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G.P.S. Clock Device Outputs for Time Synchronization Applications

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Abstract – **This paper highlights the advantages of G.P.S. Clock devices which are used to synchronize the slave device clock which are synchronize with the global time. This paper describes all the outputs of time format provided by G.P.S. Clock devices which are as recognized as international standard by the electronics community. G.P.S. clock devices are also used for providing the accurate position of G.P.S. device and accurate time outputs in multiple formats.**

Keywords – **G.P.S., N.T.P., I.R.I.G., P.P.S., N.M.E.A., P.T.P., O.C.X.O., T.C.X.O., P.P.M.**

I. INTRODUCTION

G.P.S. (Global Position System) system is a satellite based Navigation system which comprise of network of satellites placed in earth's orbit. G.P.S. based G.P.S. receivers are used to get accurate position of devices and accurate time which is a satellite based time. Now days, all devices in industries such as power industries, telecommunications field, internet network devices and other various industries require accurate time for their devices.

It is the G.P.S. receivers equipped in G.P.S. devices which receives and decodes the satellite data in order to calculate device accurate position in terms of latitude and longitude as well as calculate accurate time of clock. The very stable clock in world is atomic clock which is used by satellite in order to find very high accurate time. It is very difficult as well very expensive techniques are employed used to interface device with atomic clock. Today, products are design with reduced size and cost. So, small size and low cost G.P.S. receiver module are used in G.P.S. Clock devices in order to communicate with satellites.

G.P.S. clock devices get the standard time from G.P.S. receivers and converts this time on various standard time formats such as serial frame based N.M.E.A. (National Marine Electronics Associations) time format, I.R.I.G. (Inter-Range Instrumentation Group) time code output, N.T.P. (Network Time Protocol) output, P.T.P. (Precision Time Protocol) output as well as other customized serial time frames.

II. G.P.S. RECEIVER

All satellites transmits the data at 1.57542 GHz (L1) signal and 1.2276 GHz (L2) signal periodically. The satellite message contains the information of time the message was transmitted and satellite position at the time when message was transmitted. G.P.S. receiver uses this message to decode the data and calculates the accurate time depending on the distance of each satellite using speed of light and determines the transmit time of each message.

Generally, G.P.S. receivers require minimum three satellites in order to calculate its position and time. There are 24 satellites in constellation orbiting around earth at the altitude of 20,200 km. But, the accuracy of G.P.S. receiver in terms of position and time increases with minimum 4 satellites being tracked. G.P.S. receivers are able to track maximum 12 satellites which are sufficient for very good accuracy of position and time.

Besides the initial prerequisite of acquiring a fix with four satellites, the G.P.S. has a number of factors that could affect its performance in providing accurate timing and most importantly, the G.P.S. antenna position plays a crucial role in obtaining accurate timing information [2]. As a result, for optimal performance, the antenna should have an unobstructed view of the horizon in all directions. This will enable the receiver to monitor the maximum number of satellites simultaneously, and to provide a more stable G.P.S. lock [2].

III. G.P.S. Clock Basics

G.P.S. clock devices are equipped with the G.P.S. receivers. G.P.S. receivers provide accurate P.P.S. (Pulse per seconds) and serial time frame. Using this two signals, G.P.S. Clock device provides various format of time outputs. G.P.S. clock devices are capable to provide accurate time output even when the G.P.S. receiver is not able to detect satellites through G.P.S. Clock device own internal highly accurate crystal using T.C.X.O. (Temperature Controlled Oscillator), O.C.X.O. (Oven Controlled Oscillator) or Rubidium Crystal oscillators. Normal crystal are having frequency drift rate of 15 to 30 P.P.M. (Parts Per Million) which is high considerable the accuracy required when G.P.S. receiver are not able to detect satellites. This drift rate further worsens when device is operating under severe temperature conditions. T.C.X.O. and O.C.X.O. are very high accurate crystals which range from 1P.P.M. to 0.05P.P.M. drift rate which are ideal for G.P.S. applications and this crystal are temperature controlled providing ideal usage applications. Rubidium are very highly accurate crystal as compare to T.C.X.O. and O.C.X.O. crystals but are very expensive in cost and thus are used in applications which are very time critical.

