Generation of GPS Based Time Signal Outputs for Time Synchronization Application

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Abstract **- Many advanced microprocessor based systems like SCADA system, remote terminal units, protection relays, Sequence of event recorders (SER), digital fault recorders require precise timing for their proper working. In This paper a low cost Global Positioning System (GPS) based time synchronized system with various time signal output like 1 Pulse per Second (1 PPS), National Grid Technical Standard (NGTS) / T format output and National Marine Electronics Associations (NMEA) output is presented. Here T format and NMEA output is transmitted at the interval of one second, whereas NGTS output is transmitted at the interval of one minute. System is directly connected with the satellite through antenna. So it can give precise time from satellite's atomic clock.**

Keywords **– GPS, 1 PPS, NGTS, NMEA, T format.**

I. INTRODUCTION

Time is the dimension by which the event regarding past, present and future can link with each other. It can measure the duration and interval between the two respective events. Measurement of time can be done by two principal elements, the unit - Second, by which we specify the duration of events and reference point - GMT (Greenwich Mean Time is based on observations of the transit of the sun in the sky at midday at Greenwich)). In the history of radio clock, time was synchronized by time code bit stream transmitted by radio transmitter. For standard frequency radio transmission, as frequency is measured in cycle/second, it automatically provide second as a unit of time. With the development of accurate clock based on properties of atom, it was found that world did not rotate at a constant speed. So atomic clock which depend on vibration of atom, were adopted as the standard and UTC (Universal Co-ordinate Time) was established as the world standard.

Nowadays, in electronics equipments precise time is important factor. Precise time can be set by the time synchronization. Time synchronization is technique that enables a time telling device to alter to a correct local time for users. These application include power plant and subsystem automation system, Programmable Logic Controllers (PLC), Sequence of Event Recorders (SER), Digital Fault Recorders, Supervisory Control and Data Acquisition System (SCADA) and Plant Control System and so on [1].

To improve the technology of time synchronization, Global Positioning System (GPS) based time synchronization is best method. GPS has been used for highly accurate time and frequency transfer for more than two decades [2]. The time signal outputs are important factor for synchronizing the internal clock of slave devices using the master clock device. GPS receiver module is an integrated timing module device which provides 1 PPS signal and all necessary information received from satellite [3]. It has been specifically designed for use in synchronization and timing applications. GPS receiver module has an on board programmable NCO (Numerically Controlled Oscillator) that outputs a synthesized frequency up to 10MHz that is steered by the GPS receiver [4]. It has a self-survey mode of operation that allows the receiver to enter a position hold mode to allow accurate timing to be continued with only one satellite being tracked. It can also track satellites and provide GPS synchronization in weak signal area.

With the use of GPS Receiver Module, precise timing accuracy can be obtained using T- RAIM Algorithm. This algorithm serves as a function for monitoring residuals from time-only solutions. Due to that the receiver can track more satellites in parallel, redundant measurements can be made. These redundant measurements can affect the accuracy of the solution. The algorithm reduces bad measurements from the solution. The measurement is rejected if the value exceeds the alarm threshold level [3].

The GPS receiver provides position, velocity, time and satellite tracking status information via a serial port. It has a bunch of twelve parallel channels for tracking 12 satellites simultaneously. The module receives the L1 GPS signal (1575.42 MHz) from the antenna and operates on of the coarse/acquisition (C/A) code tracking [3]. Every GPS receiver input command has a corresponding response message so that the user can determine whether the input commands have been accepted or rejected by the GPS receiver. Input and output data fields contain binary data that can be interpreted as scaled floating point or integer data. Input command messages can be stacked into the GPS receiver input buffer, up to the depth of the message buffer. The GPS receiver will operate on all full messages received and will process them in the order they are received. Previously scheduled messages may be output before the responses to the new input commands.

