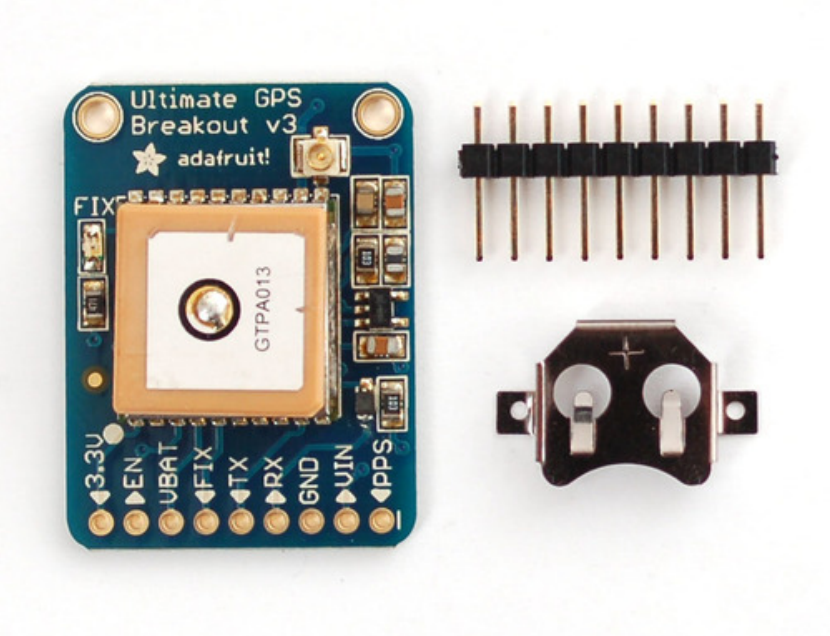
adafruit learning system

Adafruit Ultimate GPS

Created by lady ada



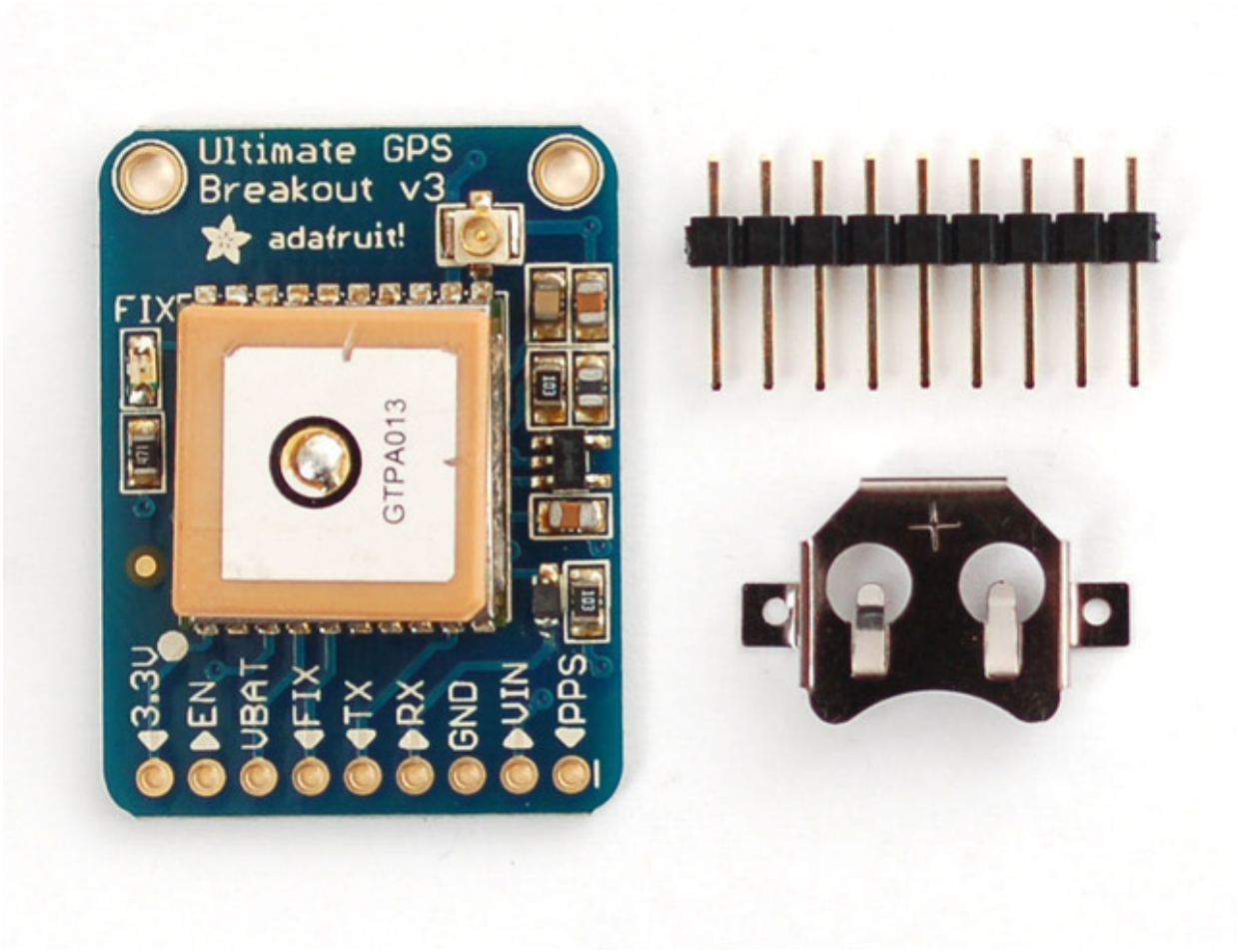
Last updated on 2014-11-12 02:30:12 PM EST

Guide Contents

Overview

We carry a few different GPS modules here in the Adafruit shop, but none that satisfied our every desire - that's why we designed this little GPS breakout board. We believe this is the **Ultimate** GPS module, so we named it that. It's got everything you want and more:

- -165 dBm sensitivity, 10 Hz updates, 66 channels
- 5V friendly design and only 20mA current draw
- Breadboard friendly + two mounting holes
- RTC battery-compatible
- Built-in datalogging
- PPS output on fix
- >25Km altitude
- Internal patch antenna + u.FL connector for external active antenna
- Fix status LED



The breakout is built around the MTK3339 chipset, a no-nonsense, high-quality GPS module that can track up to 22 satellites on 66 channels, has an excellent high-sensitivity receiver (-165 dB tracking!), and a built in antenna. It can do up to 10 location updates a second for high speed, high sensitivity logging or tracking. Power usage is incredibly low, only 20 mA during navigation.

Best of all, we added all the extra goodies you could ever want: a ultra-low dropout 3.3V regulator so you can power it with 3.3-5VDC in, 5V level safe inputs, ENABLE pin so you can turn off the module using any microcontroller pin or switch, a footprint for optional CR1220 coin cell to keep the RTC running and allow warm starts and a tiny bright red LED. The LED blinks at about 1Hz while it's searching for satellites and blinks once every 15 seconds when a fix is found to conserve power. If you want to have an LED on all the time, we also provide the FIX signal out on a pin so you can put an external LED on.

Two features that really stand out about version 3 MTK3339-based module is the external antenna functionality and the the built in data-logging capability. The module has a standard ceramic patch antenna that gives it -165 dB sensitivity, but when you want to have a bigger antenna, you can snap on any 3V active GPS antenna via the uFL connector. The module will automatically detect the active antenna and switch over! Most GPS antennas use SMA connectors so you may want to pick up one of our uFL to SMA adapters. (http://adafru.it/851)

The other cool feature of the new MTK3339-based module (which we have tested with great success) is the built in datalogging ability. Since there is a microcontroller inside the module, with some empty FLASH memory, the newest firmware now allows sending commands to do internal logging to that FLASH. The only thing is that you do need to have a microcontroller send the "Start Logging" command. However, after that message is sent, the microcontroller can go to sleep and does not need to wake up to talk to the GPS anymore to reduce power consumption. The time, date, longitude, latitude, and height is logged every 15 seconds and only when there is a fix. The internal FLASH can store about 16 hours of data, it will automatically append data so you don't have to worry about accidentally losing data if power is lost. It is not possible to change what is logged and how often, as its hardcoded into the module but we found that this arrangement covers many of the most common GPS datalogging requirements.

We've tested this version of the Ultimate GPS in a high-altitude balloon, and it kept fix up to 27km!

