NAV2300 – Accord's High Performance Low Cost Receiver Technology with Soft-Correlator™ and Programmatic Interface

M R Shenoy, Murali Krishna S, Sudhir N.S, Anjan R, Kiran S

Accord Software & Systems Private Limited
Bangalore, India

BIOGRAPHY

M.R. Shenoy is the Program Manager for GPS related research and development at Accord. He has a B.E. in Electronics and Communications from the Bangalore University and M.E. in Integrated Circuits from the Indian Institute of Technology, Madras. He has been involved in GPS research since 1992.

Murali Krishna Srikantiah is the principal architect and designer of algorithms for Accord's GPS solutions and has been with Accord for seven years. He has a Master of Technology degree in Electronic Design from the Indian Institute of Science, Bangalore.

Sudhir Narve Shankaramurthy is a senior developer of hardware and software for the NAV2300 GPS reference design and a key contributor of algorithms. He has been working with Accord for the last four years after his Bachelor of Enginering degree in Electronics and communications from the Bangalore University.

Anjan Ramakrishnan is a senior developer of RF circuits and DSP algorithms for the GPS solutions from Accord. He has been working with Accord for the last four years after his Bachelor of Engineering in Electronics and communications from the Bangalore University.

Kiran Shivaram is a senior developer of software and DSP algorithms for the NAV2300 solution. He has been working with Accord for the last four years after his Bachelor of Engineering degree in Electronics and communications from the Bangalore University.

ABSTRACT

This paper introduces NAV2300, a 12 channel and single frequency C/A code GPS receiver. Latest addition to the NAV2K™ family of solutions, the receiver core is realized around a single programmable fixed-point Digital Signal Processor (DSP) microcomputer from Analog Devices. The receiver is based on a unique Soft-Correlator™ architecture, which allows the complete GPS signal processing as well as navigation processing functions to be implemented on a single programmable fixed point DSP. This flexible implementation lends itself naturally for interfacing with any standard RF front end. It has all the advantages associated with a software solution, such as scalability, upgradeability etc. The low cost, high performance DSP microcomputer totally eliminates the necessity of a microcontroller, usually required by conventional receiver architectures. The solution includes a Programmatic Interface to the NAV2300 Core, which facilitates the OEMs to embed their own applications on the NAV2300 core along with the GPS function.

INTRODUCTION

Accord is an Independent Algorithm Vendor (IAV) to Analog Devices, Inc. Accord is a Bangalore, India based company specializing in the development of DSP based algorithms, software and hardware. The idea to develop a complete GPS receiver core using a single programmable DSP was driven by the need to effectively address the demands of the emerging applications in the fields of personal navigation, automatic vehicle location (AVL) and traffic telematics. Every new application conceived in these fields invariably involves the integration of GPS sensor technology with one or more of the technologies from among cellular telephony, hands free telephony, data modems, speech recognition, speech synthesis, audio/video compression, internet access etc. The availability of most of these other technologies from IAVs on the general purpose ADSP218x platform from Analog Devices with superlative throughputs and ever improving performance benefits enables new innovative applications incorporating multiple technologies to achieve quick time to market.

The NAV2300 has been designed to make seamless integration of multiple technologies feasible without any compromise in performance levels and without the need for customizing silicon.

To make complete exploitation of the software solution easy, the NAV2300 has been designed to include:

1. flexible software architecture with a programmatic interface
2. scalable architecture to translate the advances in the DSP core technology into performance benefits
3. optimize power consumption
4. dynamic mobilization of computing resources to sustain GPS sensor performance under adverse signal conditions

ARCHITECTURE

The NAV2300 GPS receiver is a highly integrated design comprising of two principal blocks (figure 1):

1. RF Down Converter
2. GPS Signal Processor

NAV2300 GPS receiver makes use of any standard RF down converter. The front end is typically a two/three stage superheterodyne receiver with an image rejecting front end and a fully integrated VCO. For handheld applications with passive antenna configurations, an RF front end with an integrated low noise amplifier (LNA) is preferable, but an external LNA also can be used if necessary. The down converter derives the sampling frequencies from the DSP and the resulting quantized signals are fed to the DSP which does all the signal processing and navigation processing.

