (0 - 59)	**Local:s:I.Data[7]**	DINT
Microseconds	**Real Time Microseconds** Current real time Microseconds (0 – 999 999)	**Local:s:I.Data[8]**	DINT
UTC	Current Universal Time Constant (UTC)	**Local:s:I.Data[9] To Local:s:I.Data[10]**	64BIT
CST	Current CLX Coordinate System Time (CST)	**Local:s:I.Data[11] To Local:s:I.Data[12]**	64BIT
CST Offset	Current CLX Coordinate System Time (CST) Offset Current Time = CST + CST Offset This is dependent on the configured time zone (O:e.2)	**Local:s:I.Data[13] To Local:s:I.Data[14]**	64BIT
Latitude Degrees	**Current Position Latitude Degrees**	**Local:s:I.Data[15] Low 16Bit**	INT
Latitude Minutes	**Current Position Latitude Minutes**	**Local:s:I.Data[15] High 16Bit**	INT
Latitude Seconds	**Current Position Latitude Seconds**	**Local:s:I.Data[16]**	REAL
Longitude Degrees	**Current Position Longitude Degrees**	**Local:s:I.Data[17] Low 16 Bit**	INT
Longitude Minutes	**Current Position Longitude Minutes**	**Local:s:I.Data[17] High 16 Bit**	INT
Longitude Seconds	**Current Position Longitude Seconds**	**Local:s:I.Data[18]**	REAL
Altitude	**Current Position Altitude** (Meters above mean sea level)	**Local:s:I.Data[19]**	REAL
Velocity – North	**Current Northerly Velocity** **(m/s x 10)** A negative value indicates a Southerly direction of movement.	**Local:s:I.Data[20]**	REAL

Velocity – East	**Current Easterly Velocity (m/s x 10)** A negative value indicates a Westerly direction of movement.	**Local:s:I.Data[21]**	REAL
Velocity – Upward	**Current Upward Velocity (m/s x 10)** A negative value indicates a Downward direction of movement.	**Local:s:I.Data[22]**	REAL
ECEF Position X	**Distance from Earth-centre along the X - axis. (*meters*)** Position is calculated with respect to the WGS-84 Earth-Centered Earth-Fixed co-ordinate system. The X-axis is defined as the vector with origin at the earth's centre and passing through the intersection of the equator and Greenwich meridian.	**Local:s:I.Data[23]**	REAL
ECEF Position Y	**Distance from Earth-centre along the Y - axis. (*meters*)** Position is calculated with respect to the WGS-84 Earth-Centered Earth-Fixed co-ordinate system. The Y-axis is defined as the vector with origin at the earth's centre and passing through the equator 90 degrees east of the Greenwich meridian.	**Local:s:I.Data[24]**	REAL
ECEF Position Z	**Distance from Earth-centre along the Y - axis. (*meters*)** Position is calculated with respect to the WGS-84 Earth-Centered Earth-Fixed co-ordinate system. The Z-axis is defined as the vector with origin at the earth's centre and passing through the North pole.	**Local:s:I.Data[25]**	REAL
ECEF Velocity – X	**Speed with respect to the X - axis. (m/s x 10)** The X-axis is defined as the vector with origin at the earth's centre and passing through the intersection of the equator and Greenwich meridian.	**Local:s:I.Data[26]**	REAL
ECEF Velocity – Y	**Speed with respect to the Y - axis. (m/s x 10)** The Y-axis is defined as the vector with origin at the earth's centre and passing through the equator 90 degrees east of the Greenwich meridian.	**Local:s:I.Data[27]**	REAL
ECEF Velocity – Z	**Speed with respect to the Z - axis. (m/s x 10)** The Z-axis is defined as the vector with origin at the earth's centre and passing through the North pole.	**Local:s:I.Data[28]**	REAL

6.3. Output Image

WORD	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	Reserved																															
1	Reserved																															
2	Timezone																															

6.4. Output Image Description

Field	Description	Location	Type
Reserved	Reserved 64Bits		64BIT
Time zone	**Time Zone Configuration** Used to set the module to report in local time standard. Time zone = UTC Offset where the UTC Offset is the difference, in hours, between local time and GMT. E.g. For Pacific Standard Time (GMT - 8) set time zone = -8	**Local:s:O.Data[2]**	REAL

The Time zone needs to be copied from a tag (of type real) into the output word. Appendix A and B provide example code and recommended data types.

CHAPTER 7 MODULE SPECIFIC COMMANDS

The 1756HP-GPS-IRIG-OUT module offers specific commands that enable the system to retrieve GPS satellite information, as well as performing time base conversions. These are accomplished using unconnected messaging via the MSG ladder instruction. This enables communication to the module without a direct connection.

Appendix A and B provide example code and recommended data structures that can be used to store the information.

7.1. Retrieving GPS Satellite Data

The module provides tracking data for up to 8 satellites/channels. Information pertaining to each satellite includes:

PRN,
Each operational GPS satellite has a unique PRN identification number

Elevation
Measure of the elevation of the satellite in degrees from the horizon

Azimuth
Measure of the bearing to the satellite in degrees from true north

SnR
Measure of the satellite signal strength in dBHz calculated during signal correlation.

The information is requested by setting up a CIP Generic Custom message block. The configuration of the message instruction is as follows:

Field	Value
Message Type	CIP Generic
Service Type	Custom
Service Code	0x32
Class	0x71
Instance	0x01
Attribute	0x01
Source Length	0
Destination Element	Destination tag for reply data

Table 7.1 : Satellite data request configuration.

The message instruction will return the information in the following structure :

Field	Bytes	Type	Description	
Satellite[n] Prn	1	SINT	Satellite number	[1..32]
Satellite[n] Ele	1	SINT	Elevation	[0..90]
Satellite[n] Azm	2	INT	Azimuth	[0..360]
Satellite[n] SnR	4	DINT	Signal – noise ratio	

where n indicates the channel number (1 … 8)

Table 7.2 : Satellite data information response.

The above data structure is repeated for all 8 satellites, thus giving a total length of 64 bytes for the response.

Refer to Appendix B for a recommended data structure for the satellite data.