The brief introduction of method of time synchronization using GPS receiver module is given in Section I. Introduction about the various time signal outputs is given in Section II. Information regarding experimental setup for the objective is given in Section III. Test results and its detail discussion is presented in Section IV. The conclusion of the objective is given in Section V.

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II. TIME SIGNAL OUTPUT

The time signal outputs are important factor for synchronizing the internal clock of slave devices using the master clock device. There are three types of time signal output is generated, which is defined as one pulse per second (1 PPS), two Serial Communication outputs in which a fixed serial port provides NMEA format data and configurable serial port contain NGTS or T- format output.

A. One Pulse per Second (1 PPS) Output

Many GPS receivers provide a timing pulse which is known as One Pulse per Second. This pulse normally has a rising edge aligned with the GPS second, and can be used to discipline local clocks to maintain precise synchronization with UTC. 1 PPS signal is the TTL level pulse with a width of 200ms isolated output coming from the GPS receiver. The rising edge of the 1PPS signal is considered as the time reference. The falling edge will occur approximately 200 ms (±1ms) after the rising edge.

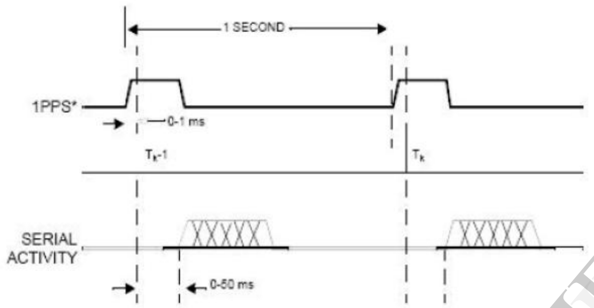

Fig. 1 PPS Output Signal Timing [5]

The falling edge will not be used for accurate time keeping. A simple timing diagram of 1PPS output signal timing is shown in Fig. 1. The Position, Status, Data message and time RAIM setup are the only output messages containing the time information. After the rising edge of 1 PPS signal, these message will be output from the receiver shortly. Generally the first data byte in the first message will be output between 0 to 50 ms after the rising edge of 1 PPS signal as shown in Fig. 1. The position, status and data message will be reflected at the output port after the first data byte.

B. Serial Communication Outputs

Serial Communication Output is divided into two parts. One is NMEA frame Output (Fixed Serial Port) and another is NGTS (At the interval of One minute) or T format (At the interval of One second) frame output (Configurable Serial Port). The National Marine Electronics Associations (NMEA) has developed a specification which defines the interface between various pieces of marine electronic equipment. Basically GPS communication receiver is defined within this specification. Most programs that provide real time position information to be in NMEA format. This Data includes the complete position, velocity and time solution computed by the GPS Receiver. NMEA frame contain a line of data called sentence which is totally independent from the other sentences. All standard sentences have a two letter prefix that defines the device that uses that sentence type (e.g. for GPS receiver prefix is GP) followed by a three letter sequence that defines the sentence contents. Each Sentence starts with a `$' and ends with a carriage return/line feed sequence [6]. The full data message of this format shall consist of data fields as given in TABLE I.

NGTS format is transmitted at an interval of every 1 minute. The settings for this format are programmable. The full data message of NGTS format shall consist of 14 printable characters and concluding CRLF as given in TABLE II.

TABLE I
RMC RECORD FORMAT

Field	Example	Comments
Sentence ID	$GPRMC,	-
UTC Time	130525.00	hhmmss.ss
Status	A,	A=Valid, V=Invalid
Latitude	4250.5589	ddmm.mmmm
N/S Indicator	N	N=North,S=South
Longitude	E	E=east=west
Speed Over Ground	008.9	Knots
Course Over Ground	279.2	Degrees
UTC Date	291206,	DDMMYY
Magnetic Variation	,	Degrees
Magnetic Variation	,	E=East, W=west
Checksum	*25	*CC
Terminator	<Cr> <LF>	Non Printing Characters

