TT RACE DATA LOGGER

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Summary

This report is made to accomplish the demand from TriCAT Racing motor race team. They suggest if it was possible to create a device capable to log data from a motorbike during a race or testing seasons, mentioning some other similar systems out on the market, but is really expensive. Taking an initial idea, we thought about one way to design a system capable of satisfy the demand of our contractor, trying to reduce costs on the design.

At this point we accept the project offered by TriCAT racing team. Known the several issues that they have about the design and studying the different ways to make it, the design is starting to be thought. The contractor needs that the system has to be capable of store the data into a SD card, this data are: position, velocity, RPM, cornering angle and lap time of a motorbike in a circuit race. For solve this issues we thought about microprocessors, GPS's, and other kind of possibilities, arriving to one possible solution.

Now the solution of design question is solved, it is possible to design a system capable to accomplish the demands of the contractor, with a microcontroller PIC18F4550 and a GPS Unit, one Accelerometer, and programming a complex program on C for microcontrollers it is possible arrive to a solution.

When we start to build the first prototype and we decide to test it a problem appears, not enough space in ROM memory. During the implementation part, we arrived the conclusion that we made an error choosing the microprocessor PIC18F4550, this error is because the ROM memory. The program that we are using is too big, and the ROM memory of the microprocessor PIC18F4550 it's not enough to contain all the program.

As a result of the short time disposed for make the project, and the errors made at the end, it is not possible to change the design, the prototype is build and we are trying to make it run. If the project could be continued for another students or another engineers, the best idea for start, is change the microcontroller for another with the minimum resources needed by the C program.

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1. Introduction

Since many years, professional teams from the high end of the TT Motorbike Races are spending thousands of Euros trying to get efficient systems that could provide detailed information about the behavior of a motorbike and his pilot during a professional race. They want Information like angle of cornering, horizontal acceleration, brake pressure, real time video streaming and recording to monitor the movements of the pilot, etc… These systems are really expensive and they are only designed to improve the performance of the bike and the driving skill of the Pilot. They are created by teams of expert engineers with a huge presupposition.

Actually, amateur races are becoming progressively more usual and more people are interested to race in a circuit. Like at professional races, to improve their skill it would be attractive to use some technology that gives to you information about the behavior of yourself and your motorbike has had during the race. We ask ourselves if it would be possible to design a cheap, easy, removable and small device that offers the maximum utilities, sensor resources and best performance that can be offered at this moment with low price. This device could not be expensive because amateur drivers compete for fun or medium level training. It means they usually don't have any source where they can provide money for improvements in their motorbikes as the professional teams have with the sponsors and the advertisement.

To complete this accomplishment is needed a previous study of the statements that we have to take care related about processional races. For example: behavior of a motorbike, structure of a motorbike, how it works, environment where it is and the forces suffered during a race. Also a study of what the technology offers at this moment and the money that's required to get it.
These studies are meant to answer this question: What can be or not be done? Have been answered this question and got a good, cheap and efficient answer, we will proceed designing an algorithm and implementing it into a Prototype. This Prototype has to be able to make data logging from a TT Race Motorbike. Getting Data from different sensors placed on the motorbike.

Tricatracing is a Duch motorrace team that offers to us the possibility of design one of those systems, given to us some information about the motorbike and also the races, with a minimum budget to design a prototype capable to do this work.

2. Goals

The main goals are focused in the study the possible solutions and build a design for a Data Logger to accomplish:

- Easy interface Data logging for amateur drivers
- Non destructible data collector
- Low price
- Easy installation

Like in professional races data logging is based in collect data from the bike and the driver for make a study of it.

This device has to be able to provide data about :

- Speed, RPM
- Acceleration
- Horizontal G Forces
- Angle
- Position on the circuit
- Chrono Time Global/ first 100m

The design is made for amateur drivers and has to be easy to install.

- Easy downloading data (USB, Removable Memory)
- Easy to install (Laptop, Mobile Phone)

This device is thought for amateur customers, it has to be cheap and reliable. The idea is to keep a design between the accuracy and the price, with enough performance and efficiency but low cost.

Implement this design into a Prototype granting all the requirements mentioned.

3. Analysis

3.1 Theory of Data Logging

The term “Data Logging” means collect information about some entity or event during time in relation with his physical properties or position. This information generates data that has to be stored for later study. “Data Logger” is an electronic device that records data over time or in relation to location either with a built
in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor (or computer), generally are small, battery powered, portable, and equipped with a microprocessor, internal memory for data storage, and sensors.

3.2 TT Race Data Logger

TT Race Data Logger should be an electronic device capable of collect and store data from nearby sensors. It’s meant to work with a motorbike, logging data about the behavior and the position during a race.

3.3 Functionality

The main idea is to generate a file with all the information about your last track, stored in one Standard removable memory (SD /MMC) in TXT format.

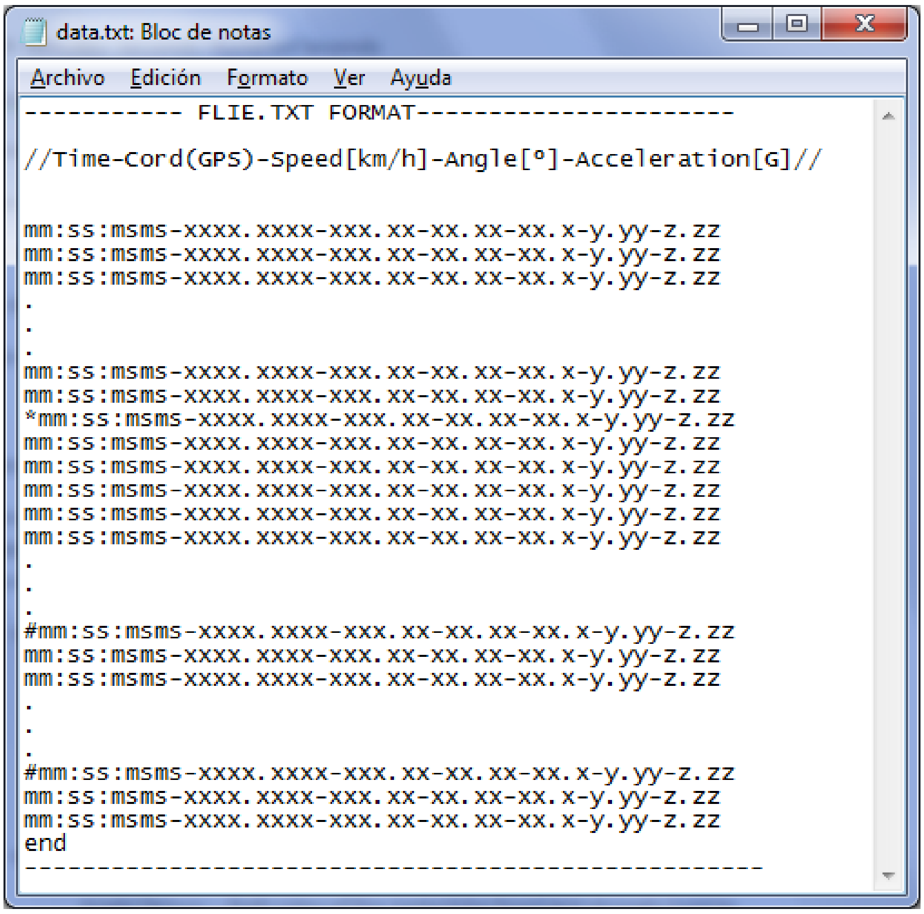
At least is needed a device capable to store data during 30 minutes of tracking race. Divide in several files.

This Txt file contains all the data showed as a clearly table with all the values in columns with a step of 1/5 second.

First contains a table with the Global time values since the beginning of the race to the end. At the end of the file, shown the average time calculated for the 100 meters.

The syntax of the table stored in the TXT file is shown below.

3.4 File format



```
----------- FLIE.TXT FORMAT----------------------

//Time-Cord(GPS)-Speed[km/h]-Angle[º]-Acceleration[G]//


mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
.
.
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mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
*mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
.
.
.
#mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
.
.
.
#mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
mm:ss:msms-xxxx.xxxx-xxx.xx-xx.xx-xx.x-y.yy-z.zz
end
--------------------------------------------------
```

Figure 1: Example file of the file obtained

Marks

- (*) is pointing the time of the 100 first meters.
- (#) is pointing the lap time, every lap the program will write an “#” for mark this line.

Units

Time → Minutes: Seconds: Hundred Seconds

Coordinates → (Latitude. Longitude) Degreesª Minutes’ Seconds’’

Acceleration → X, Y, Z ; the units for this axes are G forces.

Speed → Kilometers/Hour (Km/h)

Angle → Radians (rad)

3.5 Interface

This device is designed for amateur customers and it needs to have an easy and quick installation on the motorbike with a non destructible data collector. Also it has to have an easy extraction of the files generated.

Installation on the Motorbike (Installation needed)

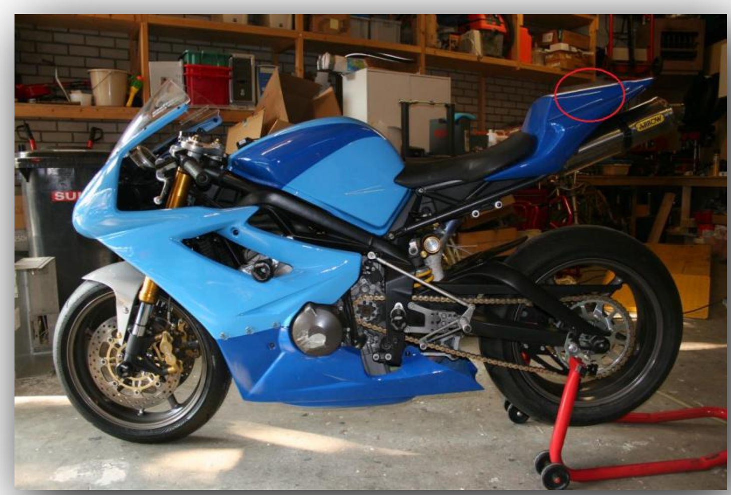
Core – Somewhere, away from warm and electromagnetic sources.

RPM Sensor – Cooper solenoid coiled to ECU's Rpm Wire or directly to spark plug with a circuit protection.

GPS antenna – Away from the main engine solenoid and directed to open sky.

Angle Sensor – Both sides of the motorbike fixed and strongly hold to the chassis

Accelerometer – Placed inside of the main core or mother board.



Picture 1 : Best location for TT Race Data Logger

Above, is shown the best location to integrate TT Race Data Logger to the motorbike if the GPS antenna is inside the device itself. This place accomplish all the requirements: open sky, away from electromagnetic sources and this area will never be covered by the pilot.

NOTE: The base of the device has to be parallel to the road, for the correct accelerometer's functionality.

Extraction of the files:

Via Standard SD/MMC Socket (Easy to plug/unplug)

Via USB 2.0 Interface (Download the Files directly to a Computer)

Power Duration - 3 Hour

3 Optional Inputs for more sensors
Memory – 512KB/1GB

Sensors Sample Rate – 100Hz

Chrono Step : 1/5 seconds

4. Study of Possibilities

A previous study of the possibilities is needed to decide the best and cheap options that the technology offers to get the desired information. It includes a study of the sensors, the GPS unit and where they should be placed. Also a review of how a motorbike behaves during a race (Max suffered G's, Cornering Angle, and engine's ECU's).

4.1 Cornering, Angle Detection and Study of Gravitational forces (G's)

One important thing on the motorbike races is the manner that the pilot is turning on the corner, this action has to be perfect to do it as fast as possible. To improve this, is important to know how the pilot is taking every corner. So is needed a system capable to measure the angle of the motorbike on each corner.

To resolve this problem we have thought of an accelerometer, with it we could take the angle, doing some calculations with the values given by this device.

Here some information about the accelerations suffer by the motorbike.