The DSP also interfaces with low cost non-volatile memory and Real Time Clock to improve the TTFF in the presence of primary estimates. The Serial communication is established by dedicated serial ports of the DSP, one of which is configured to accept the RTCM corrections for generation of differentially aided position fixes.

DSP Microcomputer

The GPS Signal Processor is the ADSSTNAV2300, a programmable DSP based on the ADSP218x core, a 16-bit fixed-point microcomputer from Analog Devices which is optimized for digital signal processing and high speed numeric processing. At 75 MIPS sustained performance and a variable voltage operation from a high of 3.3 volts to a low of 2.5 volts, it is ideally suited for high performance, low power GPS signal acquisition, tracking and navigation processing.

The DSP comes in a 100-pin TQFP package and consumes just 1.1875mW/MHz of power internally at 2.5 volts supply voltage, which means delivering 75 powerful DSP MIPS for just 89mW.

192 Kbytes of on-chip SRAM, which is configured for the GPS function as a combination of 32K words of 24 bit program memory and 48K words of 16 bit data memory, eliminates the necessity of any external SRAM on the board.

Ample number of interrupts and programmable I/Os available on the DSP take care of the various signaling and time-critical tasks and facilitate the realization of a complete receiver core engine complete with the serial I/Os and time outputs with no external glue logic.

The different low power modes available on the DSP make it easy to implement power saving GPS algorithms for handheld applications without compromising on the throughput.

The DMA ports of the processor interface with peripherals and exchange data in the background, all happening while the core functions of GPS run at full speed in the foreground.

The NAV2300 software solution is source code compatible with the future generations of the fixed point family of DSPs from Analog Devices, which means that there is virtually no limit for the possibility of delivering improved GPS sensor performance at lower cost, size and power.

FLEXIBLE SOFTWARE ARCHITECTURE

The Software Architecture of the NAV2300 GPS Receiver is designed around a few hardware interrupt service tasks, which attend to time critical events, and timer based periodic and deterministic tasks which are invoked by a Scheduler.

The receiver software has the following types of tasks:

1. Initialization tasks
2. Interrupt tasks
3. Periodically invoked tasks

Initialization tasks are invoked once on power up/reset. These tasks initialize the receiver hardware and software and perform the built in Self-test and calibration functions.

Interrupt tasks gain control of the DSP asynchronously, anytime after the software is initialized by the Initialization tasks. They are activated by hardware events.

Periodically invoked tasks are invoked at predefined intervals.

The functional decomposition of the NAV2300 software is depicted in the figure 2:

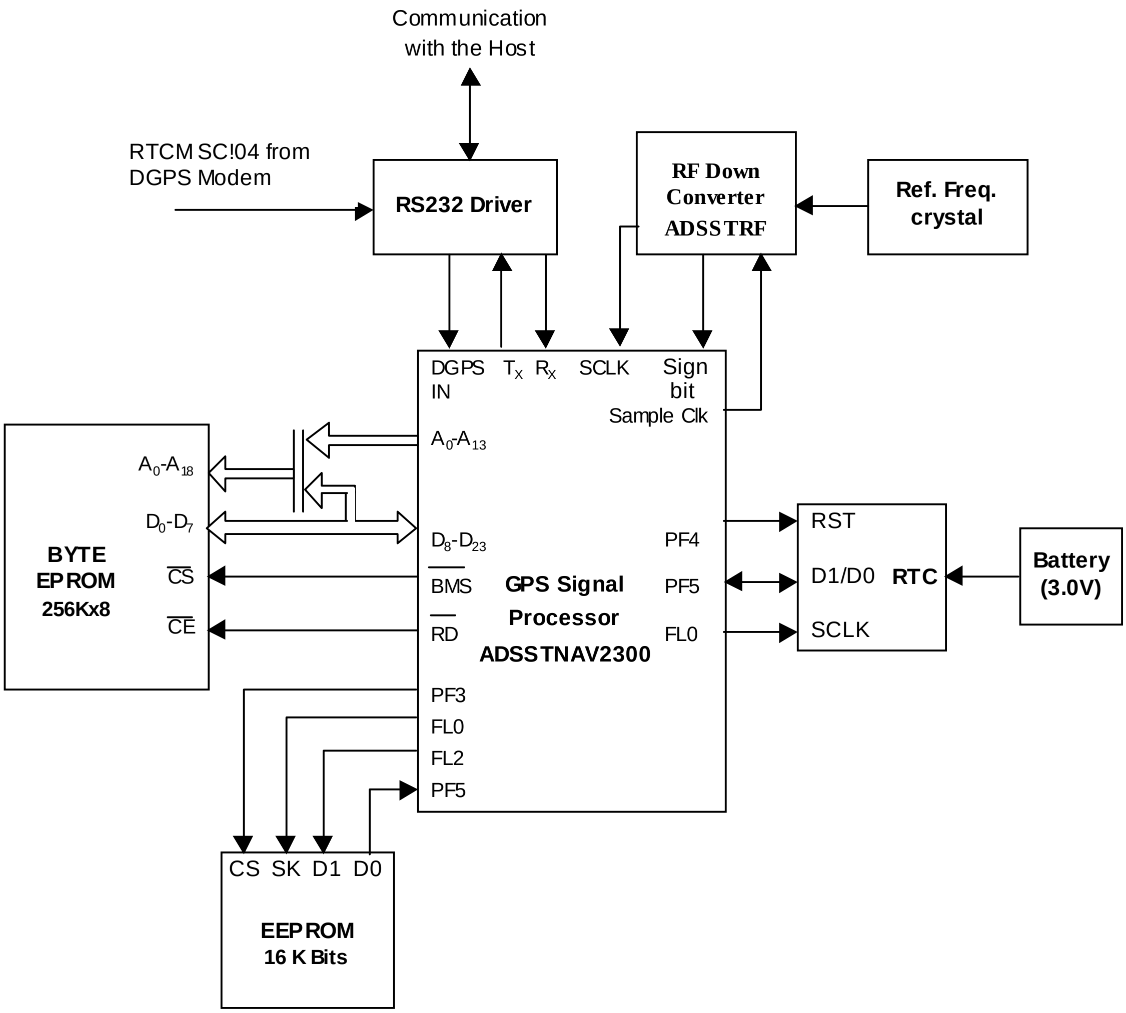

Figure 1 Receiver Architecture

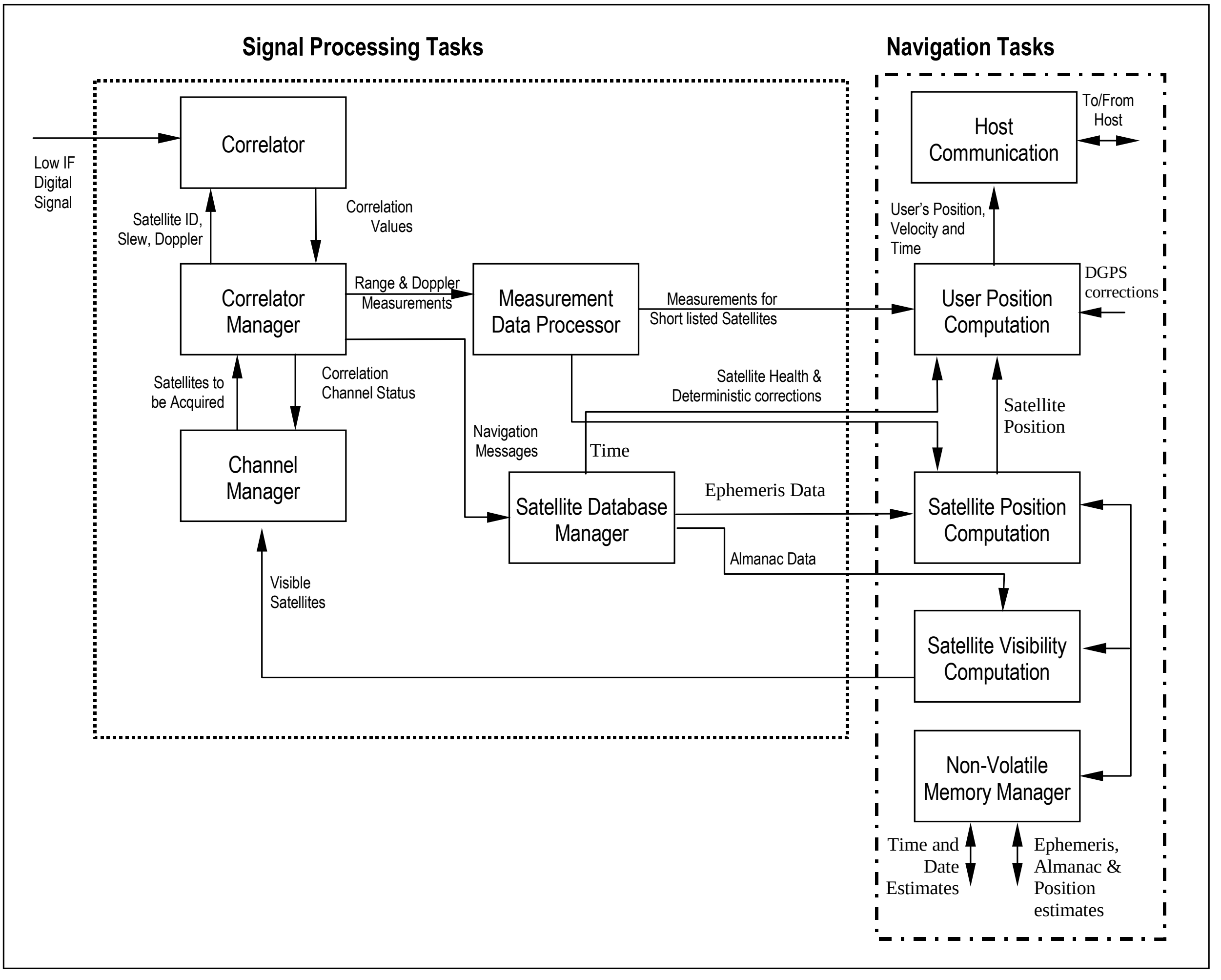

Figure 2 Functional Constituents of NAV2300

The functional components of the software are grouped under two categories:

1. Signal Processing tasks
2. Navigation tasks

Signal Processing tasks

The signal processing tasks are executed typically in response to high priority, high frequency interrupts and are predominantly intensive users of the DSP instruction set.

These tasks include:

1. Correlator which acquires and tracks signals from up to 12 satellites simultaneously, gives the Correlation values as output every millisecond
2. Correlator Manager which controls and monitors the channels of the Correlator, carries out Range and Doppler measurements and extracts navigation messages
3. Satellite Database Manager which maintains the database of navigation messages in the receiver
4. Channel Manager which assigns appropriate satellites to all the channels of the Correlator for acquisition
5. Measurements Data Processor which filters the Pseudorange and Doppler measurements for all tracking satellites and validates the measurement data for use in the navigation solution

Navigation tasks

These tasks are executed in response to less frequent but periodic events and some of these are floating point computation intensive. These include:

1. User Position Estimation Module which estimates the accurate position, velocity and time

2. Satellite Visibility Computation and Satellite Selection Module which computes the list of visible satellites based on the estimates available
3. Satellite Position Computation Module which computes the precise position and velocity of the satellites for use in the navigation solution
4. Host Communications Module which communicates with the host through RS232 link
5. Non Volatile Memory Module which manages the data in the EEPROM and RTC

The powerful floating point library available on the DSP core enables very efficient execution of the floating point intensive tasks. However, the architecture of the NAV2300 makes it feasible for the OEMs to migrate the Navigation tasks to a separate microcontroller while still maintaining a seamless interface with the signal processing tasks residing on the ADSSTNAV2300, if their overall system design considerations necessitate such a partitioning.

PROGRAMMATIC INTERFACE

The NAV2300 receiver has a unique Programmatic Interface using which a system developer can integrate his/her application with the GPS core library on the same DSP, without having to use another microcontroller.

The interface enables the application developer to:

1. Access the necessary GPS data structures
2. Make use of the real time GPS outputs
3. Link the application software to the GPS core engine library
4. Make maximum use of spare computing assets of the DSP

The GPS Engine Core software has a real time executive, which manages the resources of the DSP and provides the interface to the application developer.