TABLE II
NGTS FRAME FORMAT

Description	Number Of characters	Character Position	Ranges
Code Identification	1	1	T
Year In Century	2	2,3	0 to 99
Month	2	4,5	1 to 12
Day Of Month	2	6,7	1 to 31
Day Of Week	1	8	1 to 7
Hours	2	9,10	0 to 23

Minutes	2	11,12	0 to 59
GMT Marker	1	13	0 or 1
Validity Marker	1	14	0 or 1
CRLF	2	15,16	Non Printing Character

T Format is transmitted at an interval of every 1 second. The setting for this format is programmable. The full data message of T format shall consist of 21 printable characters with a concluding CRLF as given in TABLE III.

TABLE III
T FRAME FORMAT

Description	Number Of Character	Character Position	Ranges
Code Identification	1	1	T
Divider	1	2	:
Year In Century	2	3,4	0 to 99
Divider	1	5	:
Month	2	6,7	1 to 12
Divider	1	8	:
Day Of Month	2	9,10	1 to 31
Divider	1	11	:
Day Of Week	1	12	1 to 7
Divider	1	13	:
Hours	2	14,15	0 to 23
Divider	1	16	:
Minutes	2	17,18	0 to 59
Divider	1	19	:
Seconds	2	20,21	0 to 59
Divider	1	22	:
GMT Marker	1	23	0 or 1
Validity Marker	1	24	0 or 1
CRLF	2	25,26	Non Printing Character

III. EXPERIMENTAL SETUP

This section describes hardware configuration of experiment and method of capturing necessary information from binary frame received from GPS receiver, convert it various time signal output and transmit it. Fig. 2 illustrates the overall scheme for generation of GPS based time signal output for time synchronization application. The in use GPS receiver provides hardware synchronized 1 PPS output. According to the rising and falling of this pulse, the time related data is transmitted inform of binary message from GPS receiver via USART interface. As microcontroller receives the binary message packet, it starts to decode time, velocity and position related information from binary packet. Simultaneously microcontroller makes the packet for the NMEA frame and NGTS/T format frame. After preparing the NMEA and NGTS/T frame packets, microcontroller transmits NMEA frame as per the serial interrupt arrived and NGTS/T format frame as per the external interrupt arrived via USART interface. The 1 PPS pulse is directly transmitted via termination block and it can observed onto the CRO.

