<u>Design and Implementation of a GPS Receiver</u>

Functional Requirements List and Performance Specifications

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Introduction

The goal of this project is to explore the possibility of developing a GPS receiver using a software solution. In developing a receiver two possibilities exist:

1. Hardware-Based Design
   - Hardware chipsets are available from a number of suppliers including SiRF and Magellan. The hardware chipsets perform the correlation and signal acquisition. Most chipsets use an RS-232 interface supporting the NMEA command set.
2. Software-Based Design
   - Recently, chipsets have become readily available which sample and down-convert the C/A (Coarse-Acquisition) code. The sampled data can then be processed in software using various techniques.

This project shall focus on the software-based design approach considering the hardware-based design a contingency. The contingency is necessary as obtaining the equipment required for the software-based design is difficult due to its recent availability.

Goals

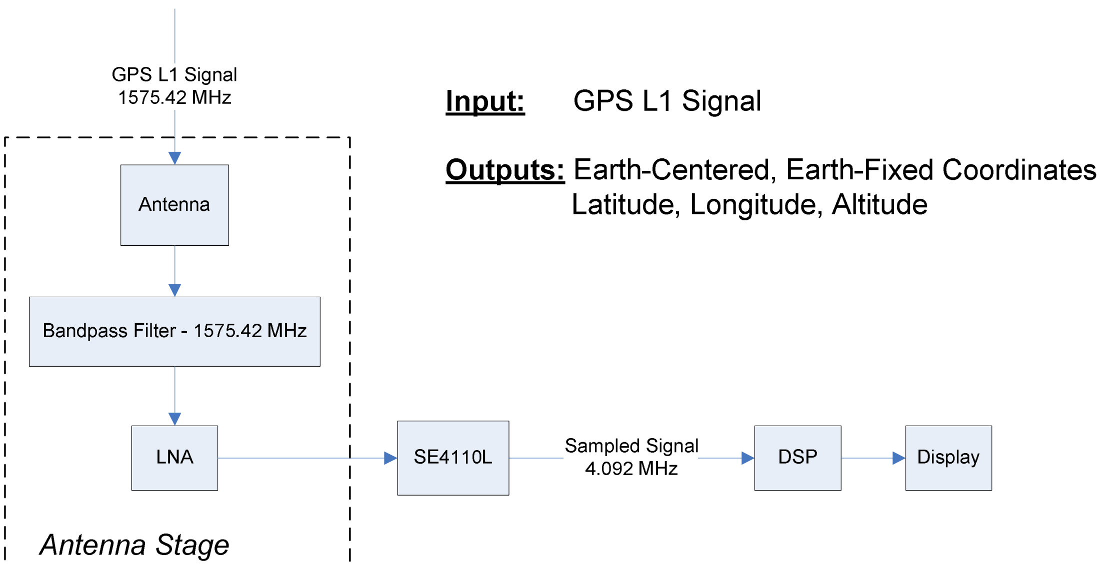
The goals of this project are described in detail below. The ultimate objective is to compute the user's position in real-time, while the rest of the objectives serve to make that goal achievable.

- Implement a software GPS L1 signal model
- Develop a software-based GPS receiver model for processing a sample input dataset
- Implement the model in a high-level language such as C++
- Process the raw data using an embedded system or DSP kit using the model developed
- Connect the embedded system or DSP kit to a sampling device and perform satellite signal acquisition
- Compute position in real-time

High-Level Block Diagram

Figure 1, below, shows the high-level block diagram for the project. The GPS L1 signal shall be received through an active GPS antenna. After the antenna stage, the SE4110L chipset shall be used to sample and down-convert the signal. A DSP kit shall then perform software processing and display the results.