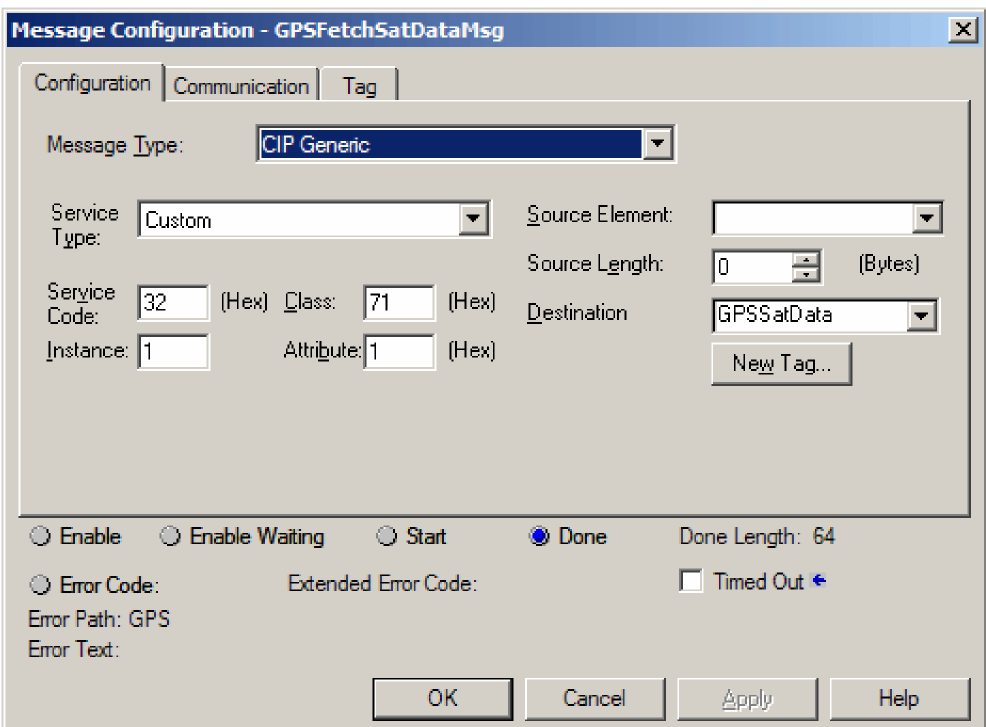


Figure 7.1 : Satellite data message structure.

7.2. Converting Time Bases

The 1756HP-GPS-IRIG-OUT stores a rolling log of the CST/UTC pairs for the last 1 hour. Timestamps in a system can either be CST or UTC values. The 1756HP-GPS-IRIG-OUT module provides functionality for converting between values that are within the last hour.

7.3. Converting CST to UTC and Gregorian

By supplying the full 64 bit CST value, the module will return the corresponding full Gregorian date and UTC value. Configuration of this message is illustrated below.

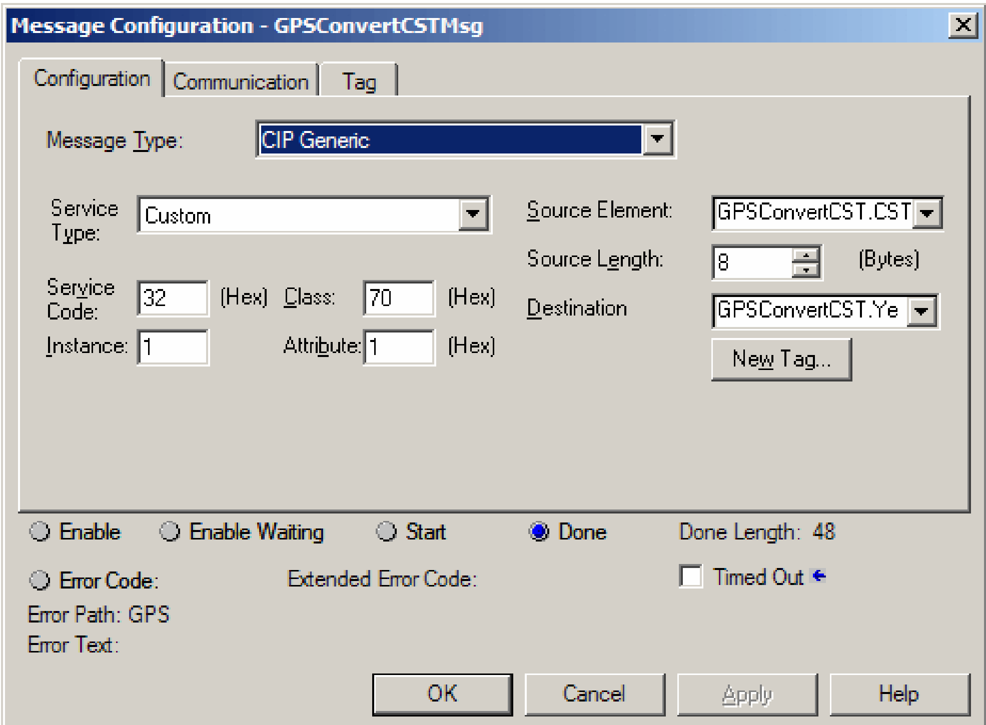


Figure 7.2: Configuring the MSG CST->UTC conversion request instruction.

Refer to Appendix A for code examples.

Field	Value
Message Type	CIP Generic
Service Type	Custom
Service Code	0x32
Class	0x70
Instance	0x01
Attribute	0x01
Source Length	0
Destination Element	Destination tag for reply data

Table 7.3: CST->UTC conversion request configuration.

The structure of the request is as follows :

Field	Bytes	Type	Description
CST	8	DINT[2]	CST value

Table 7.4 : CST->UTC conversion request data.

A successful conversion will result in the following response:

Field	Bytes	Type	Description
Year	2	DINT	Gregorian year
Month	2	DINT	Gregorian month
Day	2	DINT	Gregorian day
Hour	2	DINT	Gregorian hour
Min	2	DINT	Gregorian min
Sec	2	DINT	Gregorian sec
µSec	2	DINT	Gregorian µSec
UTC	8	DINT[2]	Corresponding UTC value
CST	8	DINT[2]	Given CST value

Table 7.5: CST->UTC conversion successful response data.

An unsuccessful response (code 0x03) will be sent back should the CST not fall within the previous logged hour.