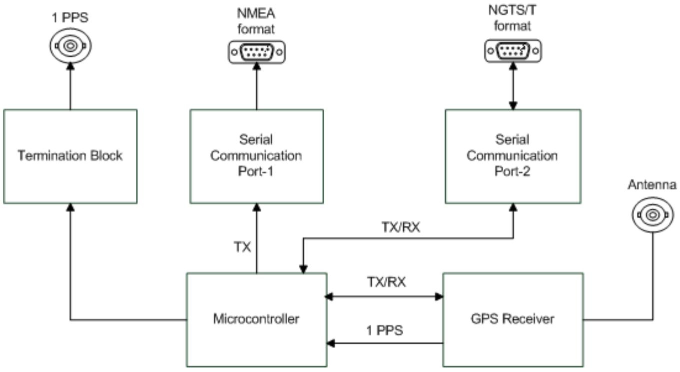

Fig. 2 Overall Hardware Level Structure

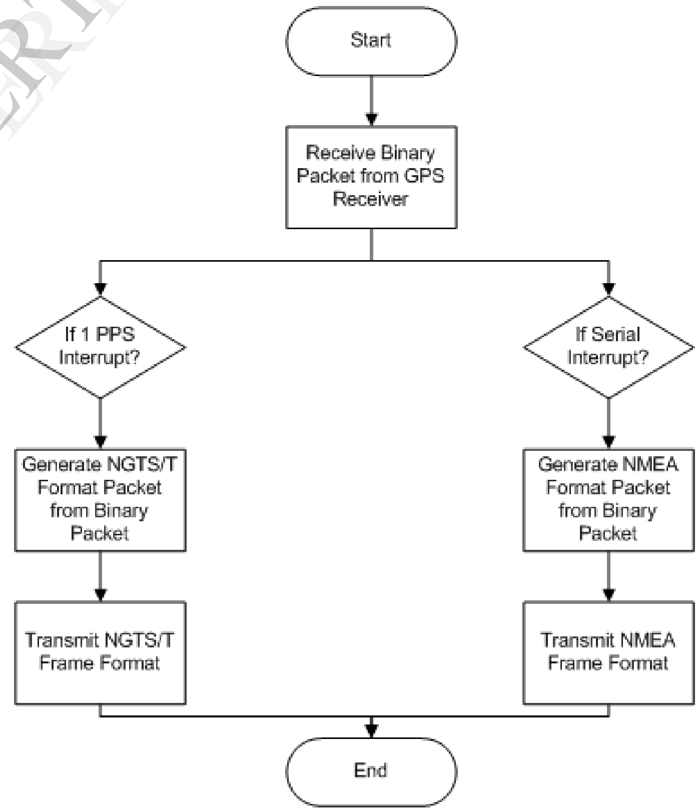

Fig. 3 Overall Software Level Flow Diagram

The Implemented algorithm for the objective is shown in Fig.3. It consists of two main subroutines for the interrupt as 1 PPS external Interrupt and serial interrupt. At the initial stage of flow diagram, Binary Packet is received from GPS receiver. As 1 PPS interrupt or serial interrupt is received, NGTS/T frame packet or NMEA frame packet is generated accordingly. Here T frame format and NMEA frame format is transmitted at the interval of 1 second, whereas NGTS frame format is transmitted at the interval of 1 minute.

IV. TEST RESULTS AND DISCUSSION

For testing the experimental setup, all time signal frame is received onto the hyper terminal and 1 PPS signal is observed onto the CRO (Fig.8). Here in the first screenshot (Fig.4), Binary frame is received which is transmitting from the receiver at the interval of 1 second. This binary frame gives the information of time, velocity, position and no. of satellites available coming from the satellite. As shown in Fig. 4, after message start characters (@@Eq) first six characters gives the information regarding date and time. After that information for latitude and longitude comes. In the binary message character no. 72 is used for position fix identification. Here '2' indicates 3-D fix position of satellites (GPS locked). In the binary message frame, 79th and 80th characters indicate no. of satellites available for fixing the position. In the second screenshot (Fig.5), NMEA frame is observed which is transmitted at the interval of 1 second on one of the UART terminal. This NMEA frame is generated from the microcontroller. NMEA frame is also gives the information of time, velocity, position in form of latitude and longitude and GPS lock/unlock information. As shown in Fig. 5, after the Sentence Id ($GPRMC), first six characters gives the information regarding time. In the information of time second is indicated in form of fractions. After time field, position fix field comes. Here character 'A' indicates 3-D fix position (GPS locked). After that information regarding latitude, longitude and velocity is comes. Then field for date is comes in the frame (indicated as labeled date in Fig. 5). Frame will be ended with checksum, carriage return and line feed accordingly.

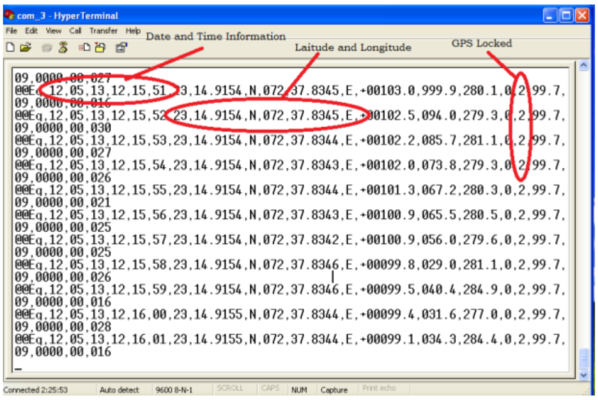

Fig. 4 Binary Frame Format (At Interval of 1 Second)