Figure 1 – High-level Block Diagram



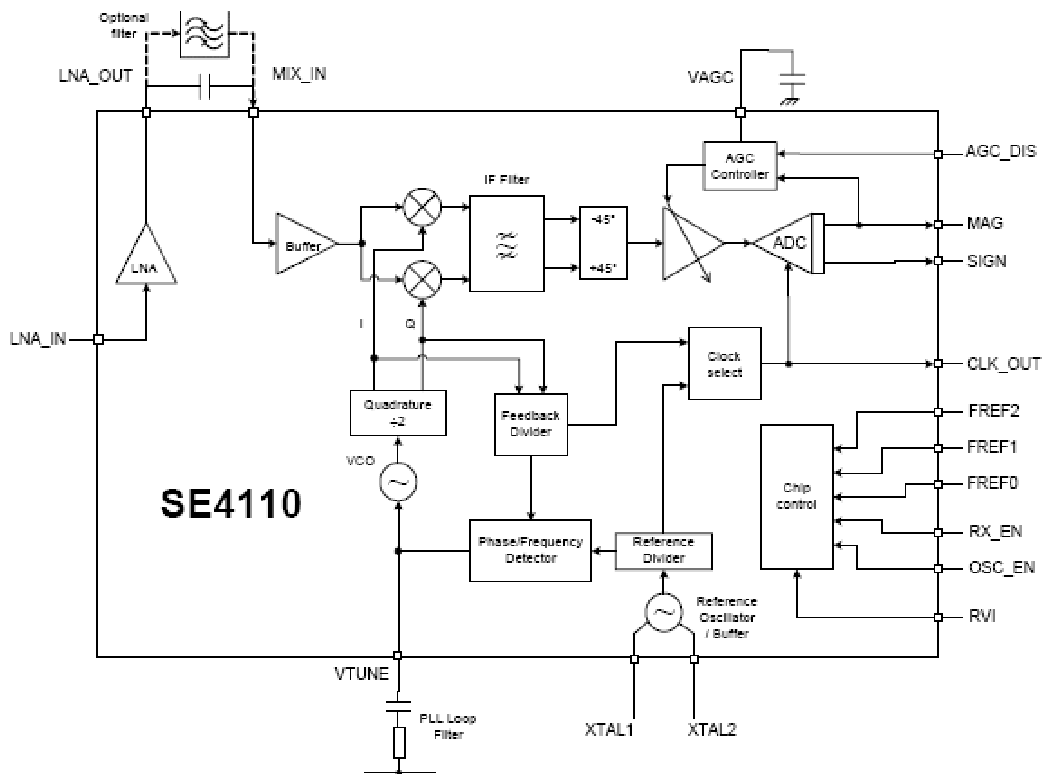
Antenna Stage

Active GPS antennas are available from a variety of manufacturers and include at a minimum a low-noise amplifier and a bandpass filter. An active antenna is necessary due to the low transmit power of GPS satellites and the degradation and attenuation of the signal as it travels through the atmosphere.

SE4110L

The SE4110L is a complicated chipset consisting of a several sub-stages. The subsystems are very similar to those of a superheterodyne receiver with the addition of a high-frequency A/D converter. The device outputs the magnitude and sign of the received signal at 4.092 MHz. [2] Figure 2, below, shows the functional block diagram from the SE4110L datasheet. Functionally, the SE4110L shall provide the digitally sampled GPS L1 signal to the DSP.

Figure 2 – SE4110L Functional Block Diagram [3]



DSP Kit

A Spectrum Digital DSP Development System shall be used for signal processing. The development board is based on a TI C6000 DSP, which is capable of hardware floating-point operations. The DSP is clocked at 225 MHz, which should provide adequate processing power for most of the software operations and hardware interfacing.

