



# 2.017 DESIGN OF ELECTROMECHANICAL ROBOTIC SYSTEMS

## *Fall 2009 Lab 3: GPS and Data Logging*

September 28, 2009

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## 1. Microcontrollers

- Introduction to microcontrollers
- Arduino microcontroller kit

## 2. Sensors and Signals

- Analog / Digital sensors
- Data acquisition
- Data processing and visualization

## 3. GPS and Data Logging

- GPS receiver and shield
- Data logging
- Visualization of data

## 4. Motor Control

- Motors
- Encoders
- Position control

# Lab 3: GPS and Data Logging



- Assemble the GPS logger shield (1:30 – 2:30)
- GPS experiments (2:30 – 4:30)
  - Test your GPS device
  - Determine the accuracy of the GPS receiver
  - Take field data
  - Process GPS data
- Project discussion (4:30 – 5:00)

# Assemble The GPS Logger Shield



- Grab a soldering iron and solder
- Power the soldering iron and set the temperature dial to 4
- Follow the on-line instructions on the web site:  
<http://www.ladyada.net/make/gpsshield/solder.html> to assemble the board
- Also solder the 9v battery holder
- Take your time. Don't rush it.

# Soldering Guidelines



- Wear safety glasses when soldering
- Do not touch a hot iron
- Never leave your iron turned on while unattended
- Never set the soldering iron down on anything other than an iron stand
- Use needle nose pliers, heat resistant gloves, or a third hand tool to hold small pieces
- Practice a few times if you have not done soldering recently
- Do not use excess amount of solder
- Double check the part you want to solder before you actually do it
- When done soldering, tinning the iron is required to protect the tip from oxidation thereby dramatically increasing its life

# Some References on GPS



- References:

- <http://edu-observatory.org/gps/tutorials.html>
- <http://www.gpsinformation.org/dale/nmea.htm>
- <http://www.cmtinc.com/gpsbook/>
- <http://en.wikipedia.org/wiki/NMEA>
- <http://vancouver-webpages.com/peter/gpsfaq.txt>
- <http://www.trimble.com/gps/index.shtml>
- <http://www8.garmin.com/aboutGPS/>
- <http://www.nmea.org/>
- ...

# Global Positioning System (GPS)



- The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. The satellites were placed into orbit by the U.S. Department of Defense. The total cost was around \$12B.
- GPS was originally intended for military applications, but in the 1980s, the U.S. Government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day.
- GPS uses these satellites as reference points to calculate positions accurate to a few meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter.



Image by NOAA.

# GPS Background



- GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.
- A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

# GPS Satellites



- NAVSTAR (DoD name for GPS)
- Orbiting the earth about 12,000 miles above us.
- Making two complete orbits in less than 24 hours with a speed of roughly 7,000 miles an hour.
- Powered by solar energy.
- On-board backup batteries to keep them running in the event of a solar eclipse, when there's no solar power.
- Small rocket boosters on each satellite keep them flying in the correct path.
- The first GPS satellite was launched in 1978.
- A full constellation of 24 satellites was achieved in 1994.
- Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
- A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
- Transmitter power is only 50 watts or less.

# GPS Data (NMEA 0183 Standard)



- The NMEA 0183 Interface Standard defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus.
- Each bus may have only one talker but many listeners. This standard is intended to support one-way serial data transmission from a single talker to one or more listeners.
- This data is in printable ASCII form and may include information such as position, speed, depth, frequency allocation, etc.

# NMEA Standard Sentences



Many sentences in the NMEA standard for all kinds of devices that may be used in different environment. Some of the ones that have applicability to GPS receivers are listed below: (all messages start with GP.)