Pick one up today at the Adafruit shop! (http://adafru.it/746)

Specifications:

Module specs:

- Satellites: 22 tracking, 66 searching
- Patch Antenna Size: 15mm x 15mm x 4mm
- Update rate: 1 to 10 Hz
- Position Accuracy: 1.8 meters
- Velocity Accuracy: 0.1 meters/s
- Warm/cold start: 34 seconds
- Acquisition sensitivity: -145 dBm
- Tracking sensitivity: -165 dBm
- Maximum Altitude for PA6H: tested at 27,000 Meters
- Maximum Velocity: 515m/s
- Vin range: 3.0-5.5VDC
- MTK3339 Operating current: 25mA tracking, 20 mA current draw during navigation

- Output: NMEA 0183, 9600 baud default
- DGPS/WAAS/EGNOS supported
- FCC E911 compliance and AGPS support (Offline mode : EPO valid up to 14 days)
- Up to 210 PRN channels
- Jammer detection and reduction
- Multi-path detection and compensation

Breakout board details:

- Weight (not including coin cell or holder): 8.5g
- Dimensions (not including coin cell or holder): 25.5mm x 35mm x 6.5mm / 1.0" x 1.35" x 0.25"

If you purchased a module before March 26th, 2012 and it says MTK3329 on the silkscreen, you have the PA6B version of this breakout with the MT3329 chipset. The MTK3329 does not have built in datalogging. If your module has sharpie marker crossking out the MTK3329 text or there is no text, you have a PA6C MTK3339 with datalogging ability. If you have the version with "v3" next to the name, you have the PA6H which has PPS output and external-antenna support

This tutorial assumes you have a '3339 type module.

Direct Computer Wiring

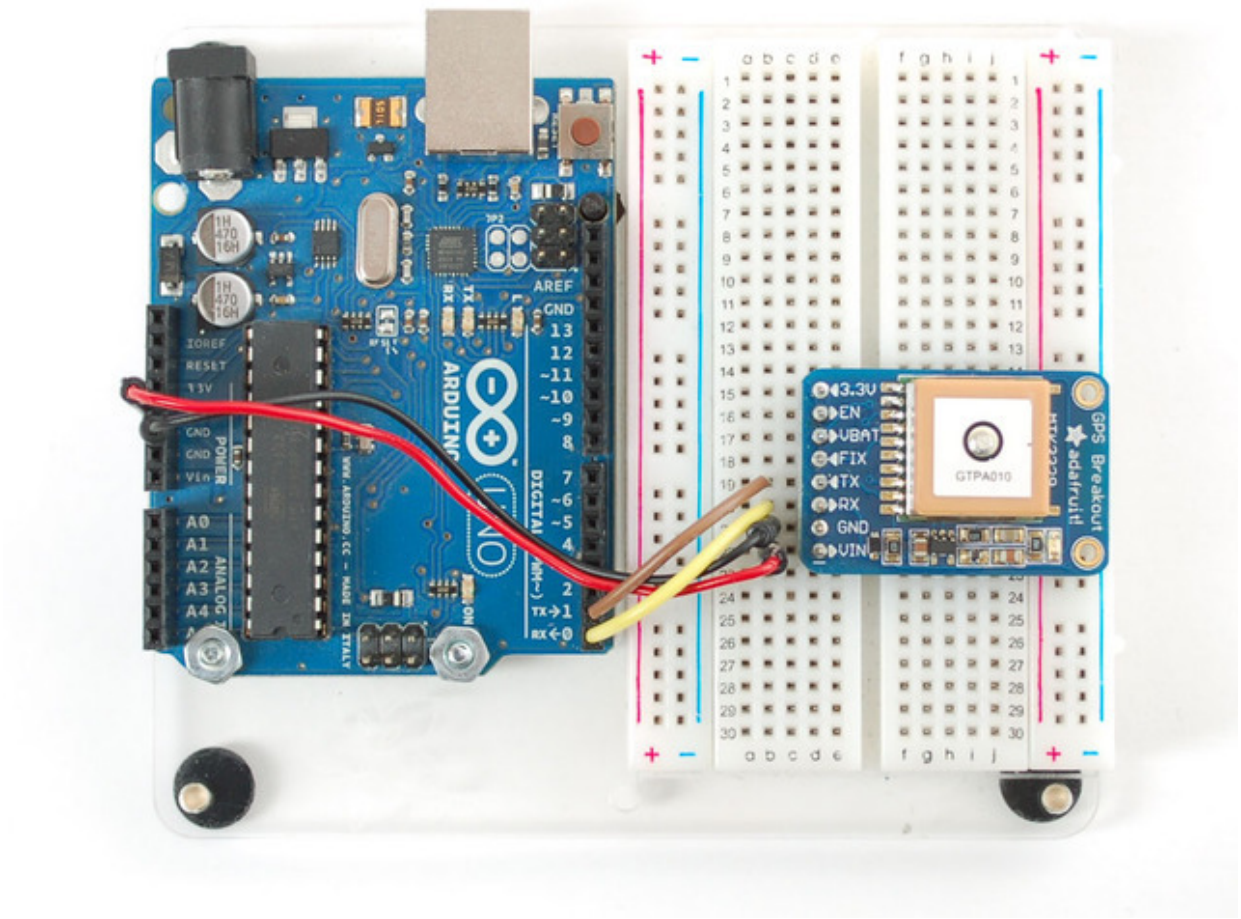
GPS modules are great in that the moment you turn them on, they'll start spitting out data, and trying to get a 'fix' (location verification). Like pretty much every GPS in existence, the Adafruit Ultimate GPS uses TTL serial output to send data so the best way to first test the GPS is to wire it directly to the computer via the TTL serial to USB converter on an Arduino. You can also use an FTDI Friend or other TTL adapter but for this demonstration we'll use a classic Arduino.

> Leonardo Users: This tutorial step won't work with a Leonardo. Go on to the next step, "Arduino Wiring", but refer back here for this discussion of the GPS data!

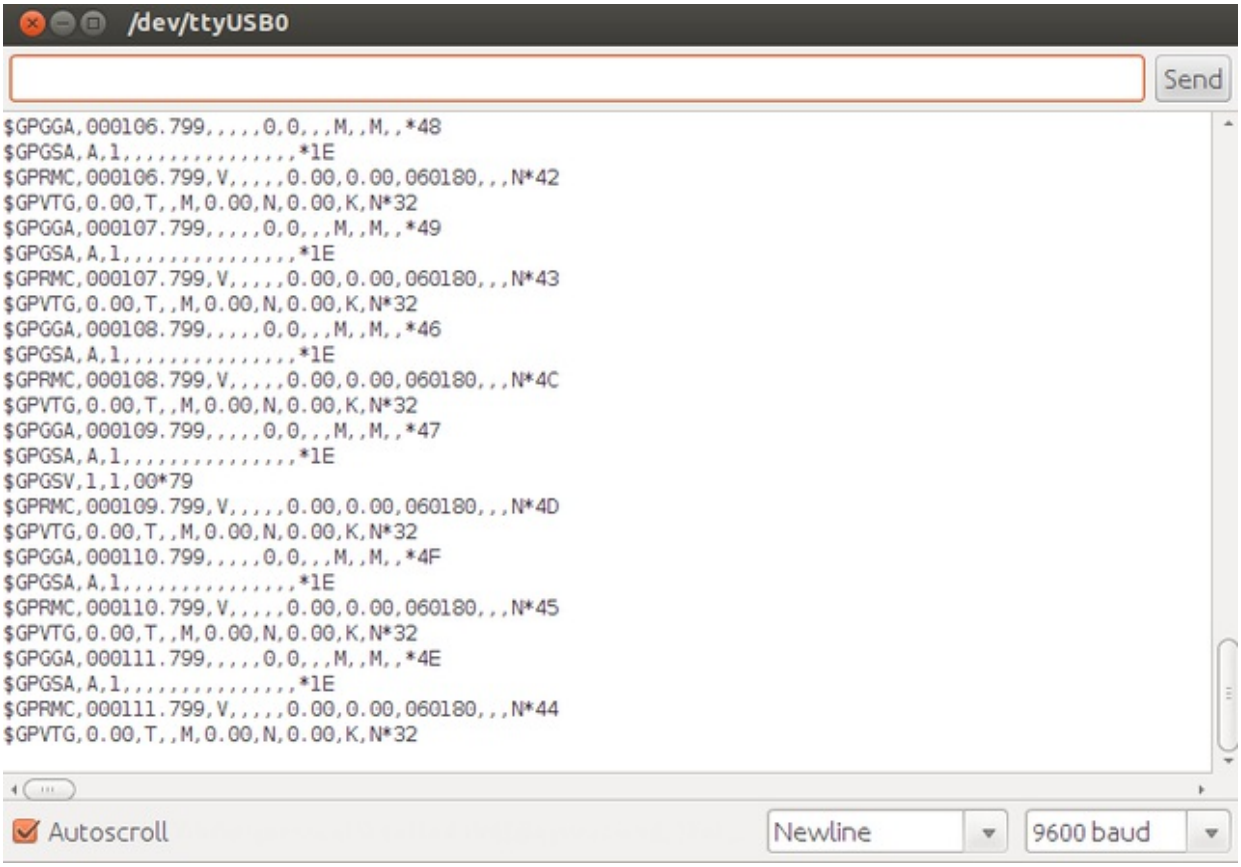
First, load a 'blank' sketch into the Arduino:

```
// this sketch will allow you to bypass the Atmega chip
// and connect the fingerprint sensor directly to the USB/Serial
// chip converter.

// Connect VIN to +5V
// Connect GND to Ground
// Connect GPS RX (data into GPS) to Digital 0
// Connect GPS TX (data out from GPS) to Digital 1

void setup() { }
void loop() { }
```