On the graph, traction is shown as the accelerative force in every direction:

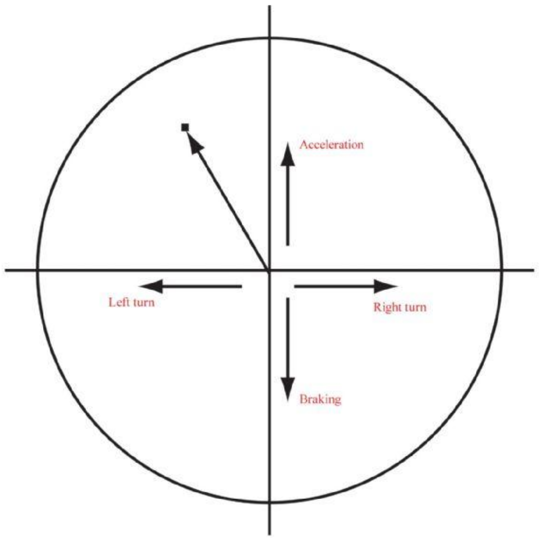


Figure 2 : G Forces Vector

What we normally call acceleration is a positive longitudinal force (longitudinal being along the direction of travel of the motorcycle).Shown on the graph as a point on the upper half.

Braking is a negative longitudinal force, shown on the bottom half of the graph. Cornering generates lateral forces, generally felt as centrifugal force when you're in a car, for instance. On the traction circle, points on the right-hand side represent a right-hand turn, and vice versa.

We've covered both axis of the graph so far, but what about points away from an axis? Say you were accelerating out of a right-hand turn, generating forces in both the lateral and longitudinal directions. This would show as a point in the upper right-hand quadrant of the graph. Likewise, trail braking into a left-hand turn is displayed as a point in the bottom left-hand quadrant.

Also we have the vertically acceleration, it means that it's possible to calculate the angle of the bike when it turns in a corner, with the acceleration forces separates in 3 axis. Each one contains the acceleration on their directions, as we told before the acceleration could be negative.

The tires on the motorcycle are capable of providing a certain level of grip in any one direction; let's say the maximum accelerative force is 1'5 G, a realistic number. This force can be applied all in one direction, such as braking or turning, or in a combination of directions-braking and turning. Since we're dealing with vector forces that are summed with a value as well as a direction, the graph of maximum grip values is shown as a circle: the traction circle with a radius of 1,5 G.

Taking the result force vector and making on it some trigonometric equations finally we could know the angle that the bike needs for remain in the road, without sliding.

If the motorbike starts to slide, the resultant angle will not be the exact one. The lateral acceleration will be highest because the motorbike is sliding, in result we will have a non exact angle.

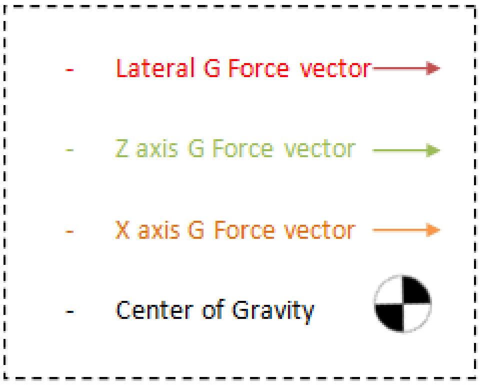
Looking at the circle, some things become apparent. Say you are at maximum lean in a right-hand turn. On the traction circle, this puts you at a point on the far right. Here, it's unwise to accelerate or brake, leaving you on the horizontal axis with no longitudinal acceleration. But what if you want to change that? Moving around the circle representing maximum available grip, it's clear that to add some longitudinal force in the form of accelerating or braking requires that lateral force be reduced to maintain a maximum total G force less than 1'5 G.

Picture 2: TT Race Driver cornering.

As we exit the turn, more acceleration force is added, requiring that less lateral force be applied: the bike must be straightened to accomplish this. Continuing on, eventually we arrive at the vertical axis of the graph with full acceleration and no turning forces.

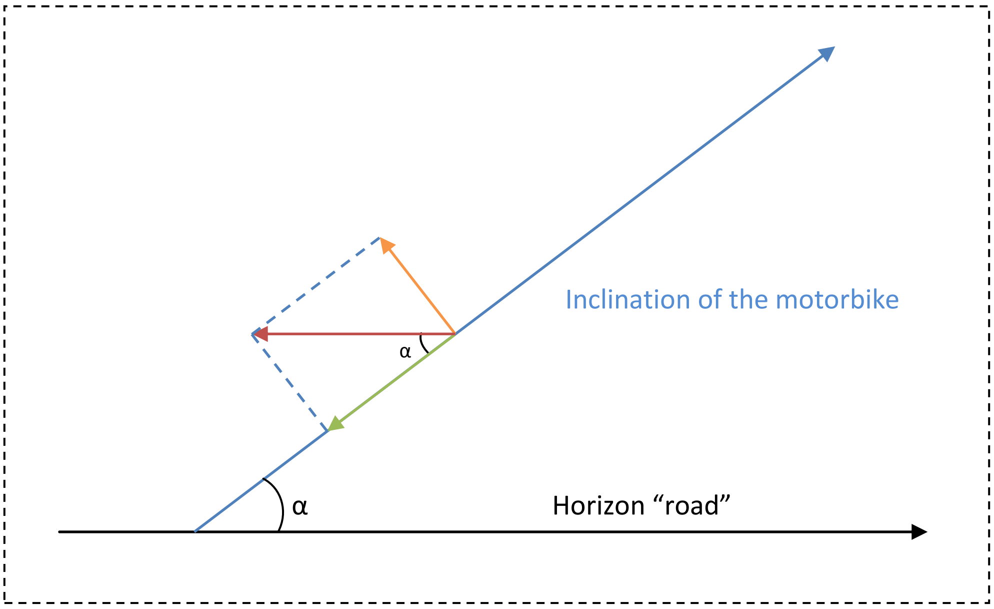
4.1.1 Theoretical example

Piucture 3 : pilot cornering



To take the angle of the motorbike in this case we need to know some trigonometric laws. The Lateral G Force vector is the result of the sum X and Z axis. Lateral G force will ever be parallel to the horizon, for remain the motorbike on the road.

Here is the study and result of the angle.



Alpha "α" is the inclination angle of the motor bike, as we know our design with an accelerometer gives to us the resultant G force on each axis, knowing the value of the G forces X axis G Force vector and Z axis G Force vector, we could calculate the value of the angle α.

Equation:

$$\alpha = \tan^{-1}\left(\frac{\text{X axis G Force vector}}{\text{Z axis G Force vector}}\right)$$

As a result of the calculations, we get the angle, also with the G forces we could make a study of the circuit race.

It's possible to make a graph with the results of the G force samples, and know how the tires are suffering in the race, the samples will descript the global forces during the race.

Here one example of all samples taken on a training session (not ours).

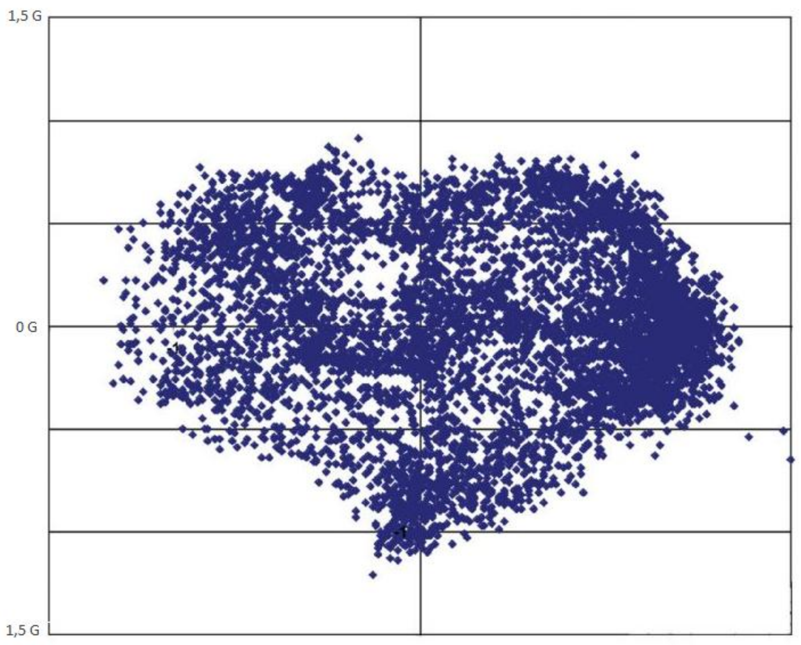


Figure 3 : G force samples

In order to see and understand the graph we know that the part of the right means turn left and left means turn right.

Gyroscopes tilt sensors and are tools that are capable to calculate the angle between an already known point to another in 3 planes of the space. They are mechanical/electrical tools it means some none desired forces applied to these sensors are going to change the correct functionally of themselves. On the other hand, the accelerometers gives the acceleration on 3 Axes. Knowing the forcers G's on the motorbike and how to calculate the angle from them an accelerometer is a good choice.

Advantages → Relative cheap for the required porpoises.

Disadvantages → Relative Accuracy.

4.2 Angle Detection By Range Finder

Range Finder is a tool capable to measure the straight distance between two points. A laser range finder with enough accuracy (3, 4 meters) will do the job. Placed and strongly hold at the chassis of the bike, we can know the distance between the bike and the road, it means, with trigonometric calculations, also the desired angle. It's a laser and the undesired gravity forces are less harmful to his functionality than a mechanical component but are afflicted by electromagnetic fields.

Advantages → Extremely high Accuracy, fidelity and performance.

Disadvantages → Extremely high price, thousands of Euros. Big Size and weight.

Laser Rage Finder Calculation example

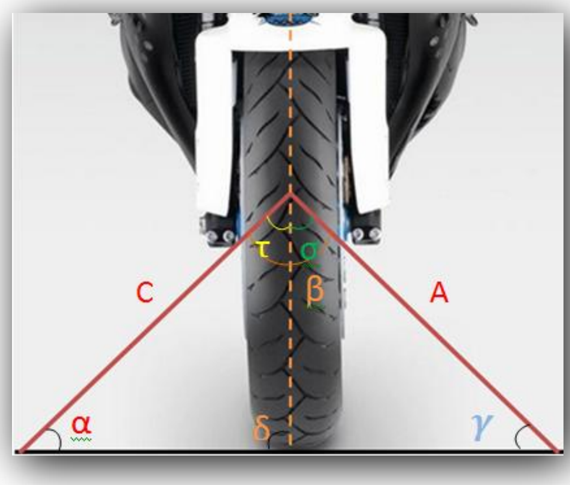


Figure 4 : Angles used to calculate the cornering angle

That picture above shows the situation of the lasers on the motorbike. We need minimum 2 lasers placed at both sides to calculate the angle. The lasers are the segments A and C. And the desired angle is Delta. The lasers are positioned making a 90º angle between each other.

We can found Delta using trigonometric equations because the lasers provide the value C and A all the time.

The calculations are:

With A and C:

$$\frac{C}{A} = \tan\gamma \rightarrow \tan^{-1}\frac{C}{A} = \gamma\,;$$

With Gamma:

$$\beta = 90^\circ\,; \quad \gamma = known\,; \quad \alpha = ?\,;$$

$$180^\circ = (\beta + \gamma + \alpha) \rightarrow \quad \alpha = 180 - \beta - \gamma;$$

With Alpha:

$$\tau = 45^\circ\,; \quad \alpha = known;$$

$$180^\circ = (\,\tau + \alpha + \delta\,) \rightarrow \quad \delta = 180 - \tau - \alpha\,;$$

We have got δ;

It’s possible to get the desired angle only with arithmetic calculations.

4.3 Power Supply

It would be interesting to design an autonomous and internal power supply system to improve performance and utility. Integrating this system, TT Race Data Logger gets complete autonomy and has the possibility to work on his own.

A power supply is compounded by a rechargeable battery, a charging system, and voltage regulators to deliver the desired voltage to all the sub-devices.

4.4 Revolutions per Minute (RPM's) and Engine Control Unit (ECU)

It consists on a cooper wire or clamp coiled or hold to the ECU's Rpm cable stealing the signal that is traveling through the cable, already installed in all motorbikes. How is required, this is a non destructible way to get the signal from de ECU.

If we have the signal from the wire, we can count the pulses generated by the ECU and calculate the frequency by an A/D conversion.