The Programmatic Interface is available in two modes -

1. Periodic Programmatic Interface
2. Background Programmatic Interface

The periodic mode of operation allocates a fixed time slice to the user's application every second.

In the background mode all the spare MIPS are made available to the user's application.

The choice of the mode for a particular application rests with the application developer.

The developer can write his/her own code either in gnu C (ANSI C compatible from Free Software Foundation) or ADSP218x assembly. He/she can access, if necessary, all the real-time GPS outputs through data structures. The user's object code should be linked with the GPS core library to generate the executable.

POWER CONSUMPTION

The NAV2300 suits the requirements of low power hand held GPS applications, by virtue of its memory integrated single chip digital design and the various low power modes of the ADSP218x core.

Under conditions when the receiver continuously tracks all visible satellites and collects data from them, the complete NAV2300 receiver reference design consumes about 465mW.

The solution also includes the following options for saving power:

1. User configurable output rates
2. Only-on-demand generation of outputs
3. Channel autoconfiguration

User configurable output rates

User can configure the rate at which navigation outputs are desired from the GPS sensor. The average power consumption of the entire GPS reference design at different output rates will be as shown in the table below:

Configured Rate	Power Consumption (average)
1 fix per second	130 mW
1 fix per 5 seconds	75 mW
1 fix per 10 seconds	63 mW

Only-on-demand generation of outputs

The User can configure the receiver to generate navigation outputs only when demanded. In this mode, the receiver will be in a low power state by default and will wake up only upon receiving a request from the host for a fix. The receiver will be active for just a fraction of a second to compute all navigation outputs and will revert back to the low power mode.

The power consumption will be about 130 mW per fix every second and will decrease with less frequent demands from the host.

Channel Autoconfiguration

Channel autoconfiguration will further reduce power consumption, by including only the barest minimum number of satellites in the navigation solution without compromising on the DOP limits.

All the calculations of power consumption above assume:

1. All the devices operate at 2.7 volts
2. There is a built-in LNA on the RF down converter
3. No external LNA used on the board
4. Passive antenna configuration
5. 8 satellites are included in the constellation on an average

PERFORMANCE HIGHLIGHTS

TTFF

The TTFF performance of the NAV2300 is greatly enhanced by virtue of the powerful DSP instruction set and innovative algorithms. Use of low cost, low ppm crystals do not degrade the TTFF performance. The various TTFF measurements carried out on the NAV2300 are as follows:

Time	With at least 4 visible SVs with nominal signal strength	With at least 4 visible SVs with good signal strength
Maximum	78 seconds	54 seconds
Minimum	34 seconds	26 seconds
Average	65 seconds	45 seconds

In the table above, the values assume that the combination of 4 satellites results in a DOP less than that configured by the user.

The TTFF figures mentioned above assume a receiver reference clock with a stability of 20 ppm.

SIZE

The reference design of the NAV2300 has a small form factor of 51 X 41 X 12mm. The size can be easily reduced to 41 X 41 X 10mm for passive antenna configurations.

OEM SUPPORT

The NAV2300 solution is backed by a software and hardware support team, which can cater to the customization needs of OEMs/application developers.

For the convenience of the OEMs' production line, the NAV2300 solution includes the *OEM Firmware Configuration Kit*, which facilitates the generation of executable NAV2300 binary files with all the desired EERPOM settings for the configurable parameters such as the DOP limit, almanac, DGPS parameters, etc.

EMBEDDED GSM/TRUNKED RADIO INTERFACE

The receiver firmware comes with an optional embedded GSM interface, conforming to the ETS 07.07 and 07.05 specifications. This enables integration of NAV2300 with GSM mobile stations.

Also, the NAV2300 includes an optional proprietary binary message protocol to interface the GPS sensor with a modem, to facilitate connection to a VHF/UHF transceiver.

DR INTERFACE CAPABILITY

The OEM can implement a hybrid navigation system by including hybrid navigation algorithms on the GPS core DSP itself, making use of the Programmatic Interface.

ROADMAP

The NAV2300 and the subsequent generations of solutions from the NAV2K™ family aim to deliver continuously improved GPS sensor performance using a software intensive approach. The NAV2300 reference designs and evaluation kits are now available. Reference designs for very low power applications, called the NAV 2500 will be available before the end of 1999.

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