This is will free up the converter so you can directly wire and bypass the Arduino chip. Once you've uploaded this sketch, wire the GPS as follows. Your module may look slightly different, but as long as you are connecting to the right pin names, they all work identically for this part



Now plug in the USB cable, and open up the serial monitor from the Arduino IDE and be sure to select **9600 baud** in the drop down. You should see text like the following:



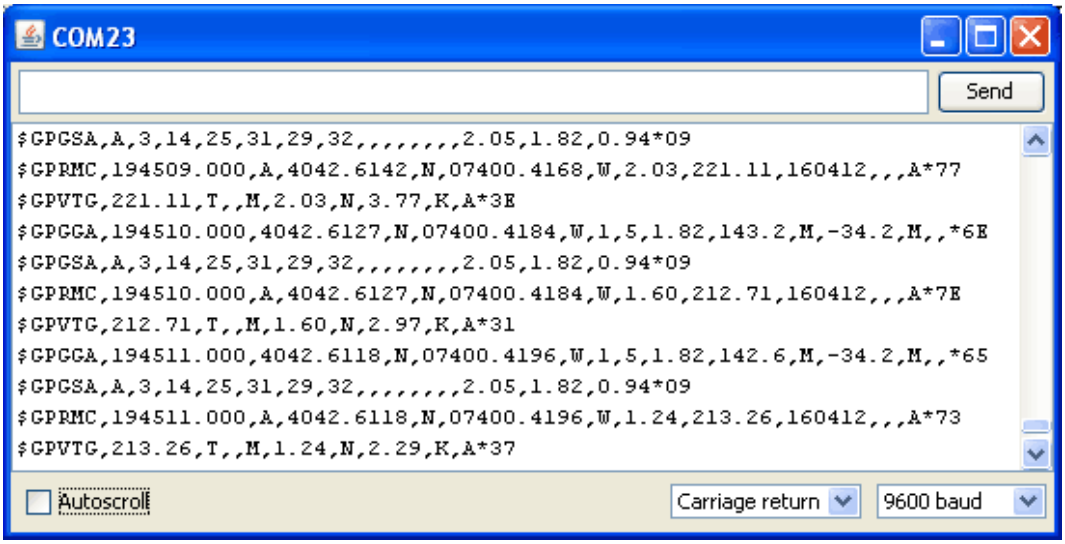
This is the raw GPS "NMEA sentence" output from the module. There are a few different kinds of NMEA sentences, the most common ones people use are the **$GPRMC** (**G**lobal **P**ositioning **R**ecommended**M**inimum **C**oordinates or something like that) and the **$GPGGA** sentences. These two provide the time, date, latitude, longitude, altitude, estimated land speed, and fix type. Fix type indicates whether the GPS has locked onto the satellite data and received enough data to determine the location (2D fix) or location+altitude (3D fix).

For more details about NMEA sentences and what data they contain, check out this site (http://adafru.it/aMk)

If you look at the data in the above window, you can see that there are a lot of commas, with no data in between them. That's because this module is on my desk, indoors, and does not have a 'fix'. To get a fix, we need to put the module outside.

GPS modules will always send data EVEN IF THEY DO NOT HAVE A FIX! In order to get 'valid' (not-blank) data you must have the GPS module directly outside, with the square ceramic antenna pointing up with a clear sky view. In ideal conditions, the module can get a fix in under 45 seconds. however depending on your location, satellite configuration, solar flares, tall buildings nearby, RF noise, etc it may take up to half an hour (or more) to get a fix! This does not mean your GPS module is broken, the GPS module will always work as fast as it can to get a fix.

If you can get a really long USB cord (or attach a GPS antenna to the v3 modules) and stick the GPS out a window, so its pointing at the sky, eventually the GPS will get a fix and the window data will change over to transmit valid data like this:



Look for the line that says **$GPRMC,194509.000,A,4042.6142,N,07400.4168,W,2.03,221.11,160412,,,A*77** This line is called the RMC (Recommended Minimum) sentence and has pretty much all of the most useful data. Each chunk of data is separated by a comma.

The first part **194509.000** is the current time **GMT** (Greenwich Mean Time). The first two numbers **19** indicate the hour (1900h, otherwise known as 7pm) the next two are the minute, the next two are the seconds and finally the milliseconds. So the time when this screenshot was taken is 7:45 pm and 9 seconds. The GPS does not know what time zone you are in, or about "daylight savings" so you will have to do the calculation to turn GMT into your timezone

The second part is the 'status code', if it is a **V** that means the data is **V**oid (invalid). If it is an **A** that means its **A**ctive (the GPS could get a lock/fix)

The next 4 pieces of data are the geolocation data. According to the GPS, my location is **4042.6142,N** (Latitude 40 degrees, 42.6142 decimal minutes North) & **07400.4168,W**. (Longitude 74 degrees, 0.4168 decimal minutes West) To look at this location in Google maps, type **+40° 42.6142', -74° 00.4168'** into the google maps search box (http://adafru.it/aMl) . Unfortunately gmaps requires you to use +/- instead of NSWE notation. N and E are positive, S and W are negative.

People often get confused because the GPS is working but is "5 miles off" - this is because they are not parsing the lat/long data correctly. Despite appearances, the geolocation data is NOT in decimal degrees. It is in degrees and minutes in the following format: Latitude: DDMM.MMMM (The first two characters are the degrees.) Longitude: DDDMM.MMMM (The first three characters are the degrees.)

The next data is the ground speed in knots. We're going **2.03** knots

After that is the tracking angle, this is meant to approximate what 'compass' direction we're heading at based on our past travel

The one after that is **160412** which is the current date (16th of April, 2012).