The following pictures show the procedure

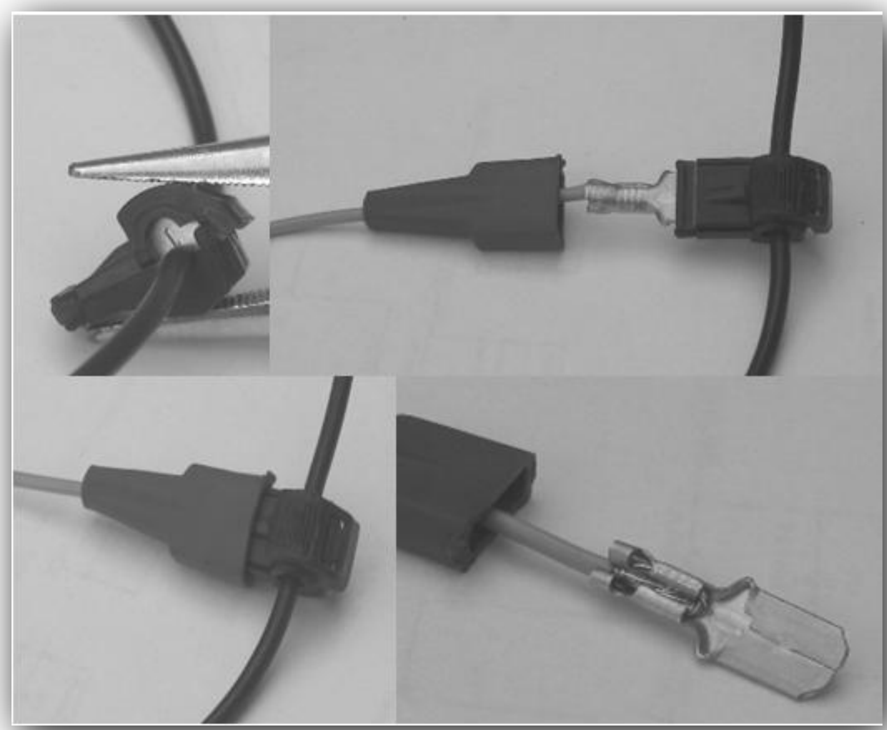


Figure 5: cable connectors for the ECU's cable

Also it's possible to do the same procedure but directly to the wire of the Spark plug but it's necessary some kind of circuit protection because the amperes generated by the spark plug are really high and not accurate. If we know the amount of cylinders, we could know the revolutions per minute.

In conclusion the best way to get the RPM's is from the ECU.

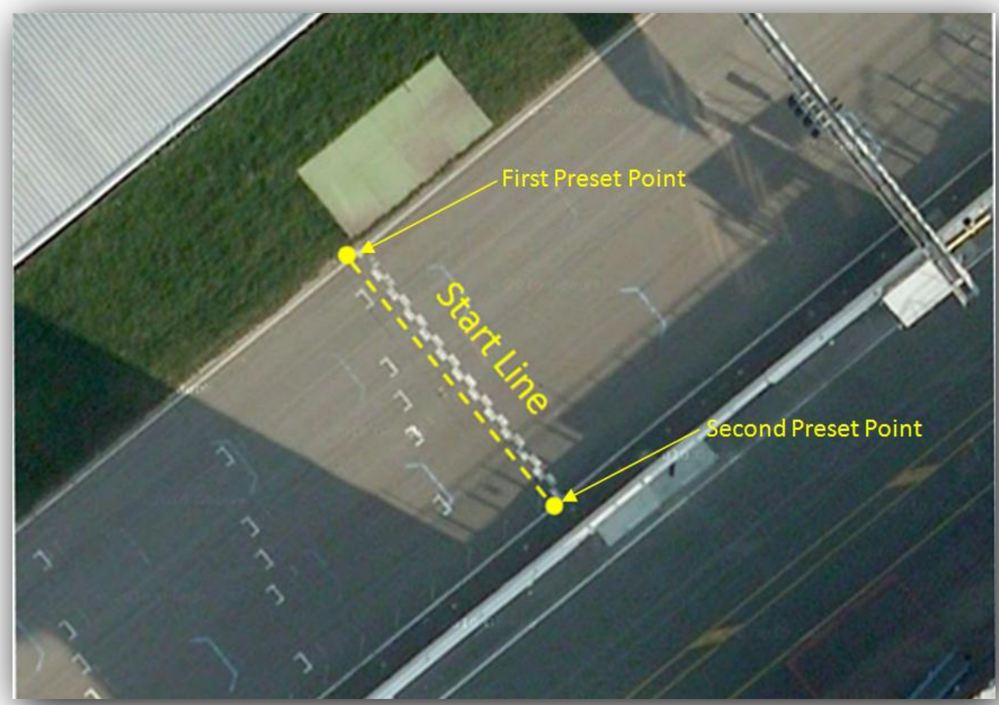
NOTE:. It's offered only a theoretical design and way of implementation but it won't be implemented in the prototype as contractor's request because is an inaccuracy system. It needs lot of testing and prototyping.

4.5 Speed and Position

There's no best option than a GPS to get the Position. Is Accurate enough, cheap and also grants the speed, date and time to our system.

It's possible to get the speed from one of the cables from the ECU with the same procedure as the RPM's.

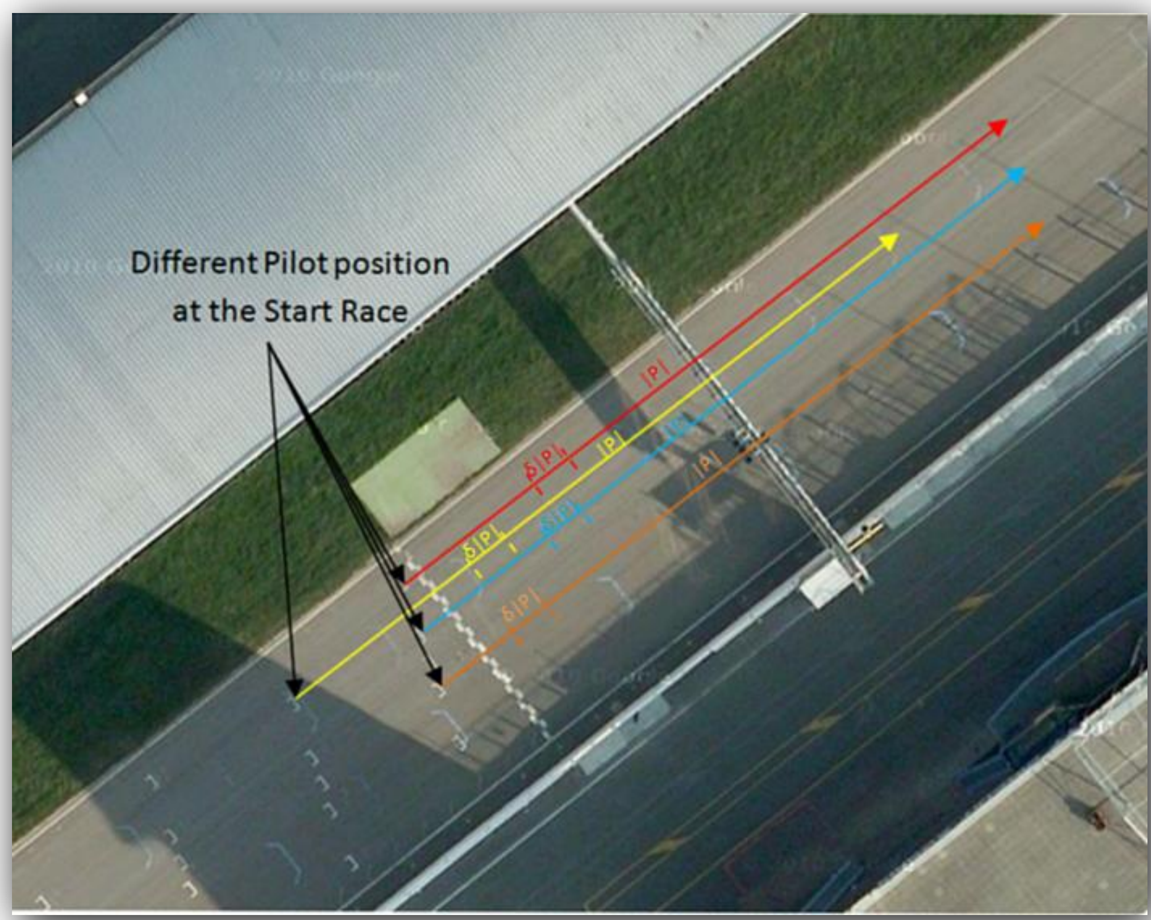
4.6 Start/End Beacon Line



Picture 4: The two Preset Points for the beacon line.

To get a preset beacon line, it is necessary to do it like is shown in the previous Picture, its necessary two presetting points. We could make and imaginary line knowing the difference between them.

4.7 Calculation time of 100 first meters



Picture 5: Vectors with a module of 100 meters

In order to know the time of the first 100 meters made by a pilot in a race, it is possible to calculate it by different ways. We decide to do it by a vector; TT Race Data Logger has to calculate every sample the module of the vector generated between the start position and the current position , when the vector module size is equal to 100 meters, the device store the time realized in those 100 meters.

The manner to do it is calculating every sample the "δ|P|" differential of the module , giving an accuracy module vector. Then comparing the value of this vector to the cipher 100m we obtain the time expended for it.

5. Hardware Requirements and Solutions

As a result of the previous investigation we decide that our TT Race Data Logger has to include the following sub-devices to grant the desired functionality.

5.1 Mother Board / Core

Our Data Logging device needs to process the amount of data generated by the sensors, it means we need some kind of processor to understand and store this data. The best and cheap option is a microcontroller programmed in assembler for our purposes. We can found the microcontroller itself but it's necessary to design the connections and the environment between the microcontroller and the sensors. Another and faster way is to use a standard prototyping board that already has all of that.

5.2 GPS Unit

To Know the position, straight acceleration, date and time is needed a GPS unit.

A Standard GPS receiver unit with antenna working with a digital protocol RX, TX, in USART mode, with enough sample rate to get the position, the speed, the acceleration and time from the satellites.

Try to design some system onboard to get the value of the speed and straight acceleration it would be redundant. GPS offer to us the best way to get this information. It's quick and exact.

GPS Accuracy -

Initialization Start – Less than 5-30 seconds

Sample Rate- 1 Mhz

Range - 5 to 10 meters (Best on the market)

The most GPS units on the market are working with NMEA protocol and It is required a previous study of this protocol to ensure a correct design.

5.2.1 The NMEA Sentence

GPS data comes in a data stream form known as NMEA sentences. NMEA is the universal standard for information coming from GPS satellites. In particular, the NMEA-0183 is of interest to our project. In order to use any of the data you must know what kind of data you need. These sentences include all kinds of information about the position, time, and direction of the receiver and this information is usually displayed on a screen or delivered to a device or computer. Several sentences are delivered to the receiver at once. These sentences are updated every 1 millisecond to every several seconds depending on the receiver and the use. Each sentence contains a different kind of data stream. Some types and examples are listed below.

Sentence	Description
$GPGGA	Global positioning system fixed data
$GPGLL	Geographic position - latitude / longitude
$GPGSA	GNSS DOP and active satellites
$GPGSV	GNSS satellites in view
$GPRMC	Recommended minimum specific GNSS data
$GPVTG	Course over ground and ground speed

Table 1: Description important kind of NMEA sentences

The GPGGA and GPVTG example are the most useful because our data logger cans incorporate the times, and date as well as the position, and speed. Most receivers transmit each type of sentence consecutively, each one beginning with a dollar sign and ending with a carriage return. The GPGGA example and its characteristics is listed below.