Error Code	Description
0x02	CST Value requested for conversion is in the future
0x03	CST Value requested for conversion is in the too far in the past (greater than 1 hour)
0x04	Unable to find match due to possible invalid time occurring during logging

7.4. Converting UTC to Gregorian Time

By supplying the full 64 bit UTC value, the module will return the corresponding full Gregorian date. Configuration of this message is illustrated below.

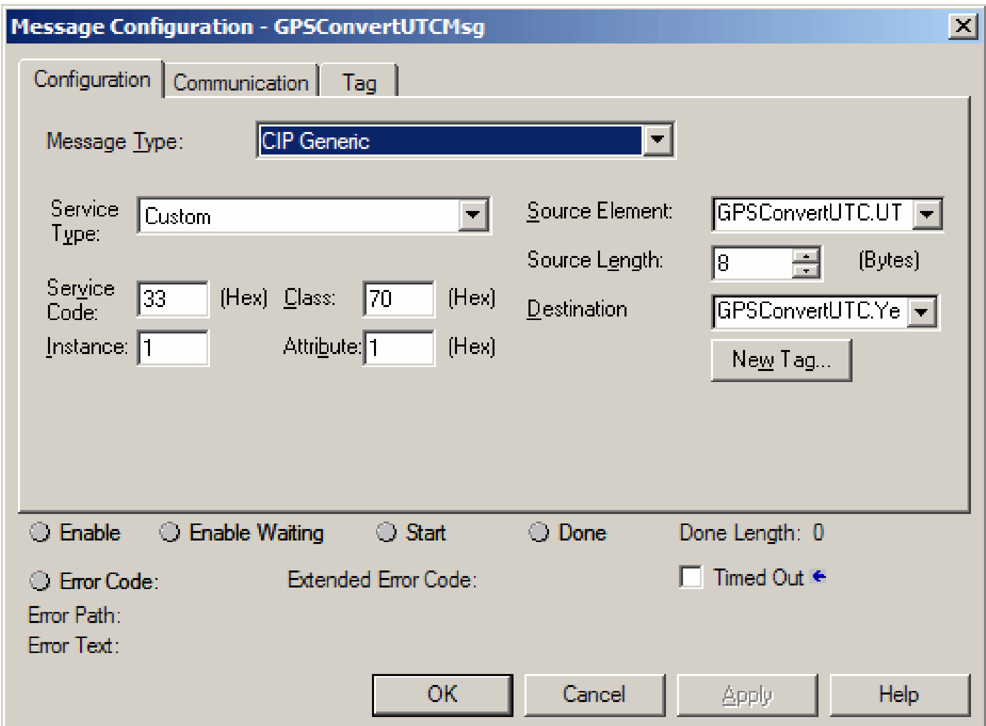


Figure 7.3: Configuring the MSG UTC->Gregorian conversion request instruction.

The message instruction should be configured as follows :

Field	Value
Message Type	CIP Generic
Service Type	Custom
Service Code	0x33
Class	0x70
Instance	0x01
Attribute	0x01
Source Element	Tag containing requested UTC value
Source Length	8
Destination Element	Destination tag for reply data

Table 7.6 : UTC->Gregorian conversion request configuration.

The structure of the request is as follows:

Field	Bytes	Type	Description
UTC	8	DINT[2]	UTC value

Table 7.7 : UTC->Gregorian conversion response data.

A successful conversion will result in the following response:

Field	Bytes	Type	Description
Year	2	DINT	Gregorian year
Month	2	DINT	Gregorian month
Day	2	DINT	Gregorian day
Hour	2	DINT	Gregorian hour
Min	2	DINT	Gregorian min
Sec	2	DINT	Gregorian sec
µSec	2	DINT	Gregorian µSec
UTC	8	DINT[2]	Corresponding UTC value

Table 7.8 : UTC->Gregorian conversion successful response data.

An unsuccessful response will be sent back should the UTC not fall within the previous logged hour.

Error Code	Description
0x02	UTC Value requested for conversion is in the future
0x03	UTC Value requested for conversion is in the too far in the past (greater than 1 hour)
0x04	Unable to find match due to possible invalid time occurring during logging

CHAPTER 8 MODULE STATUS

The following sections describe the various statuses of the module and how they may be determined via the 3 bi-color (Green / Red) LED's and the message on the display.

8.1. Status LED's

LED	DESCRIPTION	STATUS	MEANING
OK	Module Status	Solid Red	Major Hardware Fault
		Flashing Red	Major Fault
		Flashing Green	Minor Fault
		Green	Module operating correctly
LOC	GPS Lock Status	Solid Red	Antenna Failure
		Flashing Red	No Satellite found
		Flashing Green	Busy acquiring satellites
		Green	Full GPS Lock, positioning and time fixing
PPS	Pulse Per Second	Solid Red	No PPS available
		Flashing Red	Premature PPS (before lock)
		Flashing Green	Normal Synchronized to GPS Time