- AAM - Waypoint Arrival Alarm
- ALM - Almanac data
- APA - Auto Pilot A sentence
- APB - Auto Pilot B sentence
- BOD - Bearing Origin to Destination
- BWC - Bearing using Great Circle route
- DTM - Datum being used
- **GGA - Fix information**
- GLL - Lat/Lon data
- GRS - GPS Range Residuals
- **GSA - Overall Satellite data**
- GST - GPS Pseudorange Noise Statistics
- GSV - Detailed Satellite data
- MSK - send control for a beacon receiver
- MSS - Beacon receiver status information
- RMA - recommended Loran data
- RMB - recommended navigation data for gps
- **RMC - recommended minimum data for gps**
- RTE - route message
- TRF - Transit Fix Data
- STN - Multiple Data ID
- VBW - dual Ground / Water Sped
- VTG - Vector track an Speed over the Ground
- WCV - Waypoint closure velocity (Velocity Made Good)
- WPL - Waypoint Location information
- XTC - cross track error
- XTE - measured cross track error
- ZTG - Zulu (UTC) time and time to go (to destination)
- ZDA - Date and Time

`$GPRMC,135713.000,A,4221.4955,N,07105.5817,W,4.29,258.17,310809,,*16`

# RMC GPS Sentence



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Please see Table B-9 in GlobalSat Technology Corporation.  
["GPS Engine Board EM-406a."](#)

# Conversion



- UTC (Coordinated Universal Time) to local time
- Lat, Long, Alt
- Kts to m/s

# GPS Logger Shield & GPS Receiver



- EM-406a GPS engine board by GlobalSat

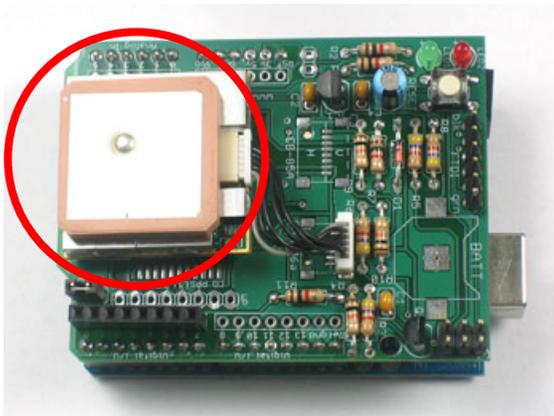


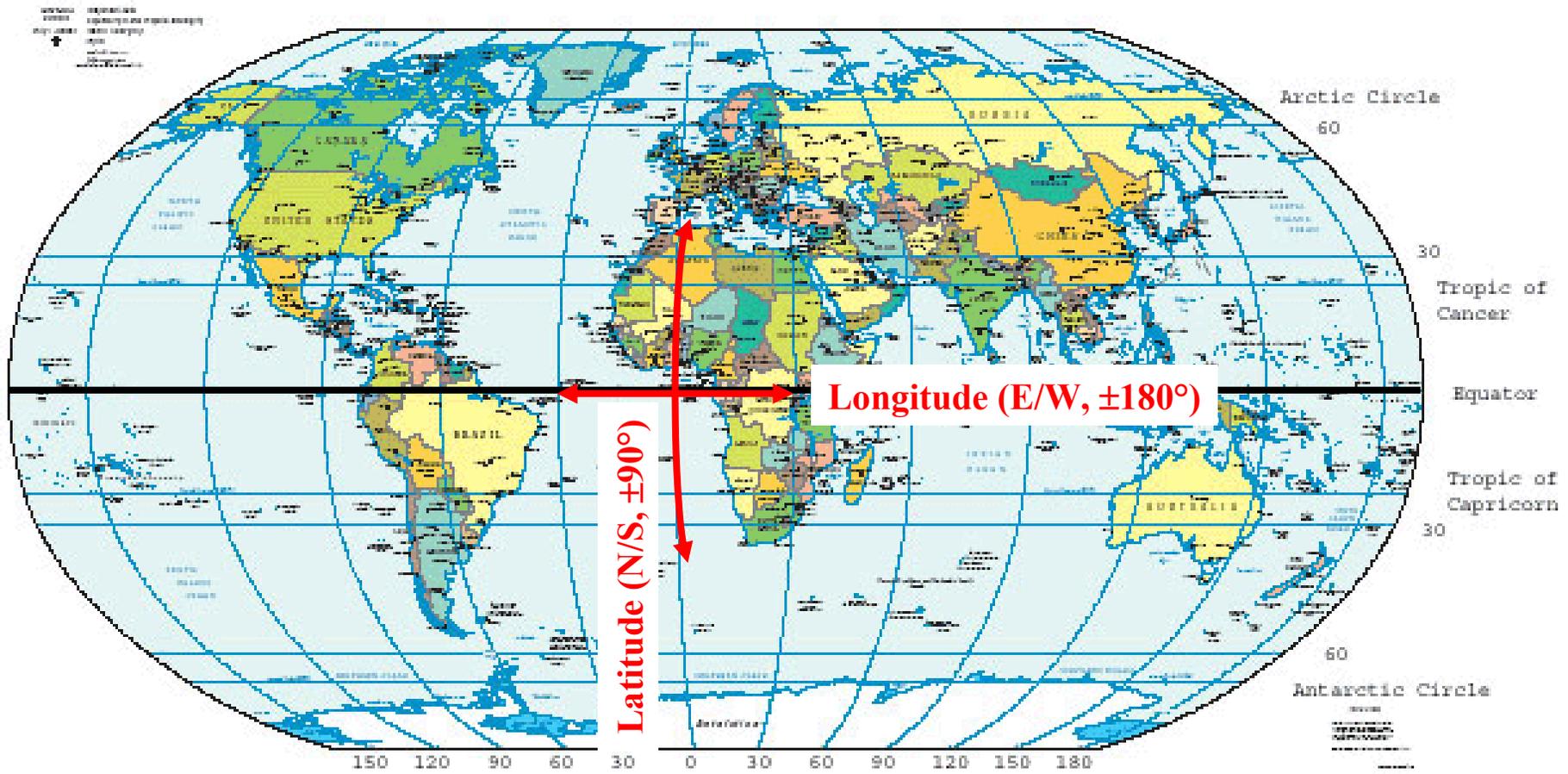
Photo by [ladyada](#) on Flickr.