Table B-2 contains the values for the following example:

GGA-Global Positioning System Fixed Data

Signal not acquired:
$GPGGA,235947.000,0000.0000,N,00000.0000,E,0,00,0.0,0.0,M,,,,0000*00 Example
Signal acquired:
$GPGGA,161229.487,3723.2475,N,12158.3416,W,1,07,1.0,9.0,M,,,,0000*18

Table B-2 GGA Data Format

Field	Example	Comments
Sentence ID	$GPGGA	GGA Protocol Header
UTC Time	092204.999	hhmmss.sss
Latitude	4250.5589	ddmm.mmmm
N/S Indicator	S	N = North, S = South
Longitude	14718.5084	dddmm.mmmm
E/W Indicator	E	E = East, W = West
Position Fix	1	0 = Invalid, 1 = Valid SPS, 2 = Valid DGPS, 3 = Valid PPS
Satellites Used	04	Satellites being used (0-12)
HDOP	24.4	Horizontal dilution of precision
Altitude	19.7	Altitude in meters according to WGS-84 ellipsoid
Altitude Units	M	M = Meters
Geoid Seperation		Geoid seperation in meters according to WGS-84 ellipsoid
Seperation Units		M = Meters
DGPS Age		Age of DGPS data in seconds
DGPS Station ID	0000	
Checksum	*1F	
Terminator	CR/LF	

Table 2: Data format

VTG-Course Over Ground and Ground Speed

Example : $GPVTG,309.62,T,,M,0.13,N,0.2,K*6E

Name	Example	Units	Description
Message ID	$GPVTG		VTG Protocol Header
Course	309.62	Degrees	Measured heading
Reference	T		True
Course		Degrees	Measured Heading
Reference	M		Magnetic
Speed	0.13	Knots	Measured Horizontal Speed
Units	N		Knots
Speed	0.2	Km/hr	Measured Horizontal Speed
Units	K		Kilometers per Hour
Checksum	*6E		
<CR><LF>			End of message termination

Table 3 : VTG- sentence explanation

Our software on the PIC18 will read each character looking for the dollar sign. Once this has been detected as the incoming character, all of the following characters are examined one by one in the PIC18, looking for the GPGGA sequence. If this sequence is not found then the entire sentence is ignored until another dollar sign is detected. If the sequence is found, then the PIC18 will wait until it receives the particular data of interest. That data is then stored in the static RAM of the PIC18 for future use. Once all of the data of interest has been acquired from the sentence, the PIC18 will ignore all of the other data and wait for the GPS to request the data. Once a request has been detected, then the PIC18 jumps to a ‘transmission of data’ routine. If there is no request of the data from the GPS, then the PIC18 will wait for the next set of sentences and update its data with the new sentences arriving from the receiver.

After the GPS data has been stored on the PIC18, it waits for a signal from the microcontroller to transmit the data. The PIC18 uses a pin to transmit the clock pulses and a pin to transmit the data bits. A beginning clock pulse will signal the start of the data. Every clock pulse afterwards on the clock pin will have a corresponding data bit on the data pin at the same time. Therefore, the microcontroller must be able to read the data while it is receiving a clock pulse. The clock pulse will remain active for 3 microseconds. After all the data has been transmitted, the PIC18 will remain waiting for a signal from the microcontroller to retransmit the data or begin a new data retrieval from the GPS receiver if the timing sequence has passed.
The NMEA sentence is broken up into many different parts. The only parts that are of interest are the UTC Time, Longitude and Latitude. This data will be sent along with our sensors data in order to make the desired 200ms cycle.

5.3 Display

A standard 16x2 LCD display is added to improve the interaction between the user and the device. Different text messages could show the different states of the TT Race Data Logger.

5.4 Accelerometer

It's required an electronic component to provide us the horizontal force in G's with a factor of 9,8 m/s2 and X,Y,Z dimensions. Capable of endure the max. G's suffered during a professional race.

5.5 Removable Memory

To store the files generated is needed a big memory, EPROM's memory modules are usually too small to store such data, an Standard Removable Memory (Mini SD / SD) has the perfect performance and size to this work, with a FAT 16 System , 2GB maximum size. It will be the best choice.

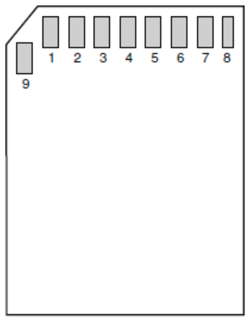
SD Cards offer a cost-effective way to store large amounts of data in a removable memory storage device. The simplicity of the SD Card protocol and the flexibility in interfacing with these devices makes them ideal for use with small microcontrollers.

Combined with a low-cost, low-power, microcontroller, a complete data logging solution can be implemented quickly and inexpensively.

5.5.1 SD Card and SPI Introduction

SD Cards (Secure Digital Cards) are quite popular these days for things like digital cameras, video cameras, mp3 players and mobile phones. The main advantages are: small size, large data storage capability, speed, cost. It has flash storage that does not require power to hold data. The current version of the SD card library that we will be using in this project works with "standard capacity" SD cards up 2gb in size. SD Card have 2 data transfer types "SD Bus" and "SPI Bus". Most PIC's have an SPI port. The "SD Bus" is faster, however uses more pins. We will be using SPI in our circuit.

These SD Cards are 3.3v devices, therefore a 5v to 3v conversion is needed between the PIC and the sd card.



Pin	Name	Function (SD Mode)	Function(SPI Mode)
1	DAT3/CS	Data Line 3	Chip Select/Slave Select (SS)
2	CMD/DI	Command Line	Master Out Slave In (MOSI)
3	VSS1	Ground	Ground
4	VDD	Supply Voltage	Supply Voltage
5	CLK	Clock	Clock(SCK)
6	VSS2	Ground	Ground
7	DAT0/D0	Data Line 0	Master In Slave Out (MISO)
8	DAT1/IRQ	Data Line 1	Unused or IRQ
9	DAT2/NC	Data Line 2	Unused

Table 4 : SD Card Pin Assignments

Serial Peripheral Interface (SPI)

SPI is a synchronous serial protocol that is extremely popular for interfacing peripheral devices with microcontrollers. Most modern microcontrollers, including the PIC18F4550 used for our prototype, support SPI natively at relatively high data rates. The SPI communications mode supports only a subset of the full SD Card protocol. However, most of the unsupported command sets are simply not needed in SPI mode. A fully-functional SD Card implementation can be realized using only SPI.

5.6 USB Interface

USB is the most common and reliable bus connection between a device and a computer. It’s strong, quick, durable and easy to plug/unplug.

It’s necessary an USB 1.0/2.0 interface to be able to download the data from the removable memory to any computer recognizing our data logging as Mass Storage Device or Car Reader.

Microchip offers a large number of free license libraries with datasheets created to be used with their components. With them is possible to design a perfect USB interface with all kind of devices, in our case with a Computer.

Further in this document, in “prototype algorithm code” we will explain the functionality and how they are implemented together with the data logging code.

5.7 Power Supply

Li-On batteries have the best endurance and performance for small electronic devices. They are small, safe, cheap, have long-life, rechargeable with quick charge and long durability. It will be interesting that TT Race Data Logger owns one of them.
If we use a Li-On battery we need some charging system to recharge it. In the market we can found some chips specially designed for this labor. The MCP73863 is a highly advanced linear charge management controller for use in space limited, high performance applications. The MCP73863 integrates most of the external components (pass transistor, reverse blocking protection, current sensing) and combines high-accuracy constant voltage/constant current regulation, cell preconditioning, cell temperature monitoring, advanced safety timers, automatic charge termination, and charge status and fault indication in a small 16-pin 4mm x 4mm QFN package.

6. TT Race Data Logger Prototype

6.1 Design

How we already mentioned, TT Race Data Logger has to be a small and easy electronic device. To accomplish these requirements the following interface and algorithm is designed for the prototype.

6.2 Interface

TT Race Data Logger will have one switch to enable or disable the battery (ON/OFF). Two buttons to manage the functionality of the system.

Preset button – Is pressed in first place to get the position of the of Start/end Line cords .

Start/Stop button – Is pressed to start/stop data logging.

To know the current working state and orientate the user with the functionality of the device is added a LCD display showing the following text messages:

"Starting System" – Appears when turn ON the battery switch.

"Preset Cords 1" – This message will appears when you press the "Preset button" for first time.

"Preset Cords 2" – This message will appears when you press the "Preset button for second time".

"Standby" – Appears when the system is started and gives the option of preset or Start data logging. Also appears when Start/Stop button is pressed after data logging.

"Ready" – Is shown when the system is monitoring the changes of the bike to start data logging automatically.

"Running" – It means that the system is storing data from the sub-devices to the SD Card.

"USB" – The device is connected to an USB and the SD card is readable.

Additionally we implement two flag led to improve the understanding of the basic states of the device. One red led, connected to the power supply shows the ON/OFF state. One green Led shows the correct connection and initialization of the GPS unit with the satellites.

SD Removable Card – A standard SD card socket holds the SD card with an easy plug/unplug method.

USB – The prototype provides this interface to read the SD card from a PC. How we said before, TT Race Data Logger will be recognized by a PC as Mass Storage Device, working with a standard driver provided by Microsoft. It won't be necessary any previous configuration, just plug it.

6.3 Algorithm

The entire functionality of the TT Race Data Logger will be defined by a Synchronous State Algorithm.

The different States and their explanations are:

Starting System – Switch is turned ON. System is starting and configuring the device. Led red will be lighting until power switch is turned OFF. This state will remain until the GPS unit gets the signal from the satellites (1 - 30 Seconds). Led green will be lighting to proof that this process was successful. LCD display will show the message "Starting System" during all the Sate. Next state is state "ready".

Standby/Sleep State - The devices enter automatically to this state from the Ready State, giving the option to the user to push the preset button to get the actual position or press Start/Stop Button to start the Data Logging without any preset. This state is a standby state; the device is only waiting the interaction of the user. Next State is "Preset State" or "Ready State". LCD display will show during all this state the message "Standby".

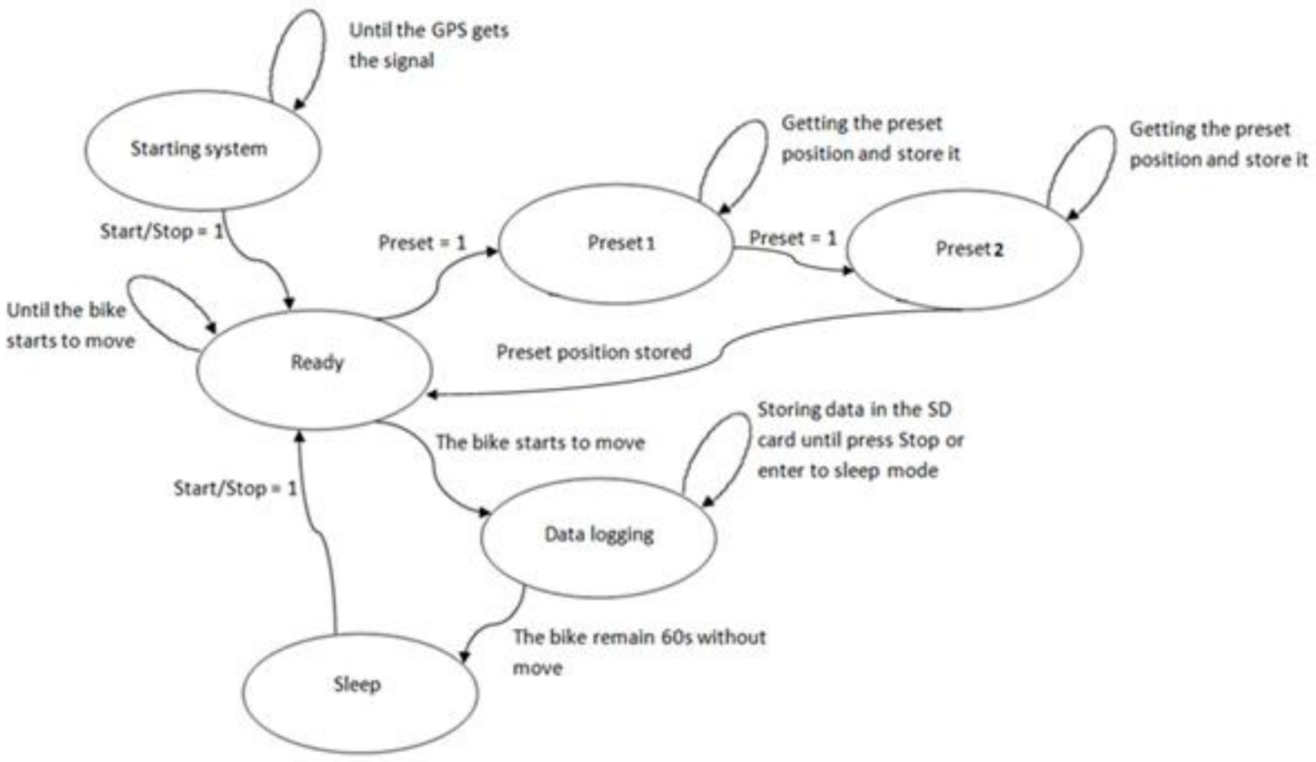
Preset1 State - When the "Preset Button" is pressed, the device enter to this state, getting the coordinates of the TT Race Data Logger at this moment. There are two Preset Points for make the imaginary beacon line. Allegedly, Start/End line from the race circuit. If this coordinates are already stored in the device by a previous preset, this state is optional. This state remains active during 3 seconds since the Preset Button was pressed. LCD Display will show during these 3 seconds the message "Preset Cords 1". Next state is "Preset2 State".