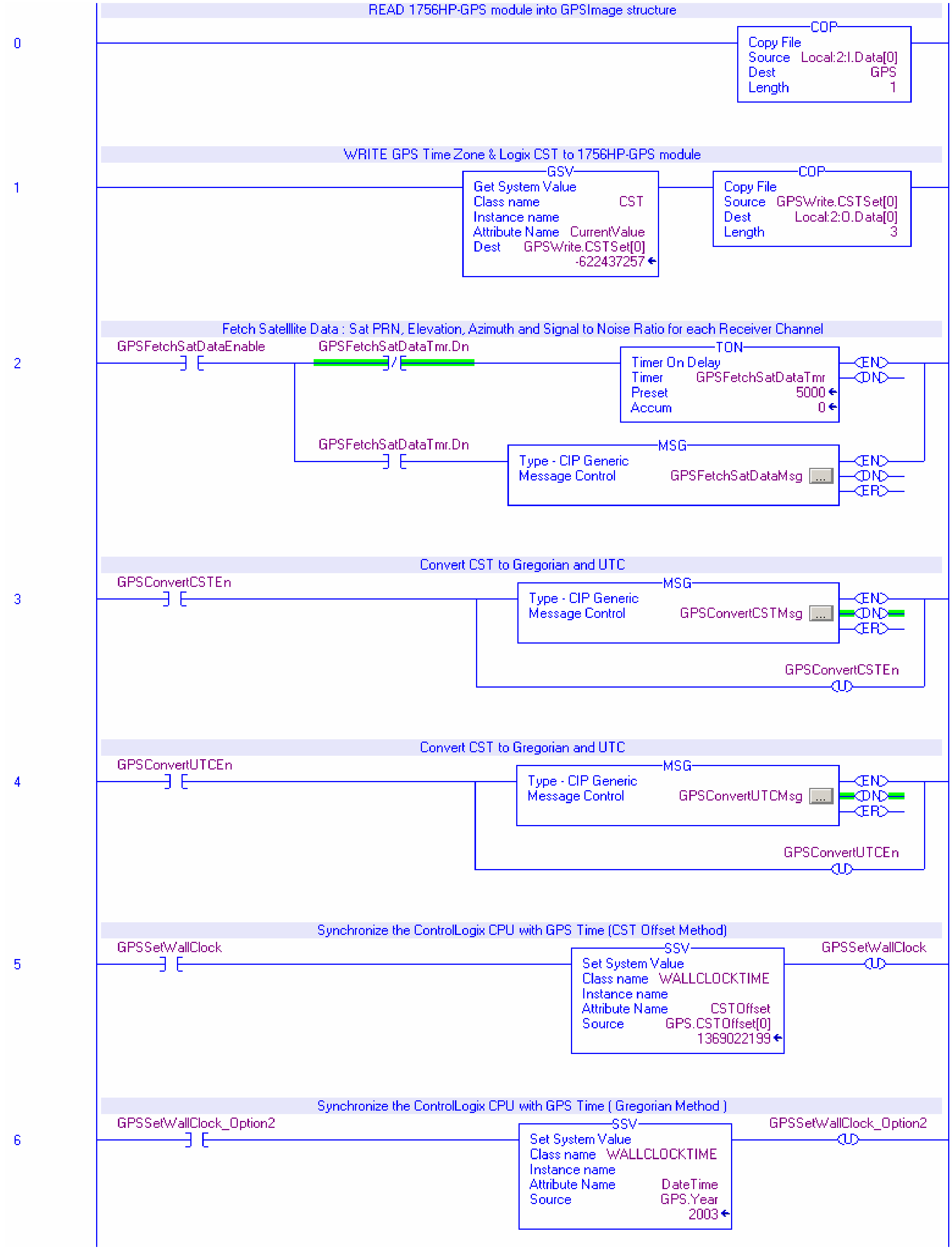
Table 8.1 : LED status information of the module.

8.2. Status Display

Init	**Initialization of Module** The module is initialized only on power-up.
Frn	**Firmware Revision** The firmware revision number is displayed on power-up.
AntO	**Antenna Open Circuit** Indicates the Antenna is not connected or damaged.
Sky	**No Sky Available** Indicates the absence of any satellite signals. This usually occurs when the Antenna is placed indoors, or during power-up before Lock is achieved.
Srch	**Satellite Search** Module is attempting to acquire satellites
Cold	**Cold Initialisation Required** Indicates that the module is devoid of internal satellite information. Module will automatically download new almanac & ephemeris data from a satellite.
Time	**Satellite Time synchronization in Progress** Indicates that the module is receiving satellite signals but has not yet been able to synchronize to GPS time.
Lock	**Satellite Lock** Indicates that sufficient satellites are being tracked to provide position fixing.
PDOP	**Position Dilution of Precision Warning** Position Dilution of Precision occurs when although there are sufficient satellites in lock, 2 or more of them appear to occupy similar positions in the sky and thus the number of effective satellites is decreased.

Trk1	**Tracking only 1 Satellite**
Trk2	**Tracking only 2 Satellites**
Trk3	**Tracking only 3 Satellites**
SBad	**Current Satellite is Bad** The satellite signal currently being acquired is suspect or unusable.
SAT	**Satellite data request** Module is processing a satellite data request
C->U	**Time Conversion CST → UTC** Module is performing a time conversion
U->G	**Time Conversion UTC → Gregorian** Module is performing a time conversion

APPENDIX A PLC LADDER EXAMPLE



APPENDIX B RECOMMENDED PLC DATA TYPES

This Appendix provides a detailed description of recommended data structures that can be used in conjunction with the provided example ladder code. The following structures (and example code) can be downloaded from the Hiprom website. (www.hiprom.com)

B.1 Input Image Structures

Data of the 1756HP-GPS-IRIG-OUT can be presented clearly by copying the input image to the GPSImage user-defined data type (UDT) structure. This structure utilizes the following embedded UDT structures (detailed below)

- GPSPolar
- GPSENU
- GPSCartesian

GPSImage		
Name	**Data Type**	**Style**
Reserved	INT	Decimal
ModuleOk	BOOL	Decimal
GPSLock	BOOL	Decimal
CSTOk	BOOL	Decimal
TimeOk	BOOL	Decimal
PPS	BOOL	Decimal
BatteryOk	BOOL	Decimal
AntennaOk	BOOL	Decimal
PDOPOk	BOOL	Decimal
West	BOOL	Decimal
South	BOOL	Decimal
IRIG-OUT	BOOL	Decimal
Reserved1	BOOL	Decimal
Dup Master	BOOL	Decimal
CST Master	BOOL	Decimal
Reserved2	BOOL	Decimal
Reserved3	BOOL	Decimal
SatelliteCount	DINT	Decimal
Year	DINT	Decimal
Month	DINT	Decimal
Day	DINT	Decimal
Hour	DINT	Decimal
Minute	DINT	Decimal
Second	DINT	Decimal
Microsecond	DINT	Decimal
UTC	DINT[2]	Decimal
CST	DINT[2]	Decimal

CSTOffset	DINT[2]	Decimal
Latitude	GPSPolar	
Degrees	INT	Decimal
Minutes	INT	Decimal
Seconds	REAL	Float
Longitude	GPSPolar	
Degrees	INT	Decimal
Minutes	INT	Decimal
Seconds	REAL	Float
Altitude	REAL	Float
Velocity	GPSENU	
Northerly	REAL	Float
Easterly	REAL	Float
Upward	REAL	Float
ECEFPosition	GPSCartesian	
X	REAL	Float
Y	REAL	Float
Z	REAL	Float
ECEFVelocity	GPSCartesian	
X	REAL	Float
Y	REAL	Float
Z	REAL	Float

Table B.1 : GPSImage UDT

GPSPolar		
Name	**Data Type**	**Style**
Degrees	INT	Decimal
Minutes	INT	Decimal
Seconds	REAL	Float

Table B.2 : GPSPolar UDT

GPSENU		
Name	**Data Type**	**Style**
Northerly	REAL	Float
Easterly	REAL	Float
Upward	REAL	Float

Table B.3 : GPSENU UDT

GPSCartesian		
Name	**Data Type**	**Style**
X	REAL	Float
Y	REAL	Float
Z	REAL	Float

Table B.4 : GPSCartesian UDT

B.2 Unconnected message Structures

An array of the following structure can be used to receive the satellite data requested from the module via the unconnected message.