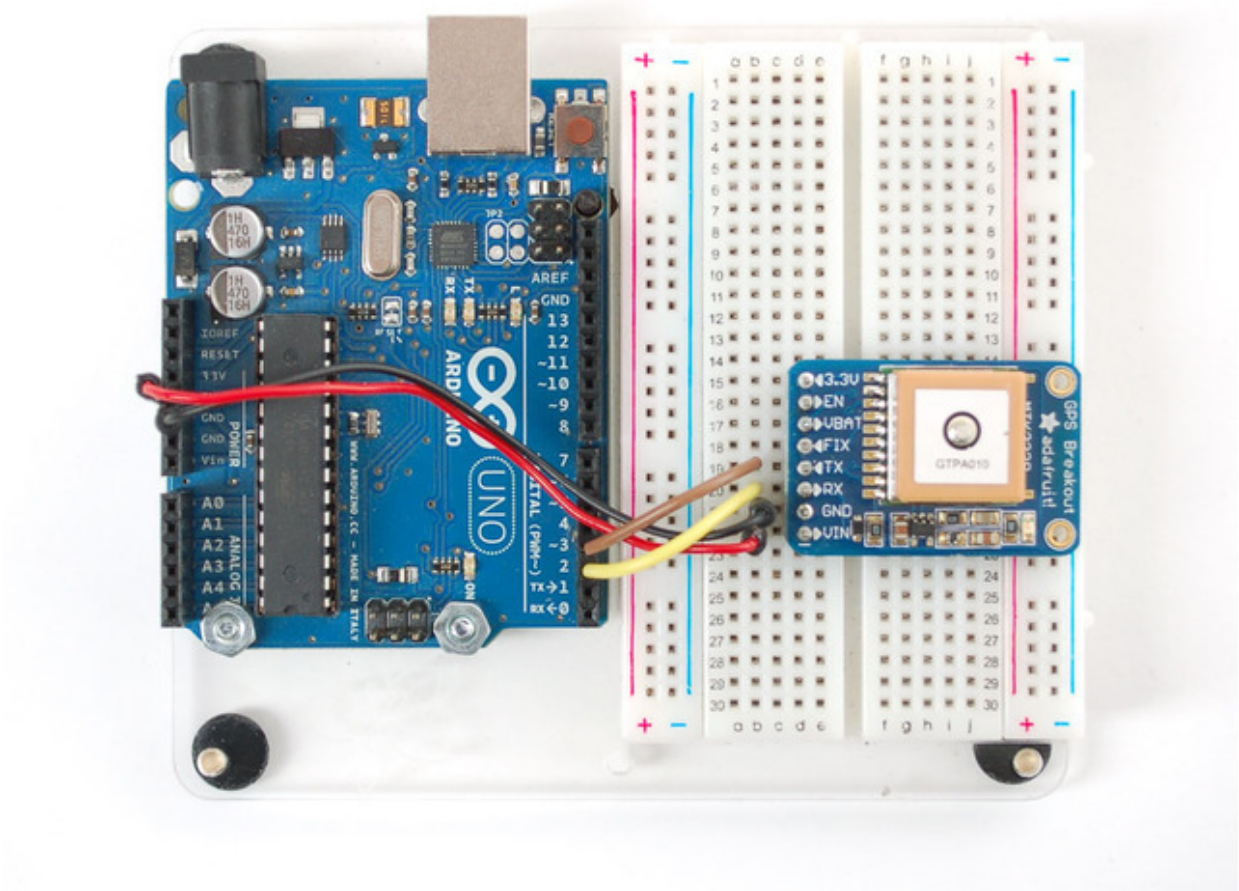
Finally there is the ***XX** data which is used as a data transfer checksum

Once you get a fix using your GPS module, verify your location with google maps (or some other mapping software). Remember that GPS is often only accurate to 5-10 meters and worse if you're indoors or surrounded by tall buildings.

Arduino Wiring

Once you've gotten the GPS module tested with direct wiring, we can go forward and wire it up to a microcontroller. We'll be using an Arduino but you can adapt our code to any other microcontroller that can receive TTL serial at 9600 baud.

Connect **VIN** to +5V, **GND** to Ground, **RX** to digital 2 and **TX** to digital 3.



Next up, download the Adafruit GPS library. This library does a lot of the 'heavy lifting' required for receiving data from GPS modules, such as reading the streaming data in a background interrupt and auto-magically parsing it. To download it, visit the GitHub repository and click the DOWNLOADS button in the top right corner (http://adafru.it/aMm) , rename the uncompressed folder **Adafruit_GPS**. Check that the **Adafruit_GPS** folder contains **Adafruit_GPS.cpp** and **Adafruit_GPS.h**

Leonardo Users: We have special example sketches in the Adafruit_GPS library that work with the Leo!

Place the **Adafruit_GPS** library folder your ***sketchbookfolder*/libraries/** folder. You may need to create the libraries subfolder if its your first library. Restart the IDE. You can figure

out your ***sketchbookfolder*** by opening up the Preferences tab in the Arduino IDE.

Open up the **File→Examples→Adafruit_GPS→echo** sketch and upload it to the Arduino. Then open up the serial monitor. This sketch simply reads data from the software serial port (pins 2&3) and outputs that to the hardware serial port connected to USB.

You can configure the output you see by commenting/uncommenting lines in the **setup()** procedure. For example, we can ask the GPS to send different sentences, and change how often it sends data. 10 Hz (10 times a second) is the max speed, and is a lot of data. You may not be able to output "all data" at that speed because the 9600 baud rate is not fast enough.

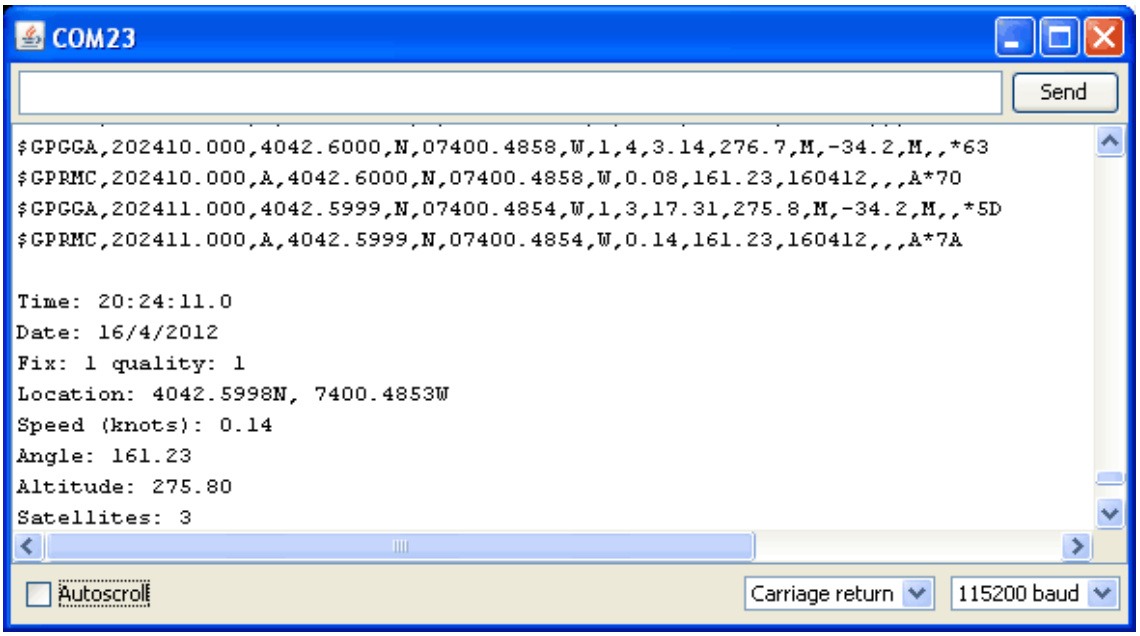
```
// You can adjust which sentences to have the module emit, below

  // uncomment this line to turn on RMC (recommended minimum) and GGA (fix data) including altitu
  GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_RMCGGA);
  // uncomment this line to turn on only the "minimum recommended" data for high update rates!
  //GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_RMCONLY);
  // uncomment this line to turn on all the available data - for 9600 baud you'll want 1 Hz rate
  //GPS.sendCommand(PMTK_SET_NMEA_OUTPUT_ALLDATA);

  // Set the update rate
  // 1 Hz update rate
  //GPS.sendCommand(PMTK_SET_NMEA_UPDATE_1HZ);
  // 5 Hz update rate- for 9600 baud you'll have to set the output to RMC or RMCGGA only (see above)
  GPS.sendCommand(PMTK_SET_NMEA_UPDATE_5HZ);
  // 10 Hz update rate - for 9600 baud you'll have to set the output to RMC only (see above)
  //GPS.sendCommand(PMTK_SET_NMEA_UPDATE_10HZ);
```

In general, we find that most projects only need the RMC and GGA NMEA's so you don't need ALLDATA unless you have some need to know satellite locations.

Parsed Data Output

Since all GPS's output NMEA sentences and often for our projects we need to extract the actual data from them, we've simplified the task tremendously when using the Adafruit GPS library. By having the library read, store and parse the data in a background interrupt it becomes trivial to query the library and get the latest updated information without any icky parsing work.

Open up the **File→Examples→Adafruit_GPS→parsing** sketch and upload it to the Arduino. Then open up the serial monitor.



In this sketch, we call **GPS.read()** within a once-a-millisecond timer (this is the same timer that runs the **millis()** command). Then in the main loop we can ask if a new chunk of data has been received by calling **GPS.newNMEAreceived()**, if this returns **true** then we can ask the library to parse that data with **GPS.parse(GPS.lastNMEA())**.