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Please see pages 2-3 in GlobalSat Technology Corporation.  
"GPS Engine Board EM-406a."

# Geographic Coordinate System



Political Map of the World, June 2003



Map by CIA World Factbook.

# Geocoding w/ GPSVisualizer



Please see GPS Visualizer's [Geocode](#)

You can type in a coordinate in Google Map or Yahoo Map and display its location

# Calculate Distance Between Two Geographic Coordinates



## Haversine formula:

$$\Delta\text{lat} = \text{lat2} - \text{lat1}$$

$$\Delta\text{long} = \text{long2} - \text{long1}$$

$$a = \sin^2(\Delta\text{lat}/2) + \cos(\text{lat1})\cos(\text{lat2})\sin^2(\Delta\text{long}/2)$$

$$c = 2\text{atan2}(\sqrt{a}, \sqrt{1-a})$$

$$d = Rc$$

Where  $R$  = Earth's radius (mean radius = 6,371km)

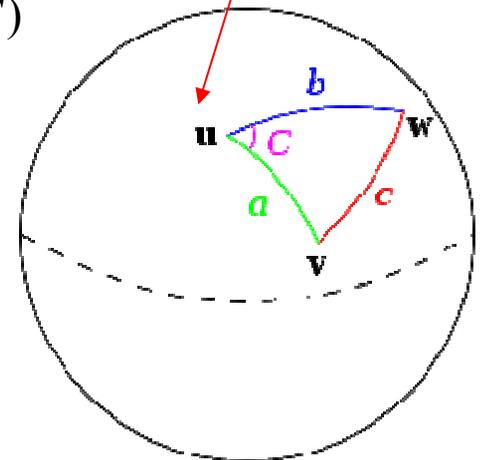
Put  $u$  at the north pole to get this formula

$$\text{haver sin}(c) = \text{haver sin}(a - b) + \sin(a)\sin(b)\text{haver sin}(C)$$

$$\text{haver sin}(\theta) = \sin^2\left(\frac{\theta}{2}\right)$$

... or use MATLAB's distance function to find the arc length in degrees...