GPSSatData		
Name	**Data Type**	**Style**
Prn	SINT	Decimal
Ele	SINT	Decimal
Azm	INT	Decimal
Snr	REAL	Float

Table B.5 : GPSSatData UDT

The following structure can be used for the CST to Gregorian conversion via the unconnected message. The structure holds both the data sent and received.

GPSConvCST		
Name	**Data Type**	**Style**
CSTRequest	DINT[2]	Decimal
Year	DINT	Decimal
Month	DINT	Decimal
Day	DINT	Decimal
Hour	DINT	Decimal
Minute	DINT	Decimal
Second	DINT	Decimal
Microsecond	DINT	Decimal
UTC	DINT[2]	Decimal
CST	DINT[2]	Decimal

Table B.6 : GPSConvCST UDT

The following structure can be used for the UTC to Gregorian conversion via the unconnected message. The structure holds both the data sent and received.

GPSConvUTC		
Name	**Data Type**	**Style**
UTCRequest	DINT[2]	Decimal
Year	DINT	Decimal
Month	DINT	Decimal
Day	DINT	Decimal
Hour	DINT	Decimal
Minute	DINT	Decimal
Second	DINT	Decimal
Microsecond	DINT	Decimal
UTC	DINT[2]	Decimal

Table B.4 : GPSConvUTC UDT

APPENDIX C SPECIFICATIONS

Parameter	Specification
General	
Module Location	Any Slot
Electrical	
Backplane Current	515mA @ 5.1V
	3mA @ 24V
Schedules Connection Paramters	
RPI	1.0ms to 750ms
GPS Receiver Specification	
General	L1 frequency (1575.42 MHz), C/A code (Standard
	Positioning Service), 8-channel, continuous tracking receiver,
	32 correlators
Accuracy Horizontal	<6 meters (50%), <9 meters (90%)
Altitude	<11 meters (50%), <18 meters (90%)
Velocity	0.06 m/sec
Time	±95 ns or 1 RPI
Hot Start	<14 sec. (50%), <18 sec. (90%)
Warm Start	<38 sec. (50%), <45 sec. (90%)
Cold Start	<90 sec. (50%), <170 sec. (90%)
Antenna	
Antenna Connector	SMA female connector
Frequency Range	1575.42 MHz ± 1.023 MHz
Polarization	Right-hand circular polarization (RHCP)
Output Impedance	50Ω
VSWR	2.0 maximum
Axial Ratio	90°: 4.0 dB maximum; 10°: 6 dB maximum
Gain	35 dB ± 3 Db
Out of Band Rejection	fo: 1575.42 MHz
	fo ± 20 MHz : 7dB min
	fo ± 30 MHz : 12dB min
	fo ± 40 MHz : 20dB min
	fo ± 100 MHz : 100dB min
Azimuth Coverage	360° (omni-directional)
Elevation Coverage	0° to 90° elevation (hemispherical)
Antenna Patch Lead	
Coax Type	RG-58
Impedance	50Ω

APPENDIX D GPS OPERATION

The Global Positioning System (GPS) is a satellite based navigation system operated and maintained by the U.S. Department of Defence. The system consists of a constellation of 24 satellites providing world-wide, 24 hour, three dimensional (3D) coverage. Although originally conceived for military needs, GPS has a broad array of civilian applications including surveying, marine, land, aviation, and vehicle navigation. GPS is the most accurate technology available for vehicle navigation.

As a satellite based system, GPS is immune to the limitations of land based systems such as Loran. Loran navigation is limited in coverage and is encumbered by adverse weather. In addition, the accuracy of Loran navigation varies with geographic location and, even under ideal conditions, cannot compare with GPS. By computing the distance to GPS satellites orbiting the earth, a GPS receiver can calculate an accurate position. This process is called satellite ranging. A 2D position calculation requires three satellite ranges. A 3D position calculation, which includes altitude, requires four satellite ranges. GPS receivers can also provide precise time, speed, and course measurements which are beneficial for vehicle navigation.

D.1 GPS Satellite Message

Every GPS satellite transmits the Coarse/Acquisition (C/A) code and satellite data modulated onto the L1 carrier frequency (1575.42 MHz). The satellite data transmitted by each satellite includes a satellite almanac for the entire GPS system, its own satellite ephemeris and its own clock correction.

The satellite data is transmitted in 30-second frames. Each frame contains the clock correction and ephemeris for that specific satellite, and two pages of the 50-page GPS system almanac. The almanac is repeated every 12.5 minutes. The ephemeris is repeated every 30 seconds. The system almanac contains information about each of the satellites in the constellation, ionospheric data, and special system messages. The GPS system almanac is updated weekly and is typically valid for months. The ephemeris contains detailed orbital information for a specific satellite. Ephemeris data changes hourly, but is valid for up to four hours. The GPS control segment updates the system almanac weekly and the ephemeris hourly through three ground-based control stations. During normal operation, the 1756HP-GPS-IRIG-OUT receiver module updates its ephemeris and almanac as needed. The performance of a GPS receiver at power-on is determined largely by the availability and accuracy of the satellite ephemeris data and the availability of a GPS system almanac.