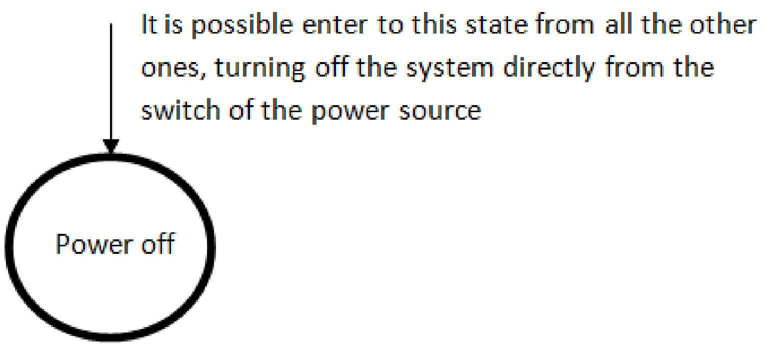
Preset2 State – Second Preset to get the second Spot of the start line. Next state is Ready State after press start/stop button. LCD will show "Preset Cords 2" also during 3 seconds.

Ready State – Had been pressed "Start/Stop Button" the device enter to Ready state, in this state where the device is collecting data from the accelerometer and the GPS, monitoring the G's and the position. This state needs to process the data from the accelerometer and the GPS but it's not necessary to be stored. It's included to give the device the possibility to realize when the race starts and the bike is moving. Any promptly change will start automatically the next state, “data logging state”, it means store incoming data to the SD Card. LCD display will show the message “Ready”.

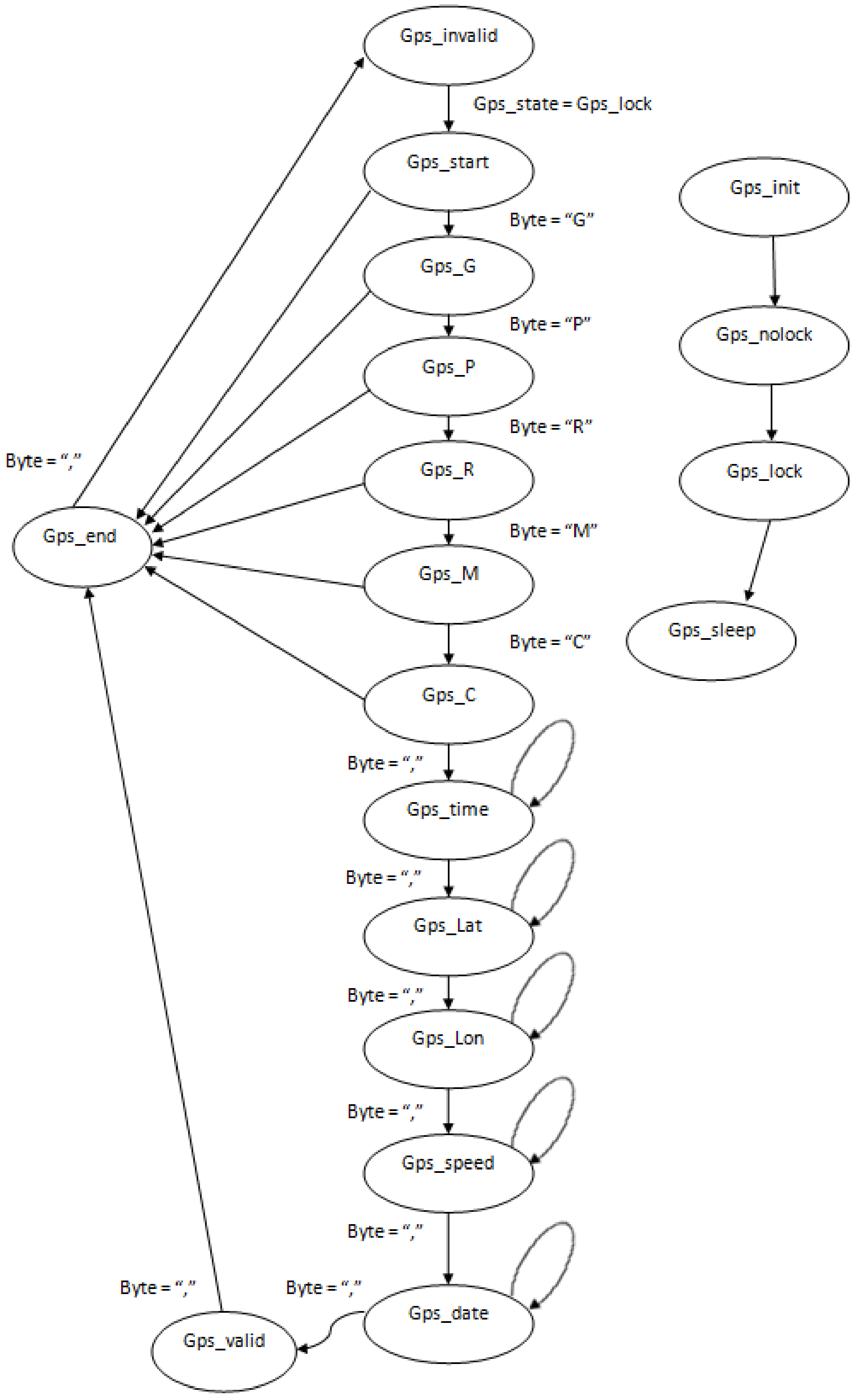
Data Logging State – The device enter to this state when the bike is moving. It’s processing the A/D channels and the GPS data, calculating the Angle, suffered G’s, speed, position, time, lap time, date, 100 meters time. An average of these values will be stored on the SD card with a cycle of 200ms. The algorithm for the calculations is designed to accomplish the starting required performance. Minimum sensor sample rate 100Hz. This state will remain until Start/Stop is pressed or the detection of any movement during 60 seconds on the device (changes on G’s and Position) automatically stops data logging. Next State is “Standby/Sleep State”. LCD display will give the message “Running”.

6.3.1 TT Race Data logging main Flow graph


Until the GPS gets the signal
Starting system
Start/Stop = 1
Getting the preset position and store it
Getting the preset position and store it
Preset = 1
Preset 1
Preset = 1
Preset 2
Until the bike starts to move
Ready
Preset position stored
Storing data in the SD card until press Stop or enter to sleep mode
The bike starts to move
Start/Stop = 1
Data logging
The bike remain 60s without move
Sleep


It is possible enter to this state from all the other ones, turning off the system directly from the switch of the power source
Power off

6.3.2 GPS State Flow Graph

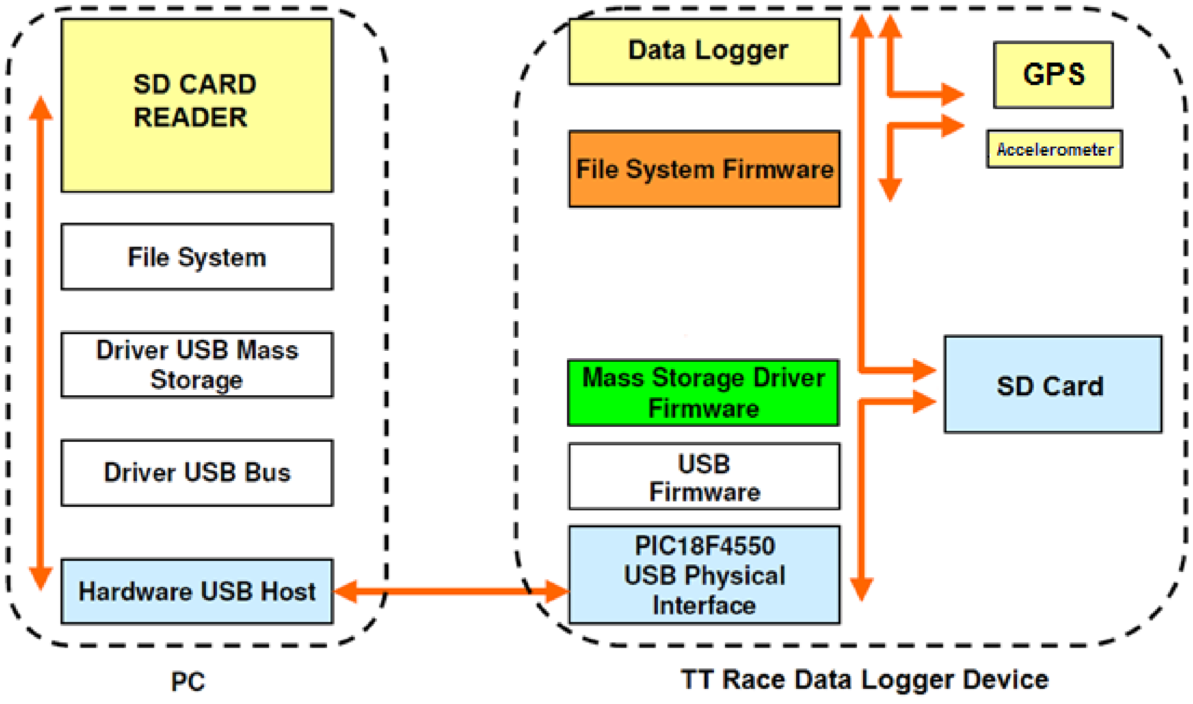


6.4 Implementation

Algorithm

The implementation of the algorithm for the TT Race Data Logger is programmed with embeds code and C language. Following the typical structure of an embed project working with files in *.h (Libraries) and .c (Includes) extensions.

6.4.1 TT Race Data Logger Firmware's diagram



Yellow – Data logger Firmware. Embed files describing the algorithm of the Data logging operations. It contains the Operations of Data processing (GPS, Analog Inputs and) and Data Calculation (Angle, Speed, Position. File creation and data storing). Also contains the configuration files of the microchip to work as a Data Logger and Card Reader. (Entire configuration of the chip resources I/O and Boot loader) .

Orange – File System Firmware. Group of files that contains the definitions and functions to manage FAT16 Tables , necessary to work with the SD card.

White – USB Firmware. Package holding functions and declarations about standard USB 2.0 communication. Only behavioral code is here. This firmware grants the device to work with all win/Mac 32/64 bits Operative systems.

Green – Mass Storage Driver Firmware. Package of files giving to our TT Race Data Logger the identity of a Standard Mass Storage Device. It means you can read the memory inside our device when you plug it with a computer.

Blue – USB Physical Interface. Files configuring the SPI communication of the chip to work through USB interface.

