Experiment 5: Positioning Satellites

Objectives

The purpose of this experiment is to familiarize the students with the Global Positioning System (GPS) by the use of the GPS Receiver Peripheral Module (PmodGPS). This PmodGPS can add satellite positioning accuracy to any embedded system.

Equipment List

- ChipKIT™ Pro MX7 processor board with USB cable
- Microchip MPLAB ® X IDE
- MPLAB ® XC32++ Compiler
- PmodGPS

Overview

The Global Positioning System (GPS)

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions.

There are three parts to a GPS system:

1. a constellation of between 24 and 32 solar-powered satellites orbiting the earth in orbits at an altitude of approximately 20000 kilometers,
2. a master control station and four control and monitoring stations (on Hawaii, Ascension Islands, Diego Garcia and Kawajale),
3. GPS receivers.

Each of the satellites is in an orbit that allows a receiver to detect at least four of the operational satellites. The satellites send out microwave signals to a receiver where the built-in computer uses these signals to work out your precise distance from each of the four satellites and then triangulates your exact position on the planet to the nearest few meters based on these distances. Hence, the process of measuring the distance from satellite to GPS receiver is based on timed signals. An example of satellite constellation is shown in Figure 15.

GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are further away than others. The distance to the GPS satellites can be determined by estimating

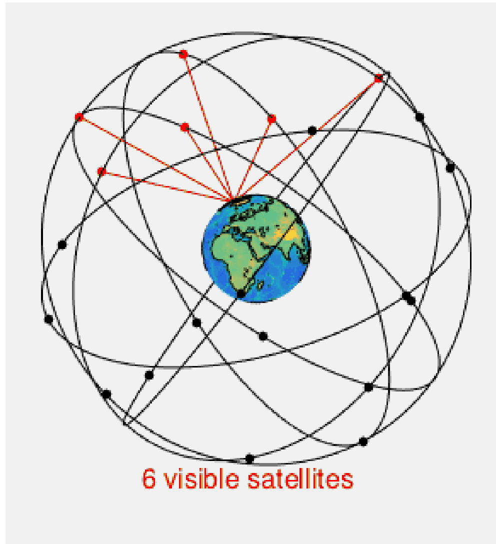
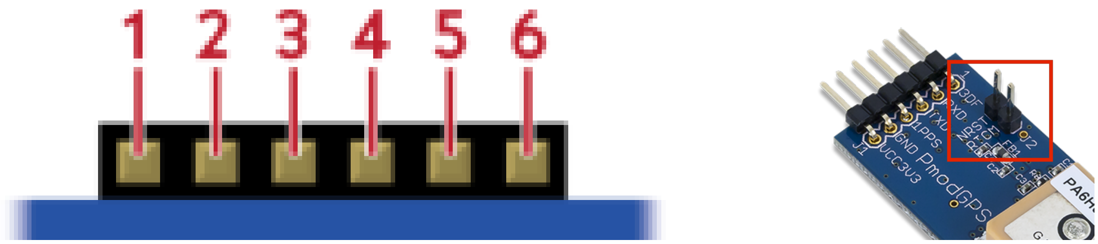


Figure 15: GPS constellation with 6 satellites in view from a given point on the earth's surface[5].



(a) Connector J1

(b) Connector J2

Figure 16: PmodGPS Pinout.

the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions.

In fact, signals from just three satellites are needed to carry out this trilateration process; the calculation of your position on earth based on your distance from three satellites. The signal from the fourth satellite is redundant and is used to confirm the results of the initial calculation.

PmodGPS: Functional Description & Interface

The PmodGPS uses a standard 6-pin port and communicates via a 2-wire Universal Asynchronous Receiver/-Transmitter (UART.) The PmodGPS also has a 2-pin port for control of the NRST pin to the module and the Radio Technical Commission for Maritime services, or RTCM pin for Differential Global Positioning System (DGPS) data using RTCM protocols[2].

As illustrated in Table 3, the PmodGPS uses a standard 6-pin connector and communicates via a 2-wire Universal Asynchronous Receiver/Transmitter (UART). The interface operates at a default baud rate of 9.6 kBd, 8 data bits, no parity, and with single stop bits. However, users can change the baud rate to predefined values that range from 4.8 kBd to 115.2 kBd.

The reset pin (NRST) on J2 allows normal operation in active low. If users toggle the NRST pin it will completely reset the module. This reset performs similar to a power cycling of the device. The 1 PPS pin on J1 provides a one pulse- per-second output synchronized with GPS time.

[2]The PmodGPS arrives with the RTCM feature inactive, to enable RTCM capabilities users should contact GlobalTop at: www.gtop-tech.com.