D.2 Satellite Acquisition and Time to First Fix

Cold-Start

The term “cold-start” describes the performance of a GPS receiver at power-on when no navigation data is available “cold” signifies that the receiver does not have a current almanac, satellite ephemeris, initial position, or time. The cold-start search algorithm applies to a 1756HP-GPS-IRIG-OUT receiver which has no memory of its previous session (i.e., is powered on without the memory backup circuit connected to a source of DC power). This is the “out of the box” condition of the GPS module as received from the factory. In a cold-start condition the receiver automatically selects a set of eight satellites and dedicates an individual tracking channel to each satellite, to search the Doppler range frequency for each satellite in the set. If none of the eight selected satellites is acquired after a predetermined period of time (time-out), the receiver will select a new search set of eight satellites and will repeat the process, until the first satellite is acquired. As satellites are acquired, the receiver automatically collects ephemeris and almanac data. The Lassen SQ GPS receiver uses the knowledge gained from acquiring a specific satellite to eliminate other satellites, those below the horizon, from the search set. This strategy speeds the acquisition of additional satellites required to achieve the first position fix. The cold-start search sets are established to ensure that at least three satellites are acquired within the first two time-out periods. As soon as three satellites are found, the receiver will compute an initial position fix. The typical time to first fix is less than 2 minutes. A complete system almanac is not required to achieve a first position fix. However, the availability and accuracy of the satellite ephemeris data and the availability of a GPS almanac can substantially shorten the time to first fix.

Warm Start

In a warm-start condition the receiver has been powered down for at least one hour but has stored a current almanac, an initial position, and time, in memory. When connected to an external back-up power source (battery back-up), the 1756HP-GPS-IRIG-OUT receiver retains the almanac, approximate position, and time to aid in satellite acquisition and reduce the time to first fix. When an external back-up battery is not used, the TSIP protocol allows the almanac, an initial position, and
time to be uploaded to the receiver via the serial port, to initiate a warm start.

During a warm start, the 1756HP-GPS-IRIG-OUT receiver identifies the satellites which are expected to be in view, given the system almanac, the initial position and the approximate time. The receiver calculates the elevation and expected Doppler shift for each satellite in this expected set and directs the eight tracking channels in a parallel search for these satellites. The warm start time to first fix, when the receiver has been powered down for more than 60 minutes (i.e. the ephemeris data is old), is usually less than 45 seconds.

Hot Start

A hot start strategy applies when the 1756HP-GPS-IRIG-OUT receiver has been powered down for less than 60 minutes, and the almanac, position, ephemeris, and time are valid. The hot start search strategy is similar to a warm start, but since the ephemeris data in memory is considered current and valid, the acquisition time is typically less than 20 seconds.

D.3 Satellite Mask Settings

Once the 1756HP-GPS-IRIG-OUT receiver has acquired and locked onto a set of satellites, which pass the mask criteria listed in this section, and has obtained a valid ephemeris for each satellite, it will output regular position, velocity and time reports according to the protocol selected. The satellite masks used by the 1756HP-GPS-IRIG-OUT receiver are listed in Table E.1. These masks serve as the screening criteria for satellites used in fix computations and ensure that position solutions meet a minimum level of accuracy. The 1756HP-GPS-IRIG-OUT receiver will only output position, course, speed and time when a satellite set can be acquired which meets all of the mask criteria.

Parameter	Mask
Elevation	>5°
SnR	>3
PDOP	12

Table E.1 : Satellite Mask Limits

Elevation Mask

Satellites below a 5° elevation are not used in the position solution. Although low elevation satellites can contribute to a lower/better PDOP, the signals from low elevation satellites are poorer quality, since they suffer greater tropospheric and ionospheric distortion than the signals from higher elevation satellites. These signals travel further through the ionospheric and tropospheric layers. In addition, low elevation satellites can contribute to frequent constellation switches, since the signals from these satellites are more easily obscured by buildings and terrain. Constellation switches can cause noticeable jumps in the position output. Since worldwide GPS satellite coverage is generally excellent, it is not usually necessary to use satellites below a 5° elevation to improve GPS coverage time. In some applications, like urban environments, a higher mask may be warranted to minimize the frequency of constellation switches and the impact of reflected signals.

SNR Mask

Although the 1756HP-GPS-IRIG-OUT receiver is capable of tracking signals with SNRs as low as 0, the default SNR mask is set to 3 to eliminate poor quality signals from the fix computation and minimize constellation switching. Low SNR values may result from:
• Low Elevation Satellites
• Partially Obscured Signals (e.g. Dense Foliage)
• Multi-Reflected Signals (Multi-Path)
The distortion of signals and the frequent constellation switches associated with low-elevation satellites were discussed above. In mobile applications, the attenuation of signals by foliage is typically a temporary condition. Since the 1756HP-GPS-IRIG-OUT receiver can maintain lock on signals with SNR's as low as 0, it offers excellent performance when traveling through heavy foliage. Multi-reflected signals, also known as Multi-path, can degrade the position solution. Multi-path is most commonly found in urban environments with many tall buildings and a preponderance of mirrored glass, which is

popular in modern architecture. Multi-reflected signals tend to be weak (low SNR value), since each
reflection attenuates the signal. By setting the SNR mask to 3 the impact of multi-reflected signals is minimized.

DOP Mask

Position Dilution of Precision (DOP) is a measure of the error caused by the geometric relationship of the satellites used in the position solution. Satellite sets which are tightly clustered or aligned in the sky will have a high DOP and will contribute to a lower position accuracy. For most applications, a DOP mask of 12 offers a satisfactory trade-off between accuracy and GPS coverage time.

Position Accuracy

GPS position accuracy is degraded by atmospheric distortion, satellite geometry, satellite clock errors, and receiver clock errors. Effective models for atmospheric distortion of satellite signals have been developed to minimize the impact of tropospheric and ionospheric effects. The impact of satellite clock errors is minimized by incorporating the clock corrections transmitted by each satellite used in the position solution.