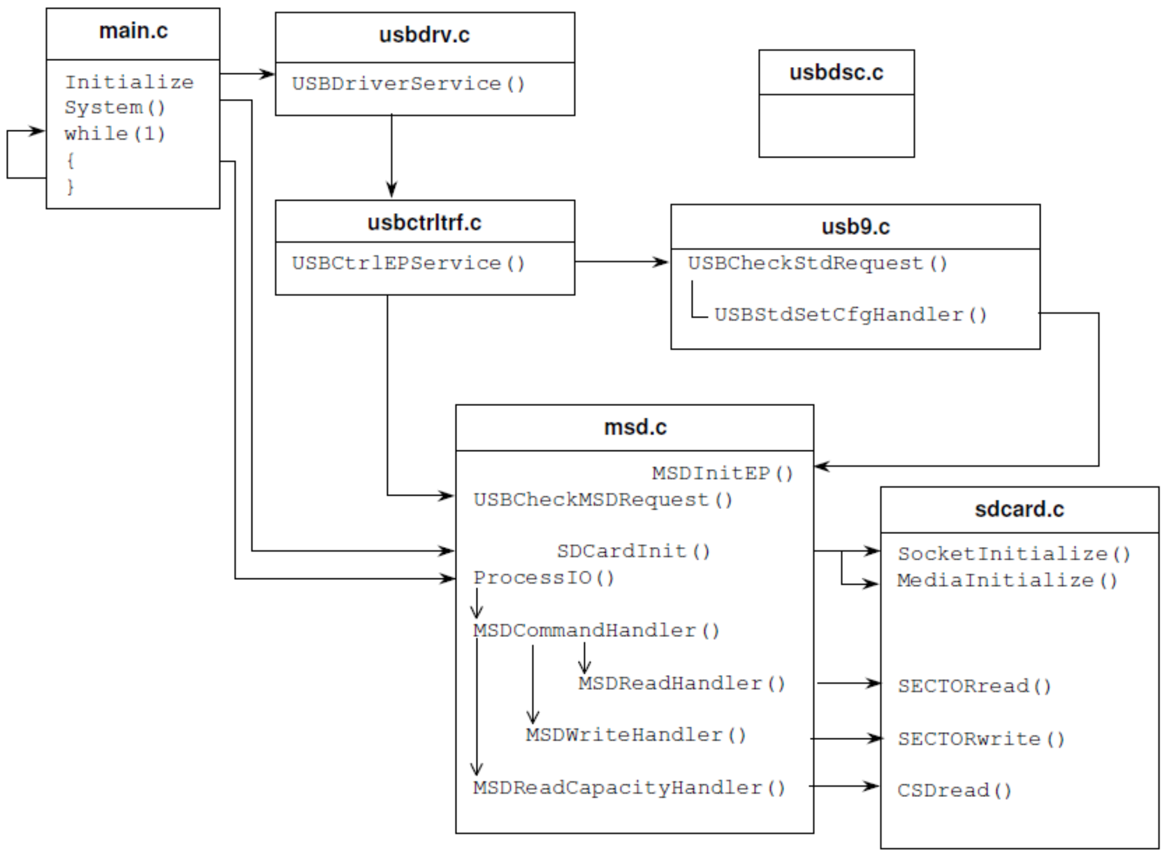
USB Interface and SD Card

The whole USB and SD Card interface is designed with the Microchip's USB 2.0 Firmware and "Mass Storage Driver Firmware" Libraries.

6.5 C Code

6.5.1 C Files and functions Graph of Microchip's firmware

This graph offers a quickly orientation of the dependences between files and functions used by the behavior of an USB 2.0 Communication and SD Card.



6.5.2 PC - Microcontroller Interface Diagram. Files and Libraries

This diagram gives a global structure about the interface between the Microcontroller and the Computer. We can observe the files used by the operative system inside the computer and the files included in the microcontroller. All the files required by the computer are provided by the operation system. The libraries needed by the microcontroller for an SD interface are assembled with the entire code of the Data logger. They were provided by Microchip and are able in the project directory.

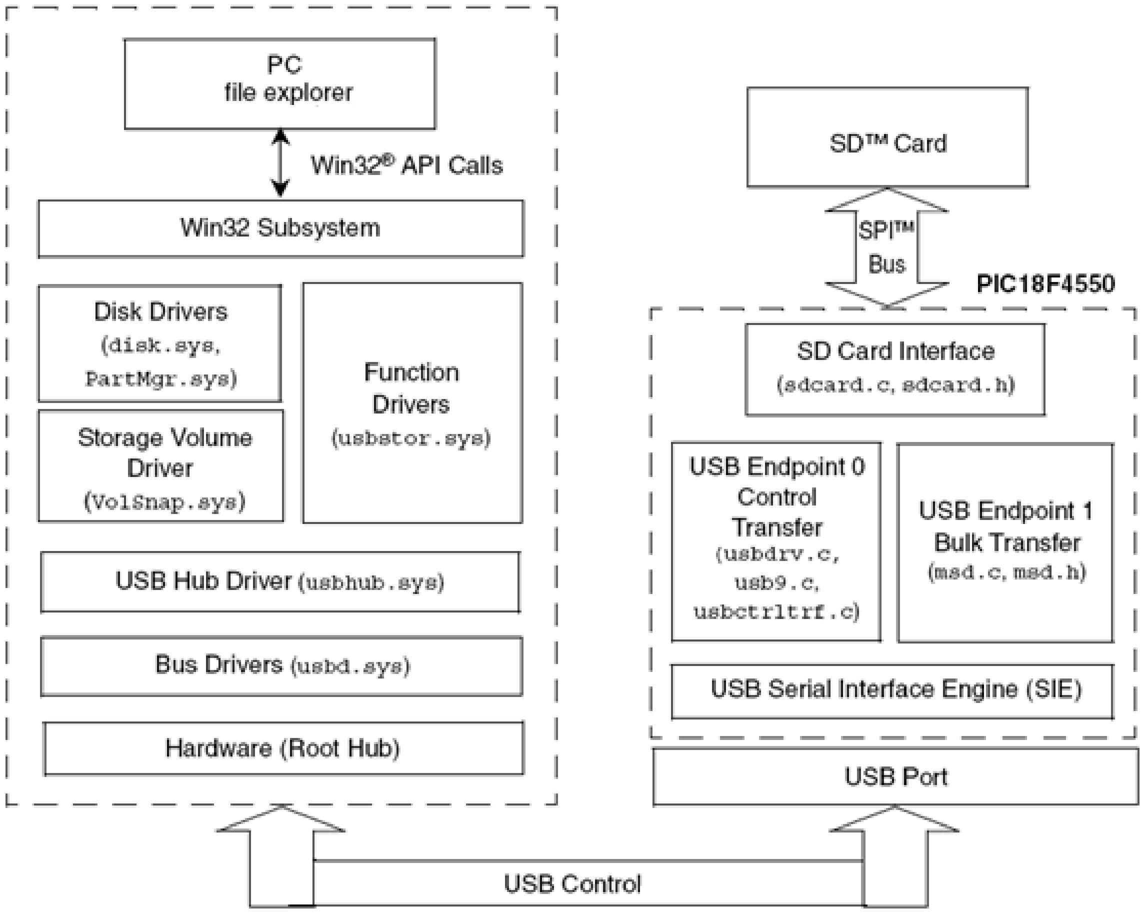
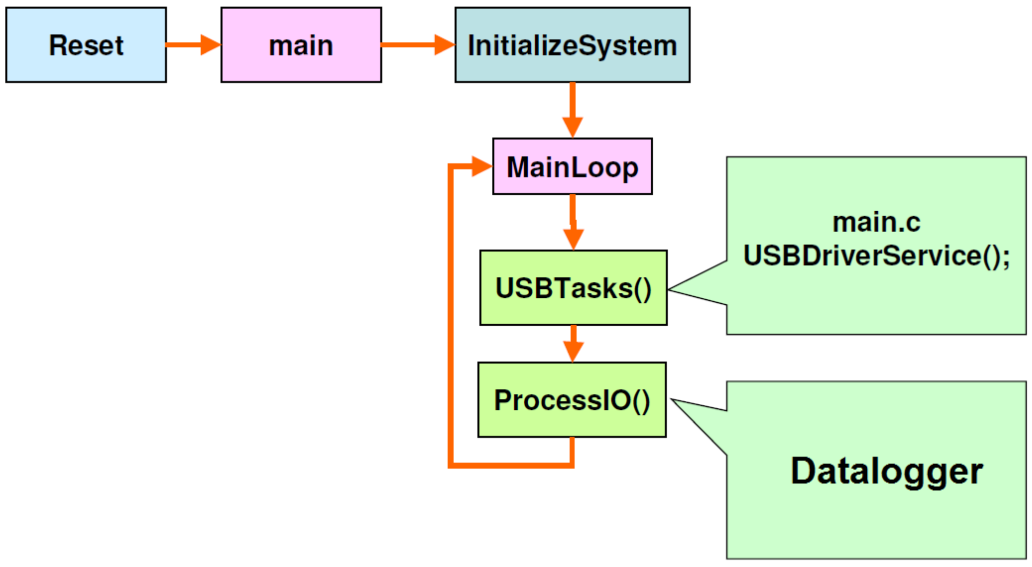

PC file explorer
Win32® API Calls
Win32 Subsystem
Disk Drivers (disk.sys, PartMgr.sys)
Storage Volume Driver (VolSnap.sys)
Function Drivers (usbstor.sys)
USB Hub Driver (usbhub.sys)
Bus Drivers (usbd.sys)
Hardware (Root Hub)
SD™ Card
SPI™ Bus
PIC18F4550
SD Card Interface (sdcard.c, sdcard.h)
USB Endpoint 0 Control Transfer (usbdrv.c, usb9.c, usbctrltrf.c)
USB Endpoint 1 Bulk Transfer (msd.c, msd.h)
USB Serial Interface Engine (SIE)
USB Port
USB Control

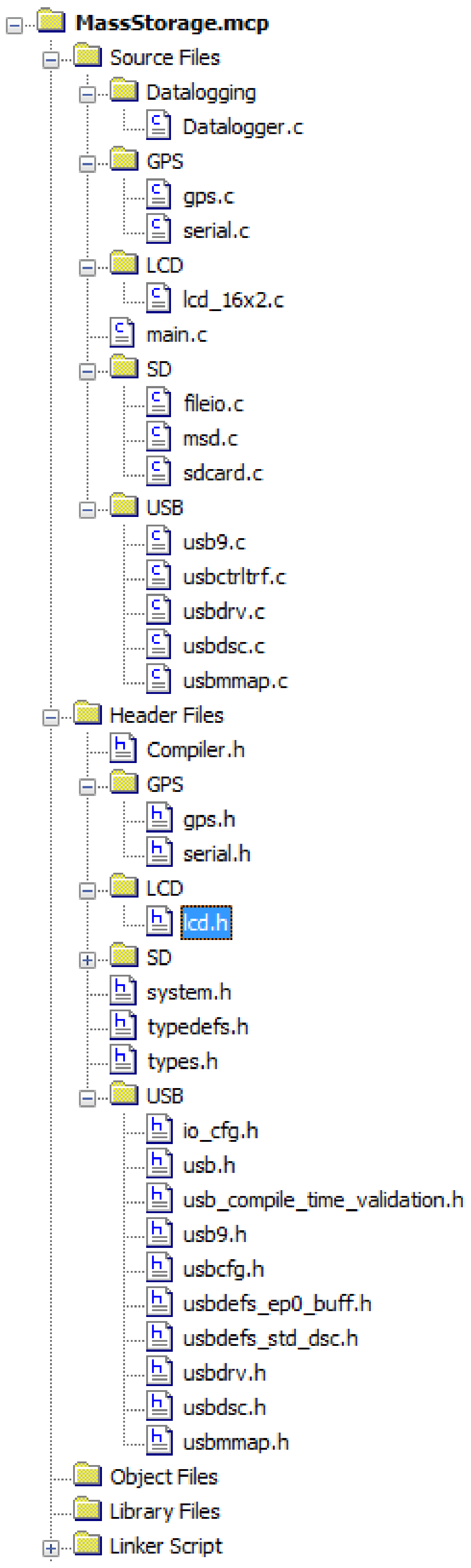
Diagram. PC - Microcontroller Interface

6.5.3 USB “Plug&Play”

To get a correct USB 2.0 functionality as a “Plug&Play” device (USB Auto detection) is needed a continuous refresh of the USB port. Calling the function USBDriverService(). This is possible implementing a loop inside the main flow code between the Data Logging tasks, calling periodically the mentioned function. An easy graph is shown below.