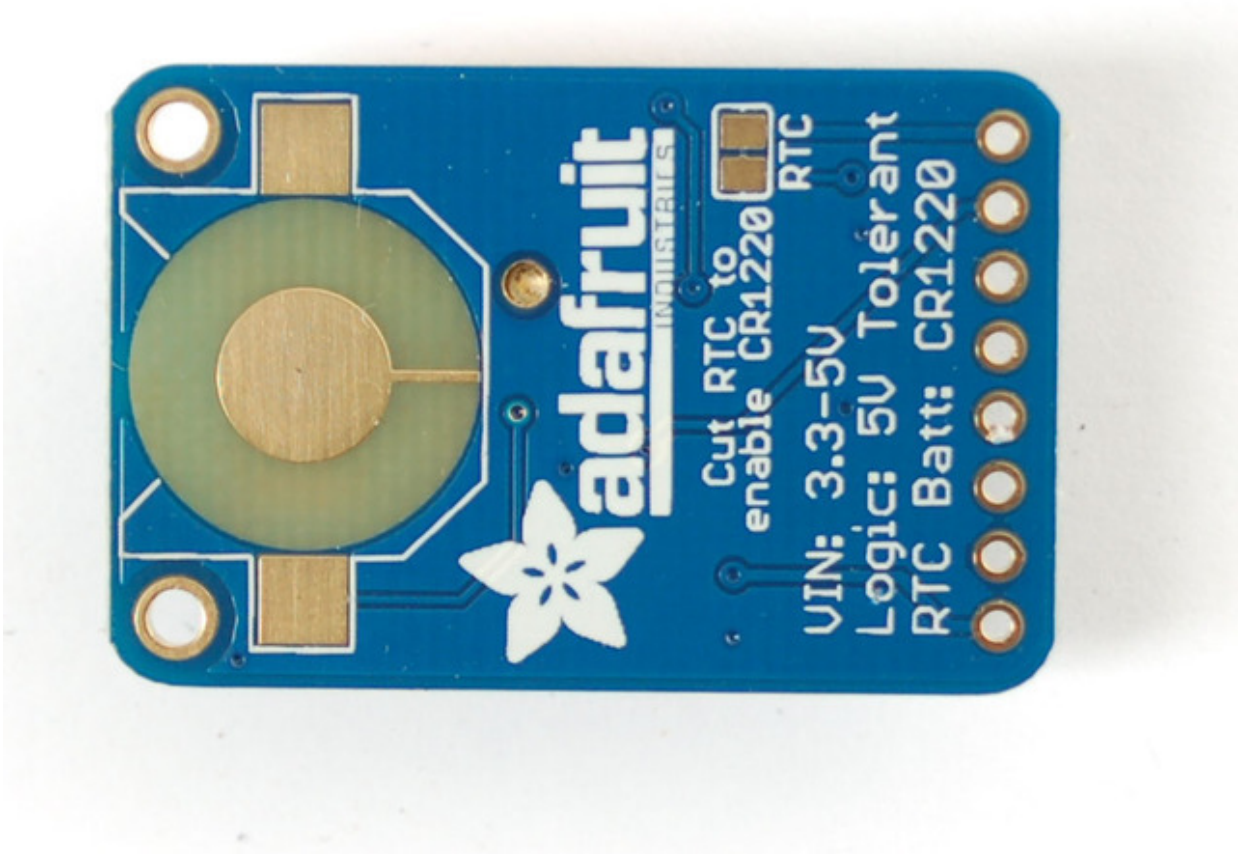
We do have to keep querying and parsing in the main loop - its not possible to do this in an interrupt because then we'd be dropping GPS data by accident.

Once data is parsed, we can just ask for data from the library like **GPS.day**, **GPS.month** and **GPS.year** for the current date. **GPS.fix** will be 1 if there is a fix, 0 if there is none. If we have a fix then we can ask for **GPS.latitude**, **GPS.longitude**, **GPS.speed** (in knots, not mph or k/hr!), **GPS.angle**, **GPS.altitude** (in centimeters) and **GPS.satellites** (number of satellites)

This should make it much easier to have location-based projects. We suggest keeping the update rate at 1Hz and request that the GPS only output RMC and GGA as the parser does not keep track of other data anyways.

Battery Backup

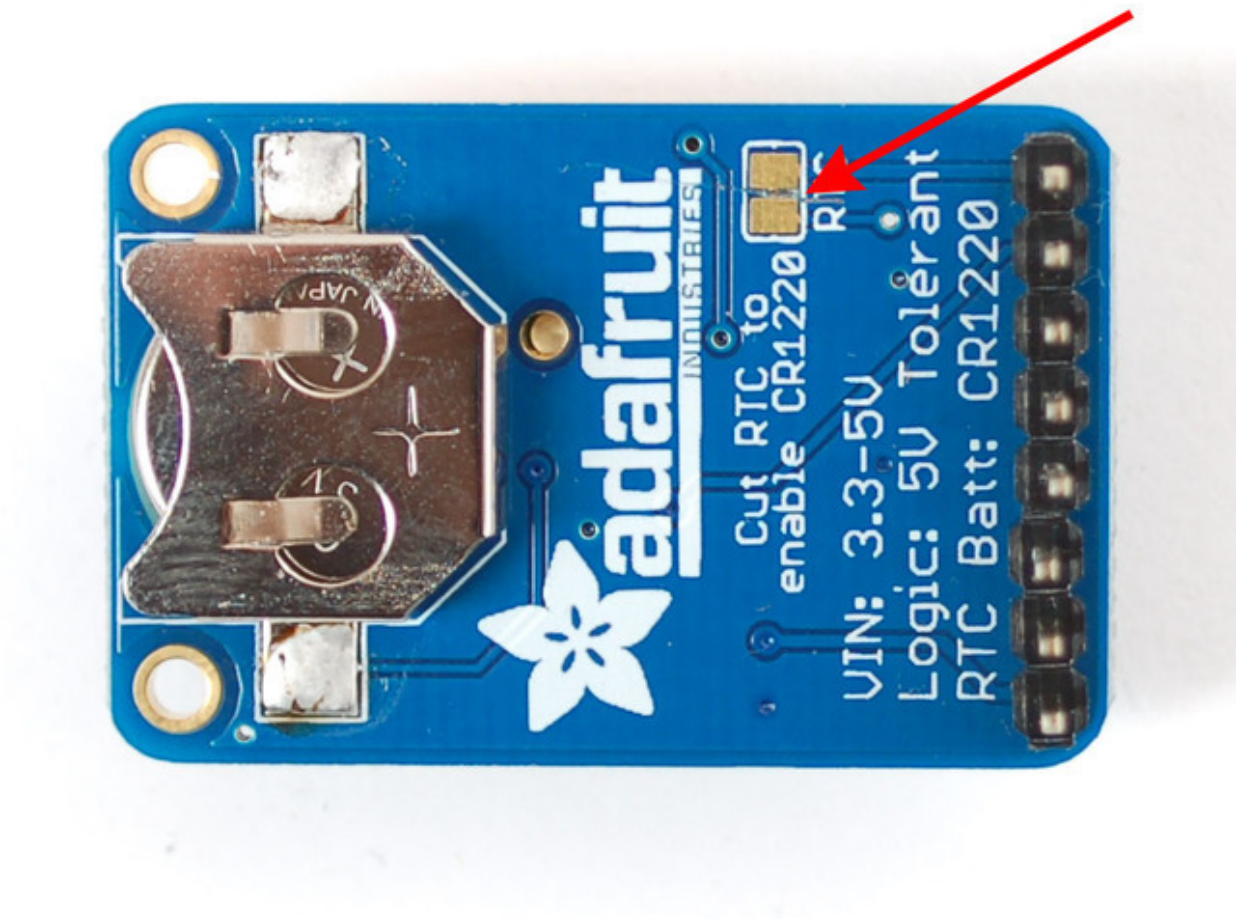
The GPS has a built in real time clock, which can keep track of time even when it power is lost and it doesn't have a fix yet. It can also help reduce fix times, if you expect to have a flakey power connection (say you're using solar or similar). To use the RTC, we need to attach a battery. There is a spot on the back for a **CR1220** sized battery holder. We provide the holder but the battery is not included. You can use any 12mm coin cell - these are popular and we also carry them in the Adafruit shop.