(1 arc deg  $\approx$  69.047 miles  $\approx$  111.12 km)



# RouteConverter Software



<http://www.routeconverter.de/>

RouteConverter 1.29 from August 12, 2009

Map Satellite Hybrid Terrain Mapnik T@H Cycle

File: I:\Chin\My Documents\MIT\2.017\Fall 2009\GPS\_Lab\mea2kml\GPSLOG02.TXT

Format: NMEA 0183 Sentences (\*.nmea)

Content: 1 track;

Position list: Position 1 to Position 2912 (Track)

Type: Track

Position count:	2912	Length:	30 Km	Duration:	00:50:38
Description	Time	Speed	Longitude	Latitude	Eleva...
Position 1	8/31/09 1:06:34 PM	0.8 Km/h	-71.26039	42.4819333	
Position 2	8/31/09 1:06:35 PM	1.2 Km/h	-71.2602	42.4820649	
Position 3	8/31/09 1:06:36 PM	1.4 Km/h	-71.260221	42.482045	
Position 4	8/31/09 1:06:37 PM	0.8 Km/h	-71.260204	42.4820816	
Position 5	8/31/09 1:06:38 PM	0.2 Km/h	-71.260135	42.4821716	
Position 6	8/31/09 1:06:39 PM	1.2 Km/h	-71.260108	42.4822083	
Position 7	8/31/09 1:06:40 PM	0.3 Km/h	-71.260126	42.4821833	
Position 8	8/31/09 1:06:41 PM	0.1 Km/h	-71.260113	42.4821966	
Position 9	8/31/09 1:06:42 PM	1.2 Km/h	-71.260144	42.482155	
Position 10	8/31/09 1:06:43 PM	2.4 Km/h	-71.260183	42.4821033	
Position 11	8/31/09 1:06:44 PM	3.1 Km/h	-71.260216	42.4820649	
Position 12	8/31/09 1:06:45 PM	2.4 Km/h	-71.260226	42.48206	
Position 13	8/31/09 1:06:46 PM	2.2 Km/h	-71.260239	42.4820466	
Position 14	8/31/09 1:06:47 PM	2.2 Km/h	-71.260255	42.4820299	
Position 15	8/31/09 1:06:48 PM	2.4 Km/h	-71.26027	42.4820116	
Position 16	8/31/09 1:06:49 PM	2.4 Km/h	-71.260286	42.4819916	
Position 17	8/31/09 1:06:50 PM	2.3 Km/h	-71.2603	42.4819749	
Position 18	8/31/09 1:06:51 PM	2.2 Km/h	-71.260313	42.4819616	
Position 19	8/31/09 1:06:52 PM	2.0 Km/h	-71.260323	42.48195	
Position 20	8/31/09 1:06:53 PM	1.8 Km/h	-71.260331	42.4819399	
Position 21	8/31/09 1:06:54 PM	1.5 Km/h	-71.260336	42.4819333	
Position 22	8/31/09 1:06:55 PM	1.2 Km/h	-71.26034	42.48193	
Position 23	8/31/09 1:06:56 PM	1.0 Km/h	-71.260343	42.4819266	
Position 24	8/31/09 1:06:57 PM	0.8 Km/h	-71.260345	42.481925	
Position 25	8/31/09 1:06:59 PM	0.6 Km/h	-71.260346	42.4819233	
Position 26	8/31/09 1:07:00 PM	0.5 Km/h	-71.260348	42.4819216	
Position 27	8/31/09 1:07:01 PM	0.5 Km/h	-71.26035	42.4819183	
Position 28	8/31/09 1:07:02 PM	0.4 Km/h	-71.260351	42.4819166	
Position 29	8/31/09 1:07:03 PM	0.4 Km/h	-71.260353	42.4819149	
Position 30	8/31/09 1:07:04 PM	0.5 Km/h	-71.260354	42.48191	
Position 31	8/31/09 1:07:05 PM	0.5 Km/h	-71.260358	42.4819066	
Position 32	8/31/09 1:07:06 PM	0.4 Km/h	-71.26036	42.481905	
Position 33	8/31/09 1:07:07 PM	0.5 Km/h	-71.260361	42.4819033	
Position 34	8/31/09 1:07:08 PM	0.5 Km/h	-71.260363	42.4818999	
Position 35	8/31/09 1:07:09 PM	0.4 Km/h	-71.260363	42.4818983	

Save as: Google Earth 5 Compressed (\*.kml)

Save as route, track and waypoint list

Convert Misc Browse

# Project Discussion

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- Work on the project proposal

# Deliverables

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- Assembled GPS logger shield and battery holder
- Answer all the questions in the Lab 3 handout
- Data plots
- Estimated GPS data scatter
- Show the teaching staff your lab notebook

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<http://ocw.mit.edu>

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Fall 2009

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