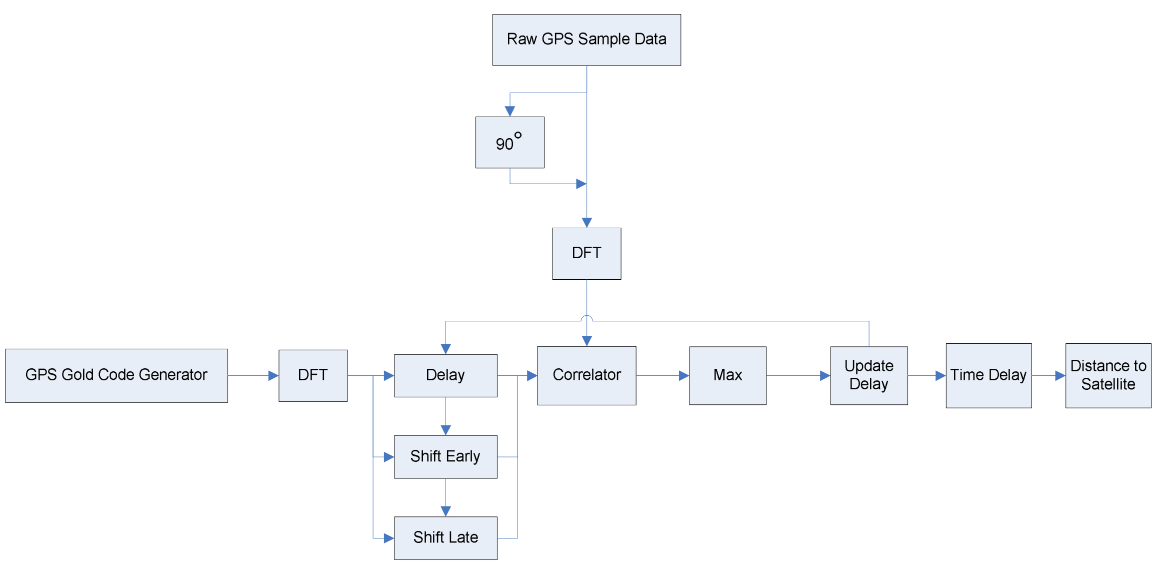
Software Processing

The bulk of this project involves software processing of the sampled signal data. Figure 3, below, shows a modification on the basic scheme as used by Kai Borre et al. for calculating the time delay in the signal. [1] The software shall work by performing a discrete Fourier transform (DFT) on the input signal and comparing it to a similar signal generated by a C/A PRN sequence generator.

Various delays are then applied to the C/A code sequence and each is correlated to the input signal. The highest correlation value is then used to adjust the delay. The delay shall then be used to determine the distance to a satellite.

The process shown in Figure 3 must be separately performed for each satellite to be acquired since the Gold (C/A) code for each satellite is different.

Figure 3 – High-Level Software Flowchart [1]



Subsystem Requirements

The subsystem requirements are given in Figure 4, below.

Figure 4 – Subsystem Requirements [1]

Error	Specification(s)
Position Error	100 m
Sampling Rate	4.092 MHz
Time to First Fix	Cold Start : 36 seconds Warm Start : 1 second
Display	Earth-centered, Earth-fixed Coordinates Latitude, Longitude, Altitude UTC Time Local Time

Position Error

The position error is determined with respect to the sampling rate. The sampling rate is 4.092 MHz, which is four times the chipping rate. Therefore, the distance to a single satellite can be determined to within ¼ of the distance related to 1 chip.

Calculation 1 – Satellite Ranging Precision

$$\lambda_{Chip} = \frac{c}{f} = \frac{3\times10^{8}\frac{m}{s}}{1.023\times10^{6}\frac{1}{s}} = 293.26\,m$$

$$\text{Precision} = \frac{\lambda_{Chip}}{4} = \frac{293.26\,m}{4} = 73.31\,m$$

Calculation 1, above, indicates that the position of a satellite can be determined accurately to within 73.31 m. However, this value does not take into account other error sources such as atmospheric effects, ephemeris errors (errors with respect to the satellites' orbits), and clock drift. [4]

Sampling Rate

The sampling rate is set by the SE4110L at 4.092 MHz. Other options are available, but the selected rate is the fastest available based on a factor that is an integer.

Time to First Fix

Acquisition requires that the satellite C/A PRN be correlated with the locally-generated C/A PRN and a complete frame of data be received. A frame lasts 30 seconds and is divided into 5 subframes lasting 6 seconds each. [1] Ideally, the time to first acquisition would depend solely on the length of the frame. However, it is quite likely that the first subframe would be received beginning somewhere other than the first byte. Therefore, the ideal acquisition time is 36 s. This specific acquisition is referred to as a "cold acquisition" and assumes that no previous data about the satellite is available. Commercial chips such as the SiRFstarIII GSD3t list the value as 36 s accordingly. [5]

If the frame data is already available, the position can be calculated as soon as the C/A PRN code is synchronized. This value should be very small with an approximate value of 1 s. Comparatively, the SiRFstarIII GSD3t lists the value as less than 1s.

Display

The display should be user-friendly and give the position in a variety of coordinate systems including Earth-centered, Earth-fixed (ECEF) and Latitude, Longitude, and Altitude (LLA). In addition, the UTC time should be displayed with a conversion to local time with the offset provided by the user.

Conclusion

This project contains many challenges which can be foreseen and many more which cannot. Nonetheless, this project shall provide insight into the practicality of software-based GPS systems as well as their accuracy.

References

[1] Kai Borre, Dennis M. Akos, Nicolaj Bertelsen, Peter Rinder, and Soren Holdt Jensent, *Software-Defined GPS and Galileo Receiver : A Single-Frequency Approach.* Birkhauser: Boston, 2007, pp. 29, 83, 105.
[2] SiGe, SE4110L-EK1 Evaluation Board User Guide.
[3] SiGe, SE4110L Datasheet.
[4] Wikipedia, "Global Positioning System" [online], available from World Wide Web: <http://en.wikipedia.org/wiki/Global_Positioning-_System>.
[5] SiRF, "SiRFstarIII GSD3t" [online], available from World Wide Web: < http://www.sirf.com/products/gps_chip2e.html>.