GPS Receivers
for
Navigation and Timing Applications

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ABSTRACT

GPS receivers for navigation and timing applications are being developed and used extensively in India by various governmental and private organizations/ industries. M/s Accord software has done a pioneering in this direction. The present paper deals with the development carried out M/s Accord software.

Accord – an ISO9000-2000 certified company- is primarily involved in the development of hardware and software for several of Aerospace applications and real time embedded systems.

INTRODUCTION

Accord has created an array of GPS-related products in the areas of Navigation and Timing. Based on the research carried out over the past decade, Accord has developed indigenous technologies to address the need of the industry. Accord's patented technologies are now available in the form of different products. The rest of the paper describes some of Accord's products in brief.

Accord's GPS for Space Application

Accord has a GPS receiver product line for Space Applications. They have been customized to meet the requirements of Indian Space Research Organization's Low Earth Orbit satellites. The following GPS receiver based Satellite Positioning Systems are successfully delivered to ISRO

Accord has designed and developed an eight channel high dynamics GPS receiver (RCE) and Spacecraft Interface Module (SIM) for IRS P4 satellite

Accord has modified the Spacecraft Interface Module with a HWDT and a limited data validation logic to cater for the radiation effects for the TES satellite, in addition to the GPS receiver.

Accord has further developed a GPS receiver with MIL 1553B interface with added feature of HWDT. The SIM card is further upgraded with extensive data validation logic of SWDT. This is for P5 and P6 satellites.

Accord is currently developing a ten channel high dynamics GPS receiver with MIL1553B interface using UTMC chips. This FPGA-based approach is likely to render better accuracies, higher number of channels and improved TTFF performances.

The technical challenges associated with the GPS receivers for Space applications include,

High Dynamics: The receiver has to function normally under very high dynamics, such as 8 km/s. At this dynamics the receiver has to meet the Time To First Fix performance and sensitivity performance, which is a challenge.

Satellite Acquisition: High Dynamics also causes a very large Doppler shift, thereby the GPS signal is offset from its nominal frequency by a large amount. GPS signal acquisition scheme has to search a much larger frequency range to acquire and track the signal.

Stringent Environment: The receiver has to work under very stringent environmental conditions. This include temperature cycle, vibration levels, radiation levels, EMI/EMC requirements, dynamics etc.

Special Interfaces: Appropriate interfaces with the on-board system. The interface include RS-422, ARINC, MIL 1553B, Biphase telemetry etc.

Satellite Positioning System (SPS), which consists of an on-board high dynamics GPS receiver gives sustained operation at high dynamics of satellite. It has inbuilt monitoring scheme comprising the independent watchdog timers for each of processors and algorithm for the navigation processor output parameters validation. Status information comprising the health of the system, total number of resets and the reason for malfunction are continuously posted to the ground station. Any malfunction of the system is detected with monitoring system and the recovery sequence will be

initiated by the monitoring system. Also, additional logics are in-built such that during maneuvering, the loss of position, if any, is limited for a short duration.

Operation mode of the SPS can be controlled with the ground station tele-commands or through MIL1553B bus from the onboard computer. The system has the onboard data storage facility, which can be downloaded when the satellite is visible. Interface and the storage related issues are implemented in Spacecraft interface Module (SIM)

SPS system allows multiplexing so that any one of the dual onboard systems can be selected using the ground commands. Mechanical, environmental and electrical issues relating to high dynamics are considered in the system design to give superior performance in on-orbit scenario.

Figure 1 shows Accord's satellite positioning system for TES

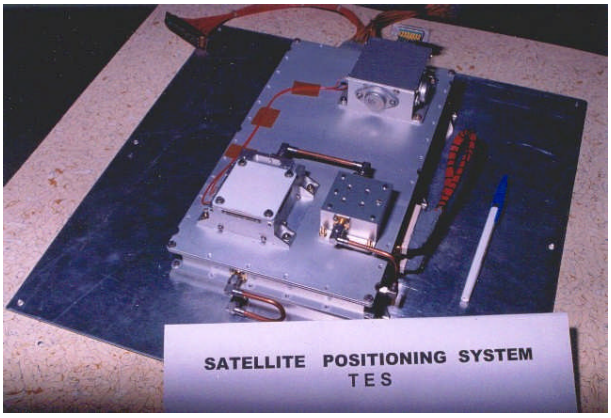

Figure 1: Satellite positioning system for TES

The following gives a brief specification of Accord's GPS receiver on-board satellite