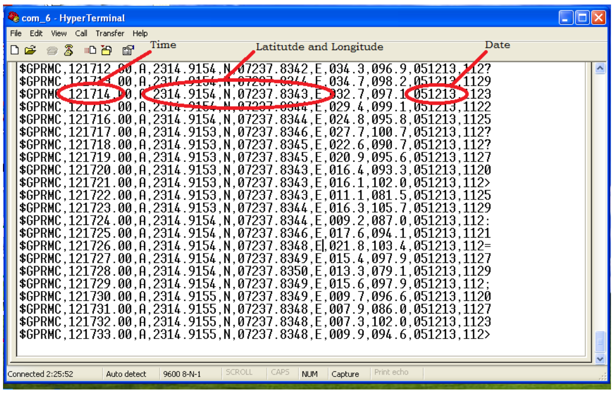

Fig. 5 NMEA Frame Format (At Interval of 1 Second)

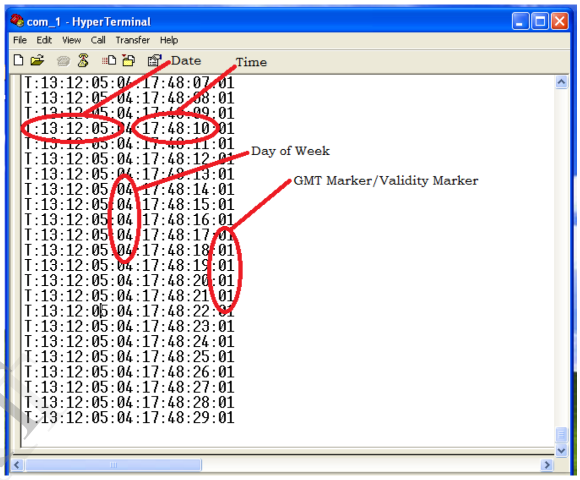

Fig. 6 T - Frame Format (At Interval of 1 Second)

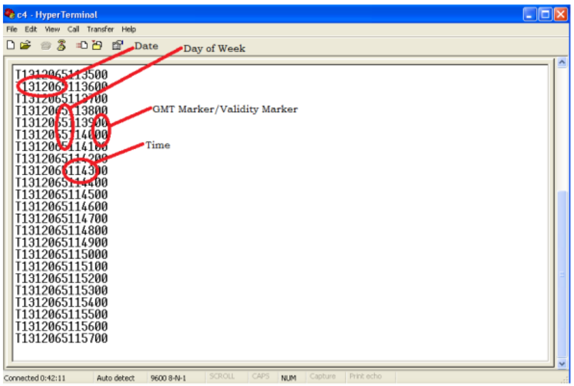

Fig. 7 NGTS Frame Format (At Interval of 1 Minute)

Fig. 8 One PPS Time Signal output

In third and fourth screenshot (fig.6 and Fig.7), T format frame and NGTS format frame is observed which is transmitted at the interval of 1 second and 1 minute respectively. Both configurable serial frame starts with the identification character 'T'. For both the frames first six characters gives the information regarding Date (Excluding divider for T frame format). Then day of week comes (Consider Monday as the first day of the week). After day of week information, field for time comes. Last two characters of both the frames gives the information regarding GMT marker and validity marker. GMT marker is used for time zone information. Here '1' indicates as time zone field is added and '0' indicates as time zone field is not added. Validity marker gives the information regarding GPS lock/unlock information.

V. CONCLUSION

The low cost GPS based time synchronized system with various time signals is presented here. Time precision can be varied from 1 second to 1 minute according to the application based on advanced microprocessor systems described in paper. As GPS satellite signal are utilized for synchronization, precise timing accuracy can obtain in every time signal output. Here one of the output mentioned as 1 PPS can be used as the time reference for synchronized another slave devices. By extending the same design, time precision can be achieved in form of millisecond using NTP and IRIG-B algorithms.

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