6.5.4 Project Files Architecture



```
MassStorage.mcp
    Source Files
        Datalogging
            Datalogger.c
        GPS
            gps.c
            serial.c
        LCD
            lcd_16x2.c
        main.c
        SD
            fileio.c
            msd.c
            sdcard.c
        USB
            usb9.c
            usbctrltrf.c
            usbdrv.c
            usbdsc.c
            usbmmap.c
    Header Files
        Compiler.h
        GPS
            gps.h
            serial.h
        LCD
            lcd.h
        SD
        system.h
        typedefs.h
        types.h
        USB
            io_cfg.h
            usb.h
            usb_compile_time_validation.h
            usb9.h
            usbcfg.h
            usbdefs_ep0_buff.h
            usbdefs_std_dsc.h
            usbdrv.h
            usbdsc.h
            usbmmap.h
    Object Files
    Library Files
    Linker Script
```

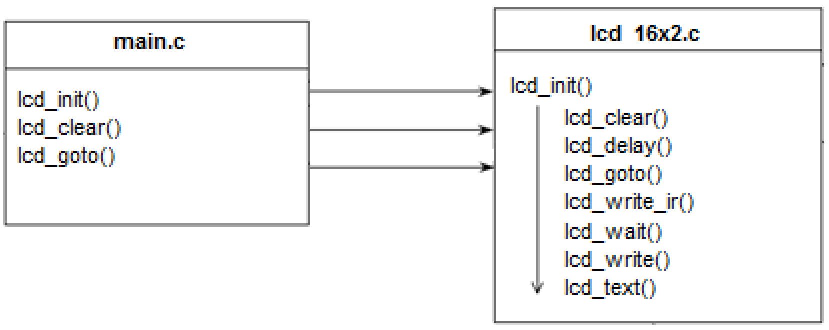
6.5.5 Data logging functions, file dependences and explanations

- Main.c
    - System Initialization
        - InitAD : Configures AN0,AN1 and AN2 for the accelerometer axes x,y,z
        - Serial_init : Initialize the serial communication with GPS
        - System_init : Configure All I/O
        - InitFAT : Initialize the SD Card Interface
        - mInitSwitch3 : Configure Switch 3
        - mInitSwitch2 : Configure Switch 2
    - USB
        - USBTasks : USB tasks for USB auto detection, called periodically
        - ProccessIO : SD Tasks to don't lose the connection
    - Datalogging
        - DoADC : Main data logging function. A/D conversion, calculations, data organization and file creation
    - LCD
        - Lcd_init : Initialize LCD
        - Lcd_clear : Clear LCD
        - Lcd_goto : Move LCD cursor
        - Lcd_write : Write character on LCD
    - GPS
        - gps_init : Initialize GPS and USART communication
        - gps_position : Get the position from the GPS, latitude and longitude in float format
- Datalogger.c
    - InitFAT
        - Socketinitialize : Initialize the SD socket and remains active always
    - ReadFile : Read One existent file stored in the SD card(Optional)
    - DoADC
        - gps_receive: Get time, date, speed and position in char format
        - itoa : Writes a variable in SD buffer

- Serial.c
  - Serial_init
    - Serial_baud : Set Serial communication's baud rate
    - Serial_enable : Enable serial communication
  - Serial_send : Send a string through the serial comunication
  - Serial_recieve : Receive a single byte from the GPS

- gps.c
  - gps_baud : Set GPS baud rate
  - gps_set_protocol : Send a string with the configuration for the GPS
  - gps_init
    - serial_baud
    - serial_send
  - gps_receive
    - serial_receive
    - serial_send
    - system_set_time : set the system time in char format
    - set_position : logs a waypoint position in char format
    - system_set_date : set date in char format
    - set_speed : set speed in char format
  - gps_ position
    - serial_receive
    - serial_send

6.5.6 Display



6.6 Important C Code Spots

6.6.1 Boot loader Remapping Vectors

Its necessary to remap these vectors for a correct boot loader functionality. Boot loader is stored from 0x0000 until 0x0800 ROM memory addresses.

```
///////////////////////////////////////////////////////////////////////////////
//
// Bootloader Configuration
//
//
#define BOOTLOADER_PRESENT  1       //Using the Microchip PICDEMFS USB Bootloader

#if(BOOTLOADER_PRESENT == 1)
    #define INTERRUPT_RESET_ADDR        0x0800
    #define INTERRUPT_LOW_ADDR          0x0818
    #define INTERRUPT_HIGH_ADDR         0x0808
#else
    #define INTERRUPT_RESET_ADDR        0x0000
    #define INTERRUPT_LOW_ADDR          0x0018
    #define INTERRUPT_HIGH_ADDR         0x0008
#endif
```

Code found in system.h

6.6.2 File management

Sprintf, prints the current date as file name and also the entire string to be stored in this file. Time and time old are comparing each other to implement 1/5 second step to store the string into the file.

```
sprintf(name,"%c", date); // We print the date on the name's file



if ((time != timeold) & (r == 1))
{

    timeold=time;

sprintf (resultf, "%c-%f-%f-%f-%c-%c\n",time, resultx, resulty, resultz, ang, position, speed);
itoa(resultx,test);
strcat(writeBffr,test);
strcat(writeBffr,tn);

if((error = fwrite (myFile, writeBffr, strlen(writeBffr))) != CE_GOOD) {
    while(1);

}

if ( fclose ( myFile ) != CE_GOOD)  // closes the file and updates the size
{
    while(1);
}
```

Code found in datalogger.c

6.6.3 Speed factor conversion

We designed this easy function that converts the speed from Knots to Km/h. Using a factor of 1km/h=0,54 Knots

```
uint8 set_speed(sfint16 sped)
{
     uint8 speed;
     sprintf(speed,"%f",sped/ksp);    //speed=speed/ksp;
                                      // Speed Factor Conversion 1km/h= 0,54 Knots

     return speed;
}
```

Code found in gps.c

6.6.4 Auto Shut-Down after 60 seconds of non activity

We implemented this algorithm to be possible an auto-shutdown for a possible unwanted data logging caused because the user forget the devices running.

```
if (c == 0)
{
    passcordslat,passcordslon = gps_position();
}
if (c == 60)                            //aprox. 1 min counter
{
    currentcordslat,currentcordslon = gps_position();

    if((currentcordslat == passcordslat) & (currentcordslon == passcordslon))       // auto shut-down after 60 seconds
    {
        r=0;
        c=0;
        f=0;
        sprintf(x,"Standby");
        lcd_clear();
        lcd_goto(0, 0);

        for(count = 0; count == sizeof(x); count++)
        {

        char chr = x[count];
        lcd_write(chr);

        if(count == 15)
        lcd_goto(0, 1);      //jump to next line
    }

    count=0;
        DEVState = DEV_SLEEP;
        break;
    }

    passcordslat=currentcordslat;
    passcordslon=currentcordslon;
}

if (f == 25000000)   //1sec counter
{

    f=0;
    c++;
}

f++;
```

Code found in main.c

6.6.5 Non rebounding button system

We use an loop the generate a delay for a correct button functionality

```
BOOL Switch3IsPressed(void)                    //switch3 no-rebound
{
    int i;
    if(sw3 != old_sw3)
    {
        for  (i=0;i<=500;i++);
        if(sw3 != old_sw3) {
          old_sw3 = sw3;
          if(sw3 == 0)                         // If pressed
               return TRUE;                     // Was pressed
        }
    }//end if
    return FALSE;                             // Was not pressed
}//end Switch3IsPressed
```

Code found in main.c

6.6.6 USB Tasks

How we already said, this function has to be summoned periodically for properly usb auto detection.

```
void USBTasks(void)
{
    /*
     * Servicing Hardware
     */
    USBCheckBusStatus();                    // Must use polling method
    if(UCFGbits.UTEYE!=1)
        USBDriverService();                 // Interrupt or polling method

}// end USBTasks
```

Code found in main.c

Also for a desired auto detection is necessary connect USB power sense and USB sense.

```
/** U S B ***********************************************************/
#define tris_usb_bus_sense   TRISDbits.TRISD3    // Input

#if defined(USE_USB_BUS_SENSE_IO)
#define usb_bus_sense        PORTDbits.RD3
#else
#define usb_bus_sense        1
#endif

#define tris_self_power      TRISDbits.TRISD2    // Input

#if defined(USE_SELF_POWER_SENSE_IO)
#define self_power           PORTDbits.RD2
#else
#define self_power           1
#endif
```

Code found in io_cfg.h

6.6.7 SD Socket and SPI connection Definitions

Definition of necessary pins for a SD card

```
/** S P I : Chip Select Lines ***************************************/
#define tris_cs_temp_sensor TRISBbits.TRISB2    // Output
#define cs_temp_sensor      LATBbits.LATB2

#define tris_cs_sdmmc       TRISBbits.TRISB3    // Output
#define cs_sdmmc            LATBbits.LATB3

/** S D M M C *******************************************************/
#define TRIS_CARD_DETECT    TRISBbits.TRISB4    // Input
#define CARD_DETECT         PORTBbits.RB4

#define TRIS_WRITE_DETECT   TRISBits.TRISB5    // Input
#define WRITE_DETECT        PORTB5bits.RB5
#endif //IO_CFG_H
```

Code found in io_cfg.h

6.6.8 LCD Port Definitions

LCD Display Port Pins definitions. We use Port D for control signals and Port E(0-3) for the data.

```
#define LCD_PORT    PORTE   // The phyical port the LCD is connected to
#define LCD_DDR     TRISE   // Data direction register for the LCD port

////////////////////////////////////////////////////////////////////////
//
// LCD Pinout
//
//        PORTD/E
//       --------
//   RS .| o   o |   EN
//   RW  | o   o |
//   E0  | o   o |   E1
//   E2  | o   o |   E3
//   5V  | o   o |   GND
//       --------

#define LCD_RS  PORTDbits.RD0   // Strobe
#define LCD_EN  PORTDbits.RD1   // Enable
#define LCD_RW  PORTDbits.RD4   // Read/-Write
```

Code found in lcd.h

6.6.9 NMEA Configuration String

We have to send a configuration string to the GPS in NMEA format.

```
//SiRF-II configuration command
const char sirf_config[] = {0xA0, 0xA2, 0x00, 0x18,     //start and length (24 bytes)
                            0x81, 0x00,          //Switch to NMEA, no debug messages
                            0x01, 0x01,          //Enable GGA with checksum
                            0x00, 0x00,          //Disable GLL
                            0x01, 0x01,          //GSA
                            0x00, 0x00,          //GSV
                            0x01, 0x01,          //RMC
                            0x01, 0x01,          //VTG
                            0x00, 0x00,          //MSS
                            0x00, 0x00,          //unused EPE not supported
                            0x00, 0x00,          //unused ZDA not supported
                            0x00, 0x00,          //unused
                            0x96, 0x00,          //Baud Rate (38400)
                            0x01, 0x1F, 0xB0, 0xB3};    //Checksum and end
const char nmea_config[] = "$PSRF100,1,38400,8,1,0*3C\r\n";     //SiRF 38400, checksum
```

Code found in gps.c

6.6.10 TT Race Data Logger States

That's the definition of the different states, switching each other by "switch" statement.

```c
//TT Race Data Logger states

typedef enum {DEV_INIT = 0, DEV_SLEEP, DEV_PRESET1, DEV_PRESET2, DEV_READY, DEV_LOGGING} dev_state;
static dev_state DEVState = DEV_INIT;          //Set the initial state
```