Description	**Technical Specification**
No of channels	8
Receiver Mask angle	+/- 85 deg from Zenith
Carrier Doppler frequency (MAX)	+ / - 64KHz
Doppler Rate	70 Hz / sec
Jerk	2 g / s
System Storage Memory Capacity	2 Orbit Data
TTFF: Cold Start	100 s (typical)
Position Accuracy (Without SA)	15 m (1 sigma)
Velocity accuracy – (Without SA)	0.15 m/s (1 sigma)
Position solution mode	3D
Position update rate	1 Hz
Watch-dog timer for SIM and RCE processor with disable provision through Tele-command	Yes
Processor Reset Provision through Pulse Command	Yes
Provision for Pitch (+/- 45 deg) and Roll (+/- 26 deg) maneuver inputs to SPS through pulse commands on SIMCARD	Yes
Provision for RAIM	Yes
Provision for Monitoring the SPS command status in RT/ PB / HK outputs	Yes
Provision for RCE reset counter (This is used to count the number of RCE resets) Provision for SIM hour counter (This counter is used to tell when SIM was last reset)	Yes
Provision For SIM reset counter in RCE (updated upon SIM reset)	Yes
Hardware Watchdog timer availability for SIMCARD	Yes
RCE should be capable of accepting and Transmitting the Mil-1553B messages.	Yes
Storage of ephemeris in SIMACARD as a part of PB-buffer.	Yes
Provision of Hardware watch dog timer in RCE	Yes
Provision of Data validation logic in SIM for RCE	Yes
Operating temperature (Thermovac)	-10 to +55 degrees C
Storage temperature	-40 to +85 degrees C

Accord's GPS for Aerospace Applications

Accord has developed a GPS-WAAS Receiver for aerospace application. It is compatible with other Satellite Based Augmentation Systems (SBAS) including EGNOS, MSAS and GAGAN. It is developed around a Digital Signal Processor with optimum usage of hardware and software in the system. The receiver architecture is designed in such a way as to engineer it for avionics application after FAA certification for TSO in the En-route, Terminal and Non-precision Approach mode of operations.

The important aspects of the receiver is reliable hardware and added safety features. The failure analysis of the receiver hardware for various navigation functionalities as per ARP4761 shows acceptable performance. The power-on self test and continuous online tests to detect hardware failure enhances the

safety and reliability of usage of the equipment. Additional hardware to detect failure improves the test coverage of the equipment. The receiver accuracy, acquisition and tracking sensitivity, dynamics, time-to-first-fix and other characteristics meet the required performance specifications outlined in DO-229B as well as DO-208 for en-route, terminal, non-precision approach.. The receiver software is engineered as per DO-178B and eventually certified to make the system usable in en-route, terminal and non-precision approach applications in an aircraft.

Figure 2 shows Accord's GPS receiver for aerospace applications for en-route, terminal and non-precision mode of operations.

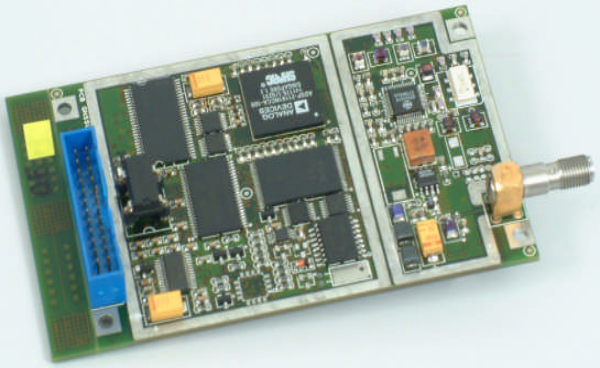

Figure 2: GPS Receiver for Aerospace applications

The following table shows some of the performance characteristics of this receiver.

Parameter	**Receiver Specification**
Type	C/A code Sensor with WAAS capability
Conformity	RTCA-DO-229C RTCA-DO-228 RTCA-DO-178B, Level B RTCA-DO-160D ARINC 743A
Certification (intended)	Beta Class 1: LNAV
No of channels	Total: 12 (GPS: 10 WAAS: 2)
Horizontal (SA off)	15 m (95%) without SA
Horizontal (Differential)	2 m (95%)
Synchronized to either GPS or UTC (SA off)	150 ns
Acquisition	-135 dBm (GPS)
Tracking	-138 dBm (GPS)
Update rate	1 Hz
RAIM	FD and FDE in absence of WAAS integrity WAAS integrity, if available All as per DO-229C
MTBF	50000 Hours
BITE	Power-on Self Test and Online BITE
RS-232	2
Message format	Messages as per ARINC 743a
Software and Magnetic Variation upgrade	Through serial port without removing the GPS card
Environmental characteristics	As per DO-160D at the Card Level

Accord's GPS for Automotive Applications

Accord has partnered with Analog Devices Inc., USA, to develop GPS receiver chipset for the automotive and hand-held market segment. Accord's research in the GPS area were primarily driven by this goal over the past decade. Accord has created several reference designs suitable for automotive applications and have done technology transfer of those design to various OEMs in India and far east.