GPS Timing

In many timing applications, such as time/frequency standards, site synchronization systems and event measurement systems, GPS receivers are used to discipline local oscillators. The GPS constellation consists of 24 orbiting satellites. Each GPS satellite contains a highly-stable atomic (Cesium) clock, which is continuously monitored and corrected by the GPS control segment. Consequently, the GPS constellation can be considered a set of 24 orbiting clocks with worldwide 24-hour coverage. GPS receivers use the signals from these GPS “clocks” to correct its internal clock, which is not as stable or accurate as the GPS atomic clocks. GPS receivers like the 1756HP-GPS-IRIG-OUT’s receiver output a highly accurate timing pulse (PPS) generated by its internal clock, which is constantly corrected using the GPS clocks. This timing pulse is synchronized to UTC within ±95 ns. In addition to serving as a highly accurate stand-alone time source, GPS receivers are used to synchronize distant clocks in communication or data networks. This synchronization is possible since all GPS satellite clocks are corrected to a common master clock. Therefore, the relative clock error is the same, regardless of which satellite or satellites are used. For timing applications requiring a “common clock”, GPS is the ideal solution. The position and time errors are related by the speed of light. Therefore, a position error of 100 meters corresponds to a time error of approximately 333 ns.

APPENDIX E TIME STANDARDS

There are many different time standards used in the world today. This chapter describes the different formats and standards used in the 1756HP-GPS-IRIG-OUT module and how the relate to one another.

E.1 GPS Time

By synchronizing with the atomic clocks on GPS satellites the 1756HP-GPS-IRIG-OUT module is able to compute accurate GPS time. GPS time differs from UTC (Universal Coordinated Time) by a variable integer number of seconds:

UTC = (GPS time) - (GPS UTC Offset)

As of April 2002, the GPS UTC offset was 13 seconds. The offset increases by 1 second approximately every 18 months. The 1756HP-GPS-IRIG-OUT module automatically acquires the UTC offset from the received GPS system almanac and calculates the correct UTC.
The 1756HP-GPS-IRIG-OUT receiver makes use of the Extended GPS Week Number as the absolute number of weeks since the beginning of GPS time or January 6, 1980. Using this, rather than the true GPS Week Number prevents any possible roll-over issues (similar to Y2K), that earlier generation GPS receivers suffered from.

E.2 Universal Coordinate Time (UTC)

Universal Coordinate Time (UTC) is the world standard maintained by an ensemble of atomic clocks operated by government organizations around the world. UTC time replaced GMT (Greenwitch Mean Time) as the world standard, in 1986. GPS time is steered relative to Universal Coordinated Time (UTC). GPS does not recognize leap seconds resulting in the aforementioned GPS UTC Offset. The 1756HP-GPS-IRIG-OUT module reports UTC as a 64 bit unsigned long integer representing the number of elapsed microseconds since 1 January 1972. This UTC value is thus independent of the Configured Time Zone.

E.3 Local Time and Time Zone Configuration

Local time is expressed in Gregorian format and takes into account the configured Time Zone. The Time Zone is the difference between local and UTC time expressed as a REAL number of hours.

NOTE: The Time Zone set in the module's output image must be in REAL format. Writing an integer directly to the module can cause unexpected results. It is recommended that the GPSImage User-defined Data Type be used. See Appendix B

E.4 Coordinate System Time (CST)

The CST (Coordinated System Time) is a 64 bit count of the number of microsecond ticks from some arbitrary instance. This value is generated by the CST master and supplied to all other modules in the rack. Only one of the modules, (usually the CPU,) in the ControlLogix rack can be configured to be the CST Master at any given time.

E.5 Wall Clock Time (WCT) and CST Offset

The wall clock object located in the ControlLogix CPU maintains the conversion of the CST value to a value that is relative to a system defined point in time. This allows the user to set the Wall Clock to coincide with local or any other time standard. WCT is derived from the CST by adding an offset known as the CST Offset.

WCT = CST + (CST Offset)

The 1756HP-GPS-IRIG-OUT module calculates the required CST Offset in order to set the WCT to UTC time or local time depending on the configured Time Zone.