If you have a v1 or v2 module ONLY:

Before inserting a battery into the battery holder, first cut the trace between the two solder pads on the back, labeled RTC (this disconnects the VIN pin from the battery input) Use a multimeter with continuity checking to verify the two pads are no longer tied together.

V3 modules do not have a trace to cut, they have a built-in diode!



Remember, the GPS does not know what time zone you are in (even though it knows your location, there is no easy way to determine time zone without a massive lookup table) so all date/time data is in UTC (aka. Greenwich Mean Time) - You will have to write the code that converts that to your local time zone and account for Daylight Savings if required! Since that's pretty complicated, most people just stick to keeping everything in UTC

Advanced Wiring

Thus far we've only used the **VIN GND TX** and **RX** pins of the GPS - but there are many other pins. What do these do and will you ever need them? Chances are, for 90% of GPS projects, the other pins are not required. But we do make them available in case you have a specific need.

FIX is an output pin - it is the same pin as the one that drives the red LED. When there is no fix, the FIX pin is going to pulse up and down once every second. When there is a fix, the pin is low (0V) for most of the time, once every 15 seconds it will pulse high for 200 milliseconds

VBAT is an input pin - it is connected to the GPS real time clock battery backup. We suggest using the battery spot on the back but if you have a project with a coin cell or other kind of battery that you want to use (and its under 3.3V) you can connect it to the VBAT pin. **For V1 and V2 modules:** If you do this, be sure to cut the trace on the back between the RTC solder pads

EN is the Enable pin, it is pulled high with a 10K resistor. When this pin is pulled to ground, it will turn off the GPS module. This can be handy for very low power projects where you want to easily turn the module off for long periods. You will lose your fix if you disable the GPS so keep that in mind.

3.3V is the output from the onboard 3.3V regulator. If you have a need for a clean 3.3V output, you can use this! It can provide at least 100mA output.

PPS is a new pin output on v3 modules. Its a "pulse per second" output. It is 50ms long so it should be easy for a microcontroller to sync up to it

Built In Logging

One of the nice things about the MTK3339 is the built in data-logger. This basic data-logging capability can store date, time, latitude, longitude and altitude data into a 64K flash chip inside. Its not a high resolution logger - it only logs once every 15 seconds when there is a fix - but for 99% of projects that want to track location, this can be a great low power way to log data - no SD card or other EEPROM required! It can store up to 16 hours of data.

The GPS module does require a microcontroller to 'kick start' the logger by requesting it to start. If power is lost it will require another 'kick' to start. If you already have some data in the FLASH, a new trace will be created (so you wont lose old data) and if you run out of space it will simply halt and not overwrite old data. Despite this annoyance, its still a very nice extra and we have some library support to help you use it

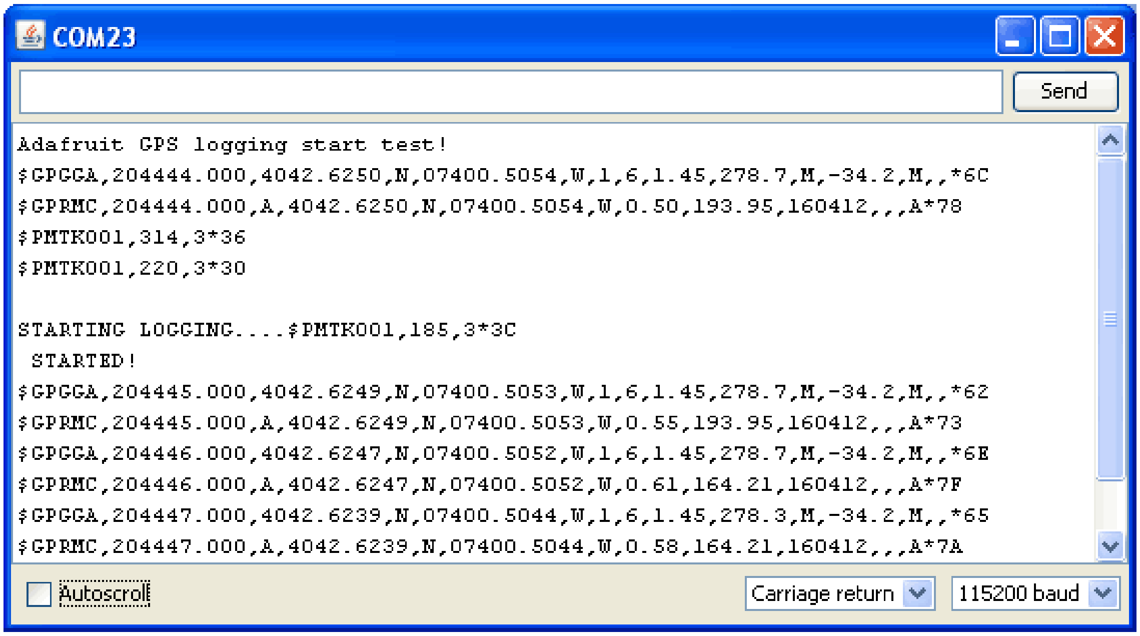
For more details check out the LOCUS (built-in-datalogging system) user guide (http://adafru.it/dL2)

First, we should try getting the logger to run.Open up the **File→Examples→Adafruit_GPS→locus_start** sketch. This will demonstrate how to start the logger (called LOCUS)

The key part is here:

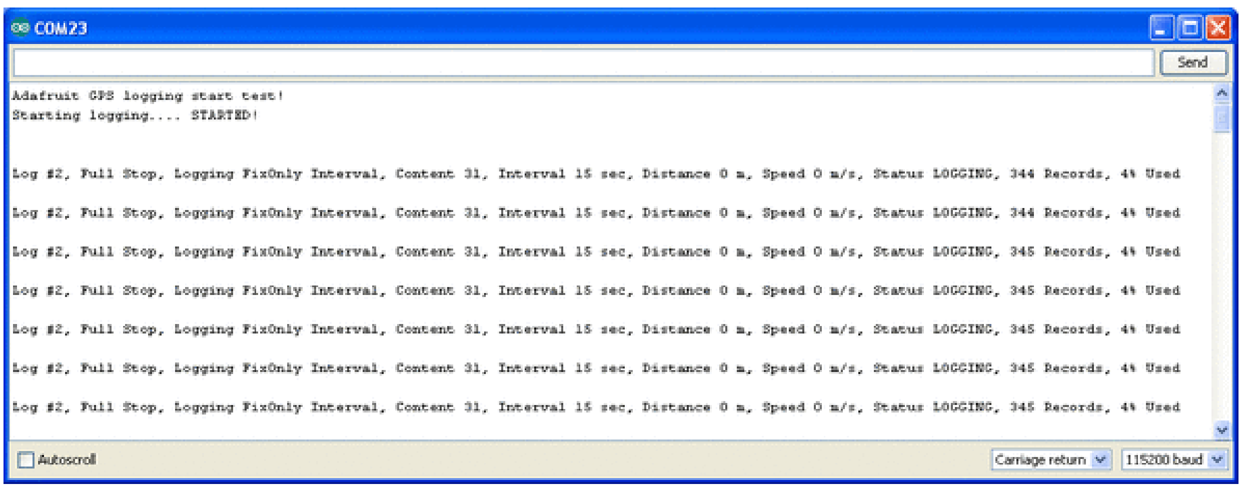
```
Serial.print("STARTING LOGGING....");
  if (GPS.LOCUS_StartLogger())
    Serial.println(" STARTED!");
  else
    Serial.println(" no response :(");
  delay(1000);
```

You should start the logger and then check the response:



Logging Status

Once you've seen that the GPS is OK with logging, you can load up the status sketch which will also give you more data. Upload **File→Examples→Adafruit_GPS→locus_status**



This output gives you some more information. the first entry is the Log #. This is how many log traces are in the memory. Every time you start and save data, a new log is made. Full Stop means that once the logger has run out of memory it will stop. Next the output indicates that we are logging only during fix data and at set intervals, with an interval delay of 15 seconds. We are not logging based on distance or speed. The current status is LOGGING (active), there's also the number of records we've stored. Each record is a timestamped location. We log once every 15 seconds, you can see the records increment from 344 to 345 here. Lastly, we can see how much of the internal flash storage is used, only 4% at this point