P.P.S. signal of G.P.S. receiver output is a TTL (Transistor Transistor Logic) signal which can be 5V signal which is generated at every 1 second. Using this P.P.S. signal, G.P.S. Clock device calibrates its internal clock with resolution may be in microseconds or milliseconds. G.P.S. clock device is able to provide time outputs in multiple formats such as serial time signal which can be transmitted at every second or minute or hour and these time frames can be standard time signals such as N.M.E.A. frame or customized time signals as per end device requirements. Also, time is transmitted in form of I.R.I.G. time codes format which may be in code A/ B/D/E/G. This format is is analog signal which is amplitude modulated time signal according to mentioned standard as per Inter-Range Instrumentation Group. G.P.S. can also provide Ethernet based time output in N.T.P. protocol. Use of N.T.P. protocol for time synchronization among internet network and other I.P. (Internet Protocol) address capable devices is now widely accepted and is considered as more reliable way of time synchronization every on thousands of kilometres distance.

Apart from above mentioned time output formats, G.P.S. Clock devices from various manufacturers also provide multiple analog outputs of 1 KHz, 10 MHz, 1 MHz signal which are accurately synchronized with respect to P.P.S. signal which are used to synchronize other slave devices clock.

IV. TIME SIGNAL OUTPUT

A. Serial Time N.M.E.A. frame output.

N.M.E.A. frame time output as per Table 1 is standard serial time frame output which provides clock time information with hour, minute, second, date, month and year information. The time information is in U.T.C. (Universal Time Coordinate) format. The N.M.E.A. frame also provides information regarding latitude, longitude and height of G.P.S. receiver device with mean sea level. It also provides information regarding satellite fix or unfix information.

$GPRMC, hhmmss.ss, a, ddmm.mmmm, n, dddmm.mmmm, w, z.z, y.y, ddmmyy,d.d, v, CC<CR><LF>

TABLE 1

$GPRMC	Start of Frame	
Hhmmss.ss	Hh = hours Mm = minutes Ss.ss = seconds	00 to 24 00 to 59 00.00 to 59.99
A	G.P.S. Status	A = Valid V = Invalid
Ddmm.mmmm	Latitude Dd = degrees mm.mmmm = minutes	 00 to 90 00.000 to 59.999
N	Latitude Direction	N = North S = South
Dddmm.mmmm	Longitude Ddd = Degrees mm.mmmm = minutes	 00 to 180 00.000 to 59.9999
W	Longitude Direction	E = East W = West
z.z	Speed over ground (knots)	
y.y	Track made good (referenced to true north)	0.0 to 359.9
d.d	Magnetic variation (degrees)	
V	Variation sense	E = East W = West
CC	Checksum	

B. I.R.I.G.-B time format.

I.R.I.G. output standard is defined by Inter-Range Instrumentation Group. There are multiple I.R.I.G. time code format which are Time Code A, Time Code B, Time Code D, Time Code E, Time Code G and Time Code H [3]. These different time codes provide time outputs in different bit rates. Bit rates refer to a pulse in each word. The time frame and index count of all time codes are different as mentioned in Table 2.

Most of I.R.I.G. time codes such as A, B, provides time information in BCD (Binary Coded Decimal) format with seconds of day information as SBS (Straight Binary Seconds) format. Time codes such as D, E, G and H also provide time information in BCD format.

TABLE 2

I.R.I.G. Time Code	**Time Frame**	**Index Count**
A	0.1 seconds	1 millisecond
B	1 second	10 milliseconds
D	1 hour	1 minute
E	10 seconds	100 milliseconds
G	0.01 seconds	0.1 milliseconds
H	1 minute	1 second

I.R.I.G. time frame indicates the time duration in which complete time code frame is transmitted and Index count is the duration of single pulse in time frame.

I.R.I.G.-B time code output is transmitted at every 1 second with 100 P.P.S. (pulse per second) with each pulse transmitted with 10 ms (milliseconds) period. Each pulse is of 10ms period. There are three types of pulse format. First is the position markers and reference identifier which have duration equal to 8ms in 10ms duration pulse, Second is bit “1” (mark) which is indicated by duration of 5ms in 10ms pulse and third is bit “0” (space) which is indicated by duration of 2ms in 10ms pulse.

I.R.I.G.-B signal frequency is 1 Khz and is amplitude modulated till 9V signal. I.R.I.G.-B signal can be pulse width output or Sine wave with amplitude modulation. The mark to space ratio is 3:1 for I.R.I.G. signals. I.R.I.G.-B time code contains information in 74 bits in which 30 bits information regarding days, hours, minutes and seconds in BCD format, 17 bits for seconds of day and 18 bits for various control functions. Each bit of data is transmitted as pulse of 10 ms duration. If the bit value is 1, it is indicated by mark and bit value is 0, it is indicated by space.