Connector J1 (Figure 16a)		
Pin	Signal	Description
1	3DF	3D-Fix Indicator
2	RX	Receiver
3	TX	Transmitter
4	1PPS	1 Pulse Per Second
5	GND	Ground
6	VCC	Power Supply (3.3v)

Connector J2 (Figure 16b)		
Pin	Signal	Description
1	NRST	Reset pin (active low)
2	RTCM	DGPS data pin (contact GlobalTop for use at `http://www.gtop-tech.com`)

Table 3: Simple serial communication

The 3DF pin on J1 indicates the status of the user's positional fix. When the module has a constant fix (2D or 3D) this pin stays low, if the module is unable to get a fix then the pin will toggle every second, as shown in Figure 17. LD1 also follows this same behavior pattern in order to give the user a visual representation.

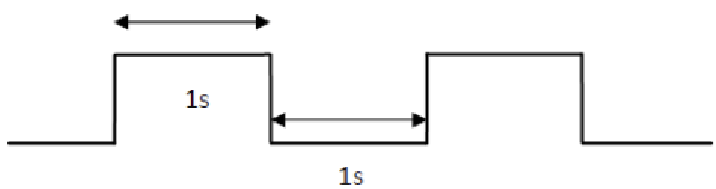


Figure 17: 3DF Pin output without a fix.

GPS - NMEA sentence information

The PmodGPS uses sentences based on National Marine Electronics Association (NMEA) protocols for data output. Once the module connects to at least four satellites, it sends several messages containing GPS data to the microcontroller.

Each NMEA message begins with a ($) dollar sign. The next five characters are the talker ID and the arrival alarm. The PmodGPS talker ID is "GP" and the arrival alarm is the specific sentence output descriptor. Individual comma separated data fields follow these five characters. After the data fields there is an asterisk followed by a checksum. Each sentence should end with <CR><LF>.

The most important NMEA sentences include the GGA which provides the current Fix data, and the GSA which provides the Satellite status data. Other sentences may repeat some of the same information but will also supply new data, such as: RMC, VTG, GSV ...etc. (For more information see NMEA Reference Manual[6]).

$GPGGA - Global Positioning System Fix Data

```
\$GPGGA,064951.000,2307.1256,N,12016.4438,E,1,8,0.95,39.9,M,17.8,M,,*65
```

The fields are explained in Table 4.

$GPGSV - Satellites in view

```
\$GPGSV,3,1,12,29,36,029,42,21,46,314,43, 26,44,020,43,15,21,321,39*7D
```

$GPGGA	Message ID
064951.000	UTC Time (hhmmss.sss)
2307.1256	Latitude (ddmm.mmmm)
N	N/S indicator
12016.4438	Longitude (ddmm.mmmm)
E	E/W indicator
1	Position Fix Indicator
8	Used satellites
0.95	Horizontal Dilution of Precision (HDOP)
39.9	MSL Altitude
M	Units
17.8	Geoidal Separation
M	Units
	Age of Diff. Corr.
*65	Checksum

Table 4: GGA Sentence Format.

```
\$GPGSV  ,3 ,2 ,12 ,22 ,28 ,259 ,16 ,27 ,13 ,107 , ,09 ,11 ,130 , ,16 ,09 ,288 ,25*79
\$GPGSV,3 ,3 ,12 ,30 ,08 ,210 ,33 ,06 ,08 ,320 ,22 ,25 ,02 ,188 ,26 ,14 ,01 ,203 ,21*7B
```

The fields are explained in Table 5.

$GPGSV	Message ID
3	Number of messages
1	Message Number
12	Satellites in View
29	Satellite ID (CH1)
36	Elevation (CH1)
029	Azimuth (CH1)
42	SNR (C/No)
...	
15	Satellite ID CH(4)
21	Elevation (CH4)
321	Azimuth (CH4)
39	SNR (C/No)
*7D	Checksum

Table 5: GSV Sentence Format.

Experiment

Once the module is connected to JF and we got a fix position (PF is 0), several messages containing GPS data will be sent to the microcontroller. In this experiment, you are asked to filter these messages into data fields so that they can be accessed individually.

Hence, we need to implement a C code to filter the received message and display them into the HyperTerminal. The navigation through the messages data fields will be done using a button (e.g., BTN1). For the communication configures the UARTs module at a 9.6 kBd, 8 data bits, no parity, and with single stop bits.

Note There are three common formats[3]:

[3] http://www.sunearthtools.com/dp/tools/conversion.php

- Degrees, Minutes and Seconds (DD° MM' SS.S"). This is the most common format used to mark maps.
- Degrees and Decimal minutes
- Decimal Degrees