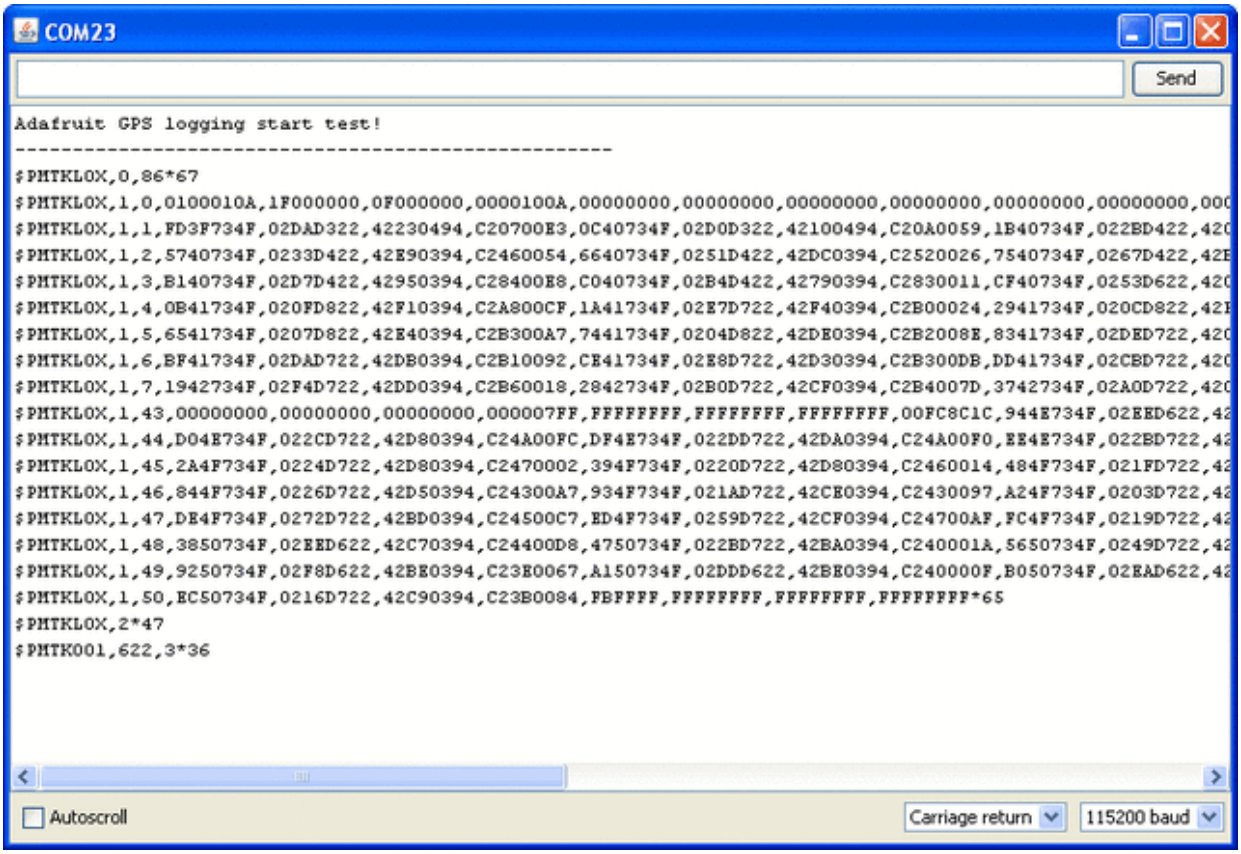
In real use, you'll probably want to start the loggging and then have your microcontroller go

to sleep to reserve power, waking up once in a while to check up on the logging status.

Downloading Data

Finally, once we're done logging we need to extract the data. To do this we need to first get the raw data out of the FLASH and then decode the sentences.
Upload**File→Examples→Adafruit_GPS→locus_dump** to the Arduino and open up the serial monitor

> PLEASE NOTE: Asking the Arduino, with 2K RAM buffer to handle 64KB of FLASH data and spit it out from the GPS can sometimes over-tax the processor. If you are having hiccups, check the GPS tool instructions below



Copy and paste all the text after the —-'s (starting with **$PMTKLOX,0,86*67** and ending with **$PMTK001,622,3*36**) then paste it into the box located on this page (http://adafru.it/cFg)

Using the GPS Tool

If you are having difficulty with the Arduino/javascript tool, you can also try using the GPS tool. The tool runs only under Windows but it is very powerful.

Connect the GPS module to an Arduino (connected with the Direct Wiring example) (http://adafru.it/aOP) , FTDI adapter or other TTL converter and download the GPS

Tool (http://adafru.it/aOQ) - connect to the GPS via the COM port of the Arduino/FTDI/TTL cable. You can then query, dump and delete the log memory

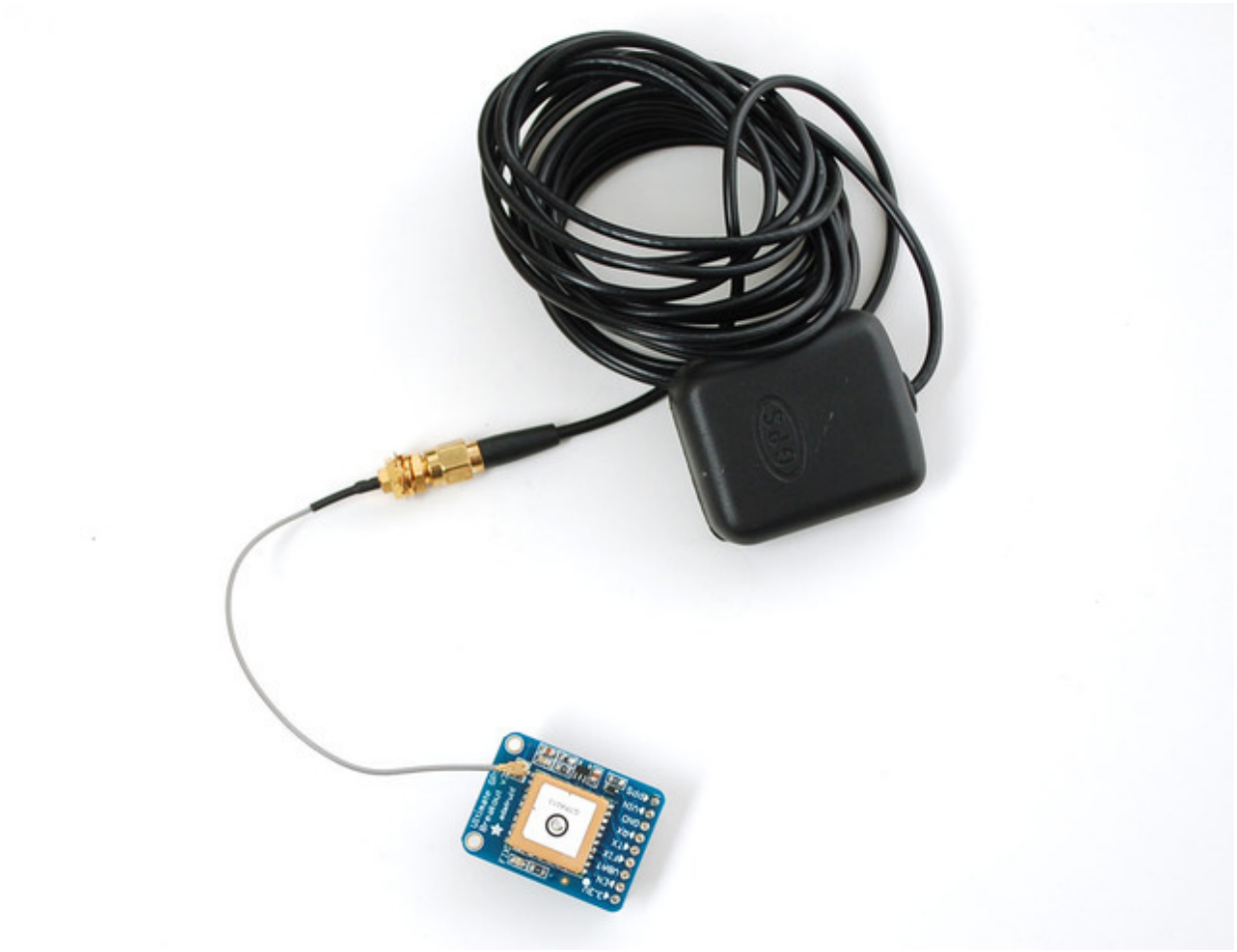
LOCUS Parser

LOCUS Parser (http://adafru.it/cFg)

External Antenna

New in version 3 of the Ultimate GPS breakout, we now have support for optional external antennas!