Some of the reference designs created by Accord for Automotive segment are

NAV2100	NAV2300
NAV2300LP	NAV2300R
NAV2400	NAV2500

NAV2400 and NAV2500 are the latest offerings from Accord. NAV2400 has a low-gate-count accelerator to expedite the signal acquisition and tracking and at a very low signal strength. This reference design is also used to develop algorithms to acquire and track GPS signals indoor or under foliage environment at less than –150 dBm.

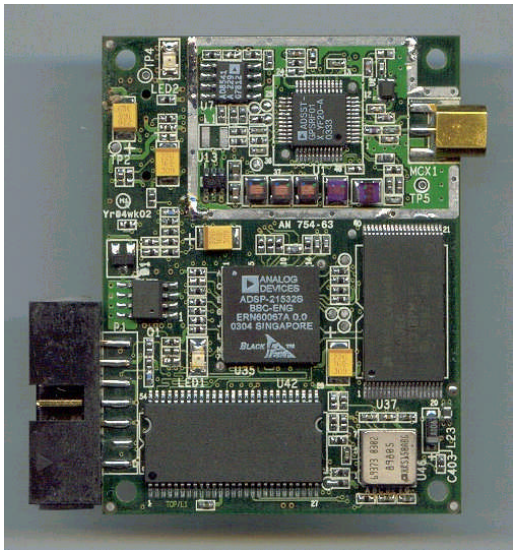

Figure 3: NAV2500 : GPS for Automotive applications

Figure 3 shows NAV2500 - Accord's GPS receiver for Automotive applications

NAV2500 is a Blackfin based reference design, which is now integrated with an on-board solid stage Gyroscope to derive a GPS-DR integrated solution. It is further integrated with GSM and car telematics to arrive at an Integrated Car Telematics System.

The following are some of the important specifications of the NAV2500 receiver.

Description	**Technical Specifications**
Receiver	12 channel L1 C/A code
TTFF	Hot start: 12 sec Warm start: 40 sec Cold start: 65 sec
Accuracy	Position: 10 m (90%) Velocity: 0.1 m (90%)
Reacquisition time	< 1 sec for less than 3 min blockage
DR performance	3% to 5% error of distance traveled up to 1 km

The advantages of this software-based correlator are

- to continuously improve the receiver's accuracy and availability characteristics without always having to invest in new hardware development and/or customization of silicon
- to make the complete GPS receiver function available as a library on a family of instruction-set-compatible programmable DSPs from Analog Devices so that reference designs can be created for a wide variety of GPS applications by integrating the GPS receiver library with other communication and multimedia programs
- to achieve scalable performance characteristics by exploiting the availability of faster DSPs with lower power consumption
- to make the base band processing architecture independent of the RF down converter architecture
- to make the software available on both floating point as well as fixed point families of DSPs from Analog Devices, so that system developers / integrators have a wider range of DSPs to choose from.

Accord's GPS for Fleet Management Applications

Accord has indigenously developed a Fleet Management System called eZfleet. The components of eZfleet are,

- Mobile Units (MU) or in-vehicle equipment
- Fleet management server at the control station (CS)
- Web based User terminal

CS and MUs communicate through the GSM network.

The overall architecture of the eZfleet is as shown in Figure 4

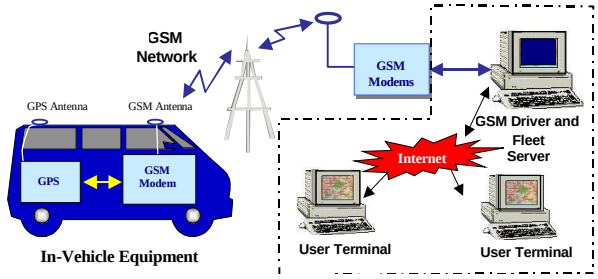

Figure 4: eZfleet components

GPS RECEIVER

The MU is built with Accord's NAV2300R GPS receiver. The highlights of the GPS receiver are its low cost, small form factor, and higher sensitivity. These advantages along with its lower power consumption make it ideal for vehicle tracking applications.