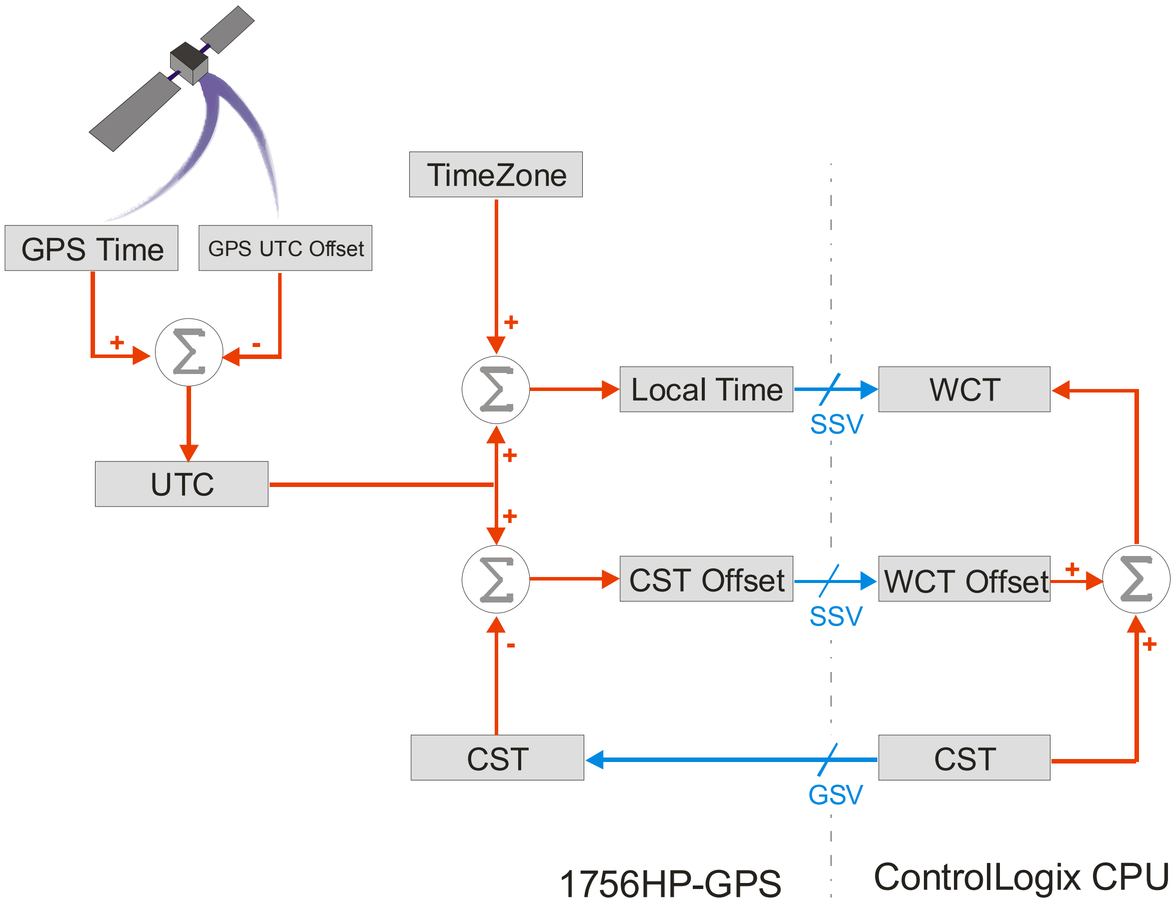


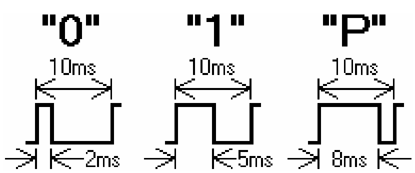
Figure F.1 : Time Standard Relationship

APPENDIX F IRIG STANDARD

IRIG was developed by the Tele Communication Working Group (TCWG) of the Inter Range Instrumentation group (IRIG) in October 1965. The latest IRIG standard is published in IRIG Standard 200-98.

IRIG is a standard for transmitting time from one system to another for time synchronization purposes. An IRIG master transmits an IRIG signal to multiply IRIG slaves on the network. The IRIG signals consist of two words which together are exactly one second long. The first word is the time of the year in binary coded decimal (BCD) with notation in seconds (7 Bits), minutes (7 Bits), hours (6 Bits), and days (10 Bits). The second word is called the Straight Binary Seconds (SBS) and is a binary counter of the number of seconds of the day, which resets at midnight (i.e. 0 to 86399 seconds).

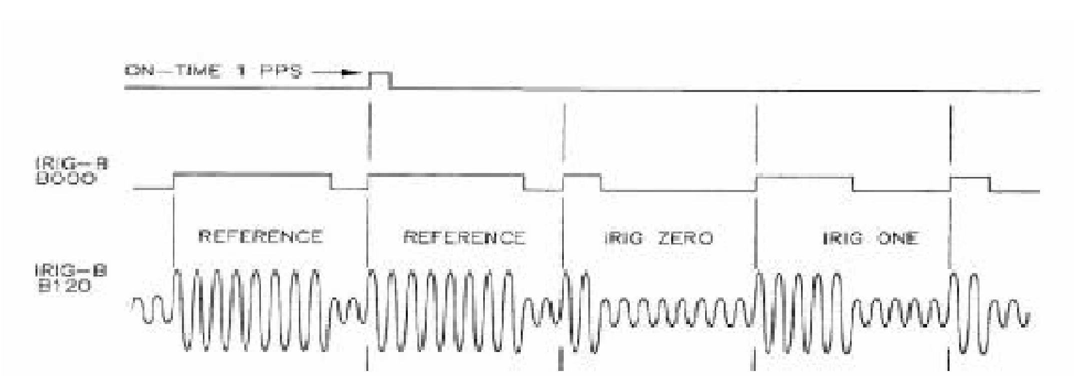
Each IRIG consists of 10 sections. Each section consists of 10 bits of 1mSec duration. Each bit can have three values: 1, 0, and position identifier (Po). A 1 is set for 5mSec, 0 for 2mSec and a position identifier is set for 8mSec as illustrated below.



FIGURE

A position identifier Po occurs between decimal digits in each group for visual separation.

An IRIG signal can either be transmitted as an amplitude-modulated or DC-level signal. The amplitude-modulated signal is modulated with a 1kHz sine wave. Below is an illustration of both signal types. The two reference bits as indicated below are the start of the IRIG frame.



APPENDIX G GLOSSARY

Communications format
Format that defines the type of information transferred between an I/O module and its owner controller. This format also defines the tags created for each /O module

Coordinated System Time (CST)
Timer value which is kept synchronized for all modules within a single ControlBus chassis. The CST is a 64 bit number with μs resolution.
Coordinated System Time (CST)

Download
The process of transferring the contents of a project on the workstation into the controller

Earth-Centered-Earth-Fixed (ECEF) coordinates
Cartesian coordinate system where the X direction is the intersection of the prime meridian (Greenwich) with the equator. The vectors rotate with the earth. Z is the direction of the spin axis, with positive through the north pole.

GPS (Global Positioning System)
A constellation of 24 radio navigation (not communication) satellites which transmit signals used (by GPS receivers) to determine precise location (position, velocity, and time) solutions. GPS signals are available world-wide, 24 hours a day, in all weather conditions. This system also includes 5 monitor ground stations, 1 master control ground station, and 3 upload ground stations.

GPS Antenna
An antenna designed to receive GPS radio navigation signals. These antennas typically comprise a Low Noise Amplifier (LNA) and are known as active, and thus require DC power.

GPS Processor
An electronic device that interprets the GPS radio navigation signals (received by a GPS antenna) and determines a location solution.

GPS Receiver
The combination of a GPS antenna and a GPS processor.

Owner controller
The controller that creates and stores the primary configuration and communication connection to a module

PDOP Position Dilution of Precision.
PDOP is a unitless figure of merit that describes how an uncertainty in pseudo-range affects position solutions.

PRN Pseudo-random noise.
Each GPS satellite generates its own distinctive PRN code, which is modulated onto each carrier. The PRN code serves as identification of the satellite, as a timing signal, and as a subcarrier for the navigation data.

Producer/consumer
Intelligent data exchange system devices in which the GPS module produces data without having been polled first.

Removal and insertion under power (RIUP)
ControlLogix feature that allows a user to install or remove a module or RTB while power is applied.

Requested packet interval (RPI)
A configurable parameter which defines when the module will multicast data

Service
A system feature that is performed on user demand

Signal to noise ratio
A measure of the relative power levels of a communication signal and noise on a data line. SNR is expressed in decibels (dB).

SV
Space Vehicle (GPS satellite).

Tag
A named area of the controller’s memory where data is stored like a variable

(………………../// end of document)