This is not available in v1 or v2 so if you do not see the uFL connector, you have an older version of the module which cannot support antennas



All Ultimate GPS modules have a built in patch antenna - this antenna provides -165 dBm sensitivity and is perfect for many projects. However, if you want to place your project in a box, it might not be possible to have the antenna pointing up, or it might be in a metal shield, or you may need more sensitivity. In these cases, you may want to use an external active antenna. (http://adafru.it/960)

Active antennas draw current, so they do provide more gain but at a power cost. Check the antenna datasheet for exactly how much current they draw - its usually around 10-20mA. (http://adafru.it/960)

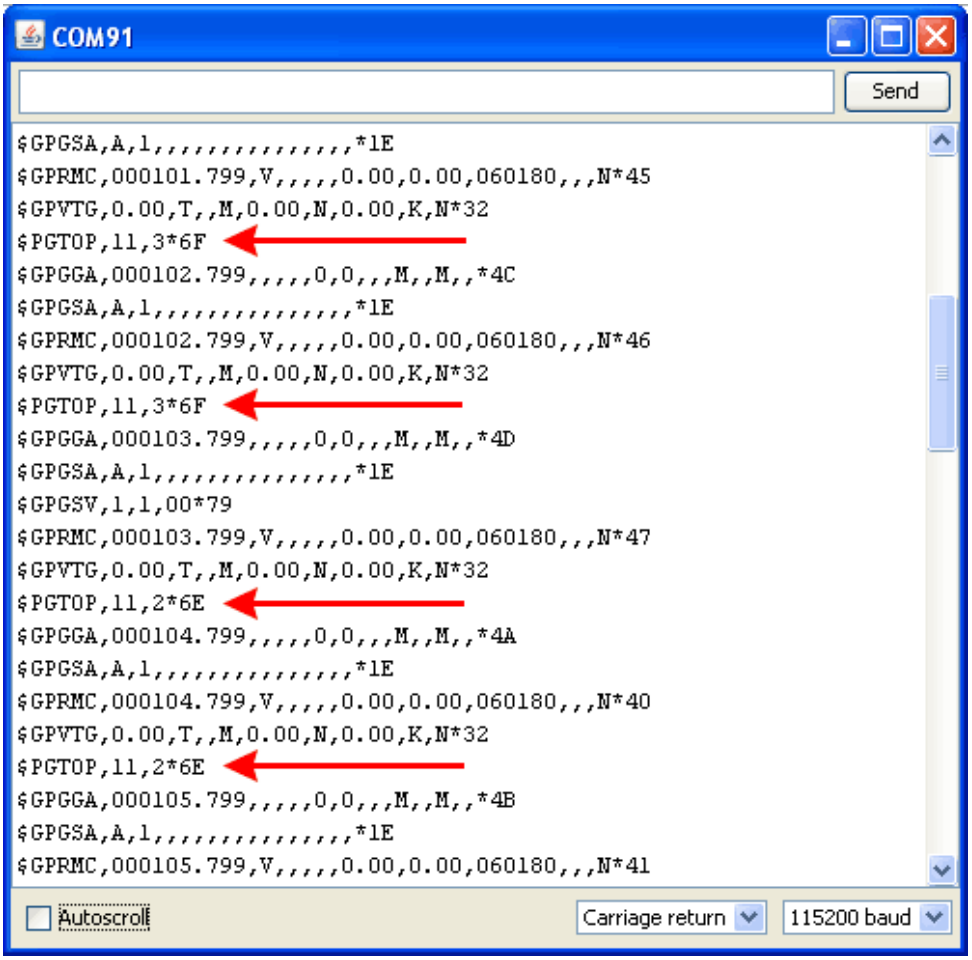
Most GPS antennas use SMA connectors, which are popular and easy to use. However, an SMA connector would be fairly big on the GPS breakout so we went with a uFL connector - which is lightweight, small and easy to manufacture. If you don't need an external antenna it wont add significant weight or space but its easy to attach a uFL->SMA adapter

cable (http://adafru.it/851). Then connect the GPS antenna to the cable.

The Ultimate GPS will automagically detect an external active antenna is attached and 'switch over' - you do not need to send any commands

There is an output sentence that will tell you the status of the antenna. **$PGTOP,11,x** where **x** is the status number. If **x** is **3** that means it is using the external antenna. If **x** is **2** it's using the internal antenna and if **x** is **1** there was an antenna short or problem.

On newer shields & modules, you'll need to tell the firmware you want to have this report output, you can do that by adding a **gps.sendCommand(PGCMD_ANTENNA)** around the same time you set the update rate/sentence output.



Downloads & Resources

- MTK3329/MTK3339 command set sheet (http://adafru.it/e7A) for changing the fix data rate, baud rate, sentence outputs, etc!
- PMTK 'complete' data (http://adafru.it/d2Q)sheet (like the above but with even more commands)
- Datasheet for the PA6B (MTK3329) GPS module itself (http://adafru.it/aMo)
- Datasheet for the PA6C (MTK3339) GPS module itself (http://adafru.it/aMp)
- Datasheet for the PA6H (MTK3339) GPS module itself (http://adafru.it/aPO)
- MT3339 GPS PC Tool (windows only) (http://adafru.it/aMq) and the PC Tool manual (http://adafru.it/aMr)
- Sample code and spec sheet for the LOCUS built-in logger (http://adafru.it/aTi)
- LOCUS (built-in-datalogging system) user guide (http://adafru.it/dL2)
- Mini GPS tool (windows only) (http://adafru.it/aMs)

More reading:

- Trimble's GPS tutorial (http://adafru.it/aMu)
- Garmin's GPS tutorial (http://adafru.it/aMv)

EPO files for AGPS use

Data format for EPO files (http://adafru.it/eb0)

MTK_EPO_Nov_12_2014.zip

http://adafru.it/eb1

F.A.Q.

Can my module do 40Km altitude? How can I know?

Modules shipped in 2013+ (and many in the later half of 2012) have firmware that has been tested at 40km.

You can tell what firmware you have by sending the firmware query command **$PMTK605*31** (you can use the echo demo to send custom sentences to your GPS)

If your module replies with **AXN_2.10_3339_2012072601 5223** that means you have version #5223 which is the 40KM version. If the number is higher then 5223 then its even more recent, and includes the 40KM support as well

HOWEVER these modules are not specifically designed for high-altitude balloon use. People have used them successfully but since we (at Adafruit) have not personally tested them for hi-alt use, we have it as a bonus extra not as a specifically-designed hi-alt module.

OK I want the latest firmware!

Here is the binary of the 5632 firmware (http://adafru.it/dR5), you can use this tool to upload it using an FTDI or USB-TTL cable (or direct wiring with FTDI) (http://adafru.it/dR6). We do not have a tutorial for updating the firmware, if you update the firmware and somehow brick the GPS, we do not offer replacements! Keep this in mind before performing the update process!

I've adapted the example code and my GPS NMEA sentences are all garbled and incomplete!

We use SoftwareSerial to read from the GPS, which is 'bitbang' UART support. It isn't super great on the Arduino and does work but adding too many delay()s and not calling the GPS data parser enough will cause it to choke on data.

If you are using Leonardo (or Micro/Flora/ATmega32u4) or Mega, consider using a HardwareSerial port instead of SoftwareSerial!

How come I can't get the GPS to output at 10Hz?

The default baud rate to the GPS is 9600 - this can only do RMC messages at 10Hz. If you want more data output, you can increase the GPS baud rate (to 57600 for example) or go with something like 2 or 5Hz. There is a trade off with more data you want the GPS to output, the GPS baud rate, Arduino buffer/processing capability and update rate!

Experimentation may be necessary to get the optimal results. We suggest RMC only for 10Hz since we've tested it.

How come I can't set the RTC with the Adafruit RTC library?

The real time clock in the GPS is NOT 'writable' or accessable otherwise from the Arduino. Its in the GPS only! Once the battery is installed, and the GPS gets its first data reception from satellites it will set the internal RTC. Then as long as the battery is installed, you can read the time from the GPS as normal. Even without a proper "gps fix" the time will be correct.

The timezone cannot be changed, so you'll have to calculate local time based on UTC!