EMBEDDED FLEET MANAGEMENT FIRMWARE

The fleet management firmware is embedded on the GPS core using the Unique Programmatic interface provided by the GPS receiver chipset. The hardware and software resources of the GPS chipset are shared along with the application. This avoids usage of additional hardware in the MU required for the Fleet Management Application thus reducing the associated cost.

CONTROL STATION

Fleet Server runs at the control station and communicates with the vehicles in the fleet through GSM Driver.

The CS comprises of two software components, namely GSM driver and User terminal.

In the User terminal, the web-based interface is implemented on Java technology. The GSM driver and the Fleet Server are implemented in Microsoft® VC++.

Figure 5 shows the plot of a trial conducted from Bangalore (southern region) to Delhi (northern region). The trip covered a total of 6000 kilometers. The MU

was configured for an update every one hour. The Coverage of GSM is poor in the northern regions.

Figure 5: eZfleet field trials from Bangalore to Delhi

Accord's GPS for Survey, Attitude Determination Applications

Accord has developed the technology (patent pending) for a high accuracy carrier phase GPS receiver for survey and attitude determination applications.

The basic characteristics for the RF front-end for High Accuracy GPS are,

High IF bandwidth for sharper correlation function. The current version uses 8 MHz RF bandwidth

High sampling frequency to utilize the IF bandwidth and also to prevent aliasing. The current version uses 22.5 MHz sampling frequency

More than single bit digitzed signal. The current version uses 2-bits.

The high accuracy GPS uses a novel technique, in which it exploits the asymmetry of the correlation function and relates it to the amount of multipath error.

The following gives the technical specifications of the high accuracy GPS receiver.

Description	**Technical Specification**
Type	GPS L1 C/A code receiver
No of channels	12 channels
Architecture	Digital Signal Processor with FPGA and RF Front-end
Horizontal (SA off)	10 m (95%) without SA
Horizontal (Differential)	1 m (95%)
Pseudorange receiver noise	20 cm (RMS) at nominal signal strength (-130 dBm)
Carrier phase noise	1 cm (RMS) at nominal signal strength (-130 dBm)
Acquisition	-135 dBm
Tracking	-138 dBm
Update rate	10 Hz

Figure 6 shows a plot of position error using this receiver due to receiver noise only and in the non-smooth mode of operation.

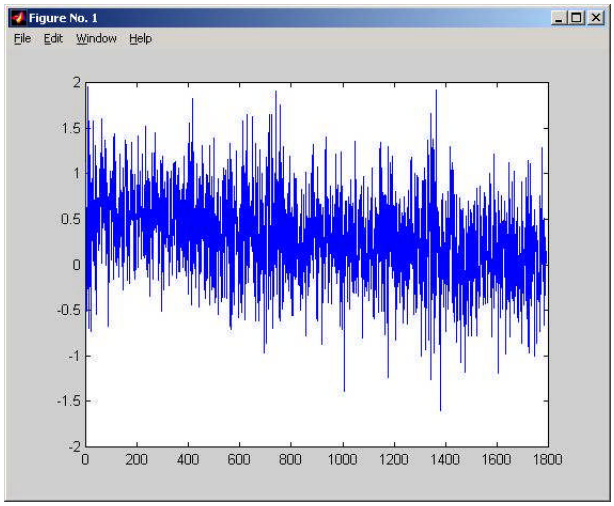

Figure 6: Position error (north-south)

Accord's Timing Receivers

Accord has developed GPS time source built around Accord's GPS receiver. In absence of GPS signal, the unit continues to provide 1 PPS signal and maintains the GPS time within 20 microsecond accuracy for at least 4 hours.

The unit generates a 1 PPS signal from an internal high stability clock and synchronizes with the 1 PPS signal output from the GPS receiver.

The Unit is specifically designed to mee the requirements of timing and synchronization applications.

The following shows the specifications of the timing source:

Description	**Technical Specification**
Receiver	12 channel L1 C/A code GPS
Accuracy	100 ns (typical)
1 PPS characteristics	Pulse width: 5 msec Level: TTL Rise time: 10 nsec
Power supply voltage	28 Vdc with option for AC supply source
EMI/EMC	Protected
Interface	IRIG
Customization	The unit can be customized as per customer's needs

Figure 7 shows Accord's GPS clock.

Figure 7: Accord's GPS Clock

Conclusions

Accord has created several GPS based products, which are now well accepted by the industry. Accord plans to continue building products for the industry and upgrade the products in tune with the modernization plans of GPS and Galileo.

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