I.R.I.G. outputs are synchronized with 1P.P.S. signal so that time frame of I.R.I.G. output starts with 1P.P.S. signal and completes exactly at the end of that 1P.P.S. signal.

C. Network Time Protocol (N.T.P.) output.

N.T.P. output is Ethernet based output which is transmitted on application layer of IP frame on UDP (User Datagram Packet) packet [4]. The UDP protocol is connectionless protocol for which there is no acknowledgment. G.P.S. clock device act as N.T.P. server which synchronizes the clock of N.T.P. enabled network devices. N.T.P. originated as SN.T.P. (Simple Network Time Protocol) and thereafter version1, 2, 3 and 4 are released. N.T.P. protocol is capable to provide time output in seconds since 1900 in UTC time format and also provide microseconds or milliseconds information. The N.T.P.

client synchronizes its clock drift according to this milliseconds or microseconds resolution in N.T.P. server packet. G.P.S. clock device provides N.T.P. output on the basis of client/server query model or broad cast model. N.T.P. protocol contains various parameters such as mode, version, stratum, poll interval, precision, reference identifier, transmit timestamp, reference timestamp, originate timestamp, and receive timestamp, root delay, dispersion as shown in Figure 1. As G.P.S. Clock device act as N.T.P. server, the mode of N.T.P. output of G.P.S. is always server mode. Version may be 1, 2, 3 or 4 depending on application requirement. G.P.S. Clock device provide time output which are most accurate time source. As a result, G.P.S. clock device act at stratum level 1. Stratum level 0 belongs to atomic clock. Stratum level greater than 2 to 255 is secondary time servers. Reference identifier of G.P.S. Clock device is Global Position System. Precision of G.P.S. Clock device depends on its internal clock precision which is mentioned in terms of seconds. Generally, G.P.S. clock devices are of very high precision. Dispersion is the maximum error in clock with respect to its source. As G.P.S. Clock device is very accurate time source as it get time from satellite data, dispersion is in microseconds. Maximum allowable dispersion of any healthy time source is approx. 1.5 seconds. The dispersion also depends on the delay in time transmission to the client device and is generally verified in N.T.P. client algorithm. Actual clock time information with microseconds or milliseconds resolution is transmitted in transmit timestamp parameter. Timestamps in N.T.P. packet is transmitted in 64 bit data with lower 32 bit data containing time in seconds since 1900 years and upper 32 bit data containing value of fraction of seconds which have resolution in picoseconds. G.P.S. clock device updates its clock time every second at every time information coming from G.P.S. receiver. As a result, reference time stamp of G.P.S. receiver is updated every second.

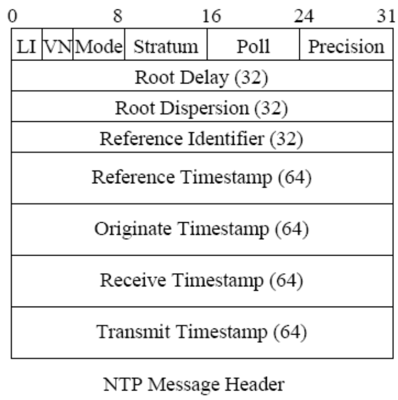

Figure 1. N.T.P. Frame

V. CONCLUSIONS

G.P.S. Clock device plays a vital role in providing time synchronization for various equipments through various time electrical formats which may be serial output, electrical I.R.I.G. TTL or AM(Amplitude modulation) signal, IP based N.T.P. protocol output. G.P.S. Serial Time output can be used for time synchronization of various time display units, equipments accepting serial time frame for time synchronization etc. I.R.I.G. output can be used for time synchronization to devices such RTU (Remote Terminal Unit), Numerical relays, Distribution Control units etc. Time synchronization have become very important in power generation and distribution industries in order to increase the efficiency and to reduce power distribution and generation losses. G.P.S. Clock device time outputs such as I.R.I.G.-AM signal provides the advantage of being transmitted over large distance in few hundred meters without getting signal degraded. If there is requirement of transmitting time output over tens or hundreds of kilometres and also to provide time outputs to multiple number of devices which may be in tens or hundreds from single time source, N.T.P. proves to the cost effective solution. G.P.S. Clock devices can be used to achieve clock calibration at well below nanosecond level [1].

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