Code found in main.c

6.6.11 GPS States

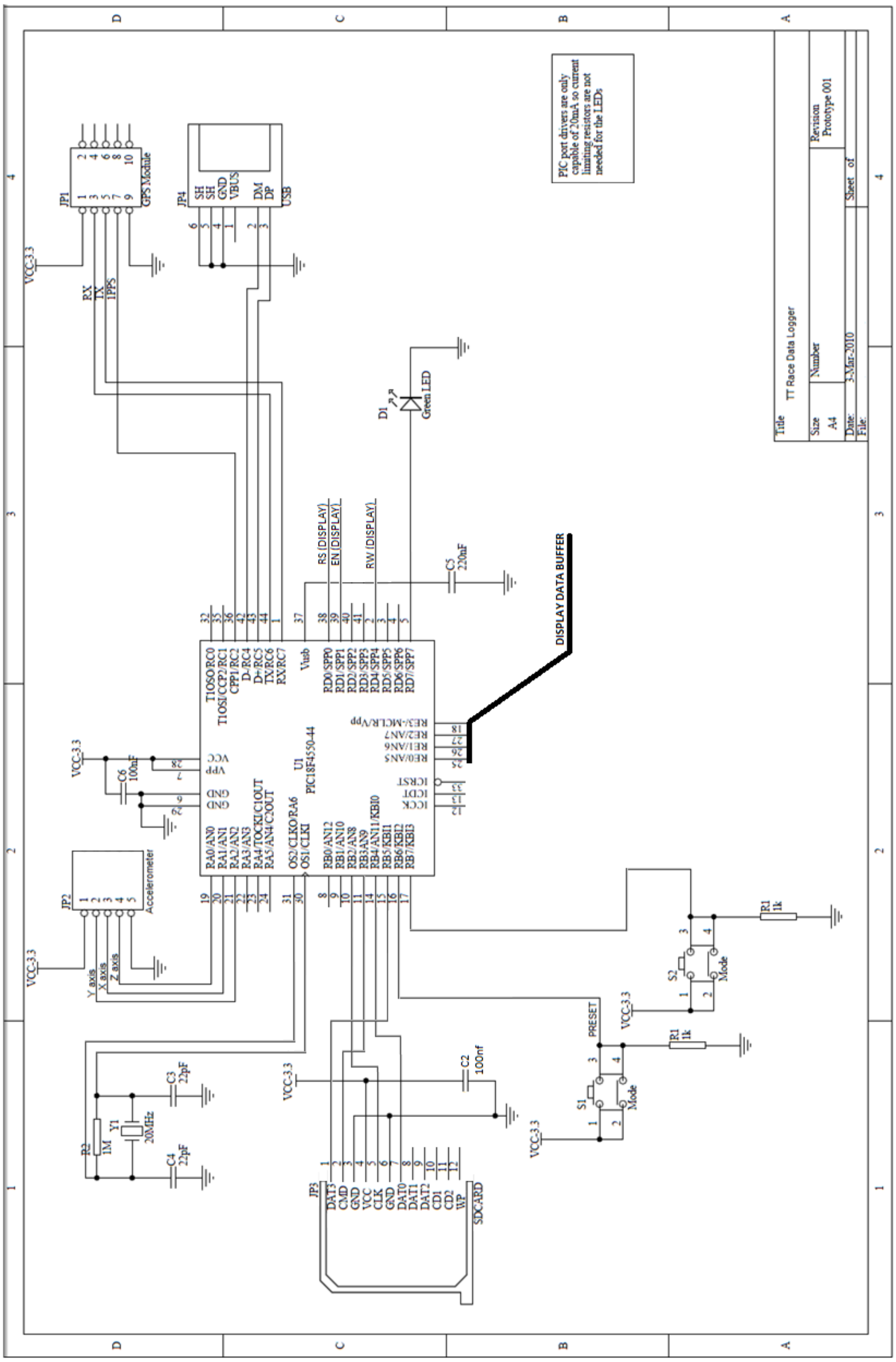
To get a byte from the GPS one by one, we implement this GPS states, also switched by a "switch" statement

```c
//GPS state
typedef enum {GPS_INIT = 0, GPS_SLEEP, GPS_NOLOCK, GPS_LOCK} gps_state;
static gps_state GPSState = GPS_INIT;          //Set the initial state

//NMEA processing FSM
typedef enum {GPS_INVALID = 0, GPS_START, GPS_G, GPS_GP,GPS_GPR, GPS_GPRM,
GPS_GPRMC, GPS_DATE,GPS_LAT,GPS_LON,GPS_SPEED, GPS_TIME, GPS_VALID, GPS_END } gps_process_state;
static gps_process_state GPSProcess = GPS_INVALID;
```

Code found in gps.c

6.7 Schematic



6.8 Components pin wire connection in the prototype

6.8.1 SD socket and pin connection

Pin #	Pin Name	SD Signal Function SD Mode	SPI Signal Function SPI Mode	Cable color
1	DAT3/CS	Data Line 3	Chip Select/Slave Select [SS]	Red
2	CMD/DI	Command Line	Master Out/Slave In [MOSI]	Brown
3	VSS1	Ground	Ground	Black
4	Vdd	Voltage Supply [2.7v or 3.6v]	Voltage Supply [2.7v or 3.6v]	White
5	Clock	Clock	Clock [SCK]	Grey
6	Vss2	Ground	Ground	Purple
7	DAT0/D0	Data Line 0	Master In Slave Out [MISO]	Blue
8	DAT1/IRQ	Data Line 1	Unused or IRQ	Green
9	DAT2/NC	Data Line 2	Unused	Orange

Table 5: SD card and socket pin connections.

Figure: SD card Socket

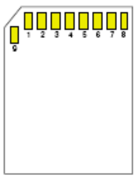


Figure: SD card pin location

Note:

That pin contacts 3 and pin 4 are bit longer than the other pins. This allows pin 3 [Vss], and pin 4 [Vdd] to make contact in the socket before the other pins. Allowing, Ground and power to be connected first to the SD socket. Pins CLK, CMC, DAT0, DAT1, DAT2, and Vss make connection after pins 3 and 4 make contact. Pin 1, DAT3 makes contact last. Of course pins 3 and 4 are also the last pins to lose contact with the socket.

6.8.2 Gps pin assignment

Pin #	Pin name	Cable color
1	Enable/Disable	Grey
2	Ground	Purple
3	RX	Blue
4	TX	Green
5	VCC	Yellow

Table: Gps pin and cable assignment

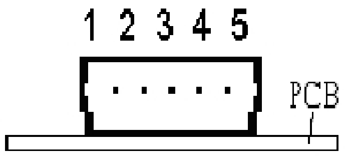


Figure: GPS pin conector

Pin Explanation

Enable/Disable: On / Off
VCC: (DC power input) This is the main DC supply for a 3.3V power module board.
TX: This is the main transmit channel for outputting navigation and measurement data to user's navigation software or user-written software.
RX: This is the main receive channel for receiving software commands to the engine board from SiRfDemo software or from user-written software.
GND: GND provides the ground for the engine boards. Be sure to connect all grounds.

6.8.3 Display pin assignment

Pin #	Symbol	Function	Color
1	VSS	GND	Red
2	VDD	+5V	Brown
3	V0	Contrast adjustmentsignal	Black
4	RS	H/L Register select	White
5	R/W	H/L Read/Write signal	Grey
6	E	H/L Enable signal	Purple
7	DB0	H/L Data bus line	Yellow
8	DB1	H/L Data bus line	Orange
9	DB2	H/L Data bus line	Red
10	DB3	H/L Data bus line	Brown
11	DB4	H/L Data bus line	Blue
12	DB5	H/L Data bus line	Green
13	DB6	H/L Data bus line	Yellow
14	DB7	H/L Data bus line	Orange
15	A	+ 4.2V for LED	“ No connection needed”
16	K	Power supply for BKL(0V)	“ No connection needed”

Table 6: Display pin and cable assignment

Note: in the prototype the Data bus line is divided in two different buses, it means 2 buses of 4 pin each one. The first 6 pins from the Display are connected together in one bus because are the control bits of the Display.

6.8.4 Accelerometer pin assignment

Pin #	Pin name	Function	Color
1	ST	Self-test	-No connect-
2	Z	Z axis	Green
3	Y	Y axis	Blue
4	X	X axis	Grey
5	GND	Ground	Black
6	VCC	Supply Voltage (1.8 V to 3.6 V).	Red

Table 7: Accelerometer pin and cable assignment

Note: **ESD CAUTION (*for device manipulation*)!**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality. It's important to know this information on time to manipulate the accelerometer.

6.8.5 Mother board pin assignment

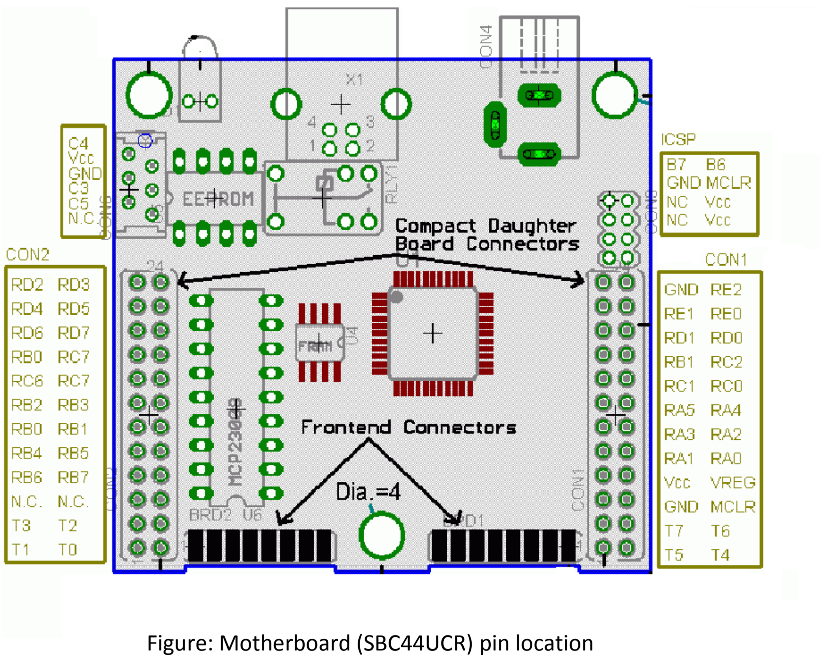


Figure: Motherboard (SBC44UCR) pin location

CON2 Daughter Board Connector		*CON1 Daughter Board Connector*	
Daughter Board Port Pin	**Signal**	***Daughter Board Port Pin***	**Signal**
T0	Port 0 of the MCP23008 I/O expander (if assembled)	T4	Port 4 of the MCP23008 I/O expander (if assembled)
T1	Port 1 of the MCP23008 I/O expander (if assembled)	T5	Port 5 of the MCP23008 I/O expander (if assembled)
T2	Port 2 of the MCP23008 I/O expander (if assembled)	T6	Port 6 of the MCP23008 I/O expander (if assembled)
T3	Port 3 of the MCP23008 I/O expander (if assembled)	T7	Port 7 of the MCP23008 I/O expander (if assembled)
SIG0	No connection	GND	Ground
SIG1	No connection	+5V	Regulated 0.5A 5V supply
B0	PIC pin RB2 – has 5K pull-up resistor.	VIN	Unregulated input voltage
B1	PIC pin RB3	CLR#	PIC pin /MCLR
B2	PIC pin RB0	A0	PIC pin RA0
B3	PIC pin RB1	A1	PIC pin RA1
B4	PIC pin RB4	A2	PIC pin RA2
B5	PIC pin RB5	A3	PIC pin RA3
B6	PIC pin RB6 – also used for ICP (1)	A4	PIC pin RA4
B7	PIC pin RB7 – also used for ICP (1)	A5	PIC pin RA5
C4	PIC pin RB0 – port pin assigned for I2C (2)	C0	PIC pin RC0
C5	PIC pin RC7	C1	PIC pin RC1
C6	PIC pin RC6 – can be used for RS232/RS485 TX	C2	PIC pin RC2
C7	PIC pin RC7 – can be used for RS232/RS485 RX	C3	PIC pin RB1 – port pin assigned for I2C (2)
D2	PIC pin RD2 (4)	D0	PIC pin RD0
D3	PIC pin RD3 (4)	D1	PIC pin RD1
D4	PIC pin RD4 (3)	E0	PIC pin RE0
D5	PIC pin RD5 (3)	E1	PIC pin RE1
D6	PIC pin RD6 (3)	E2	PIC pin RE2
D7	PIC pin RD7 (3)	GND	Ground

Table 8: Motherboard CON1, CON2 pin assignment

Note:

(1) Port Pins B6 and B7 are also used for in circuit programming, and to enter bootloader mode! If they are used, and the board should still be in circuit programmable, make sure their impedance is greater then a 1000 ohms!

(2) Port Pins C3 and C4 are connected to PIC port pins RB0 and RB1, those ports can be used for the I2C bus. When no I2C devices are used (external EEPROM or MCP23008 I/O expander for example), these ports can be used as general purpose I/O pins.

(3) If a serial FRAM chip is assembled, these pins will be used to communicate with it. By default, there is no FRAM chip assembled, and these pins can be used for general purpose I/O pins. Pin D4 has a 5K pull-up resistor connected to it!

(4) PIC port pins RD2 and RD3 are also used for “USB Self Power Sense” and “USB Bus Sense” inputs. If this functionality is not required, they can be used as general purpose I/O pins. They both have a 47k resistor that will pull it high or low, depending on how the board is currently powered.

6.9 Configuration of the connections in the prototype

6.9.1 SD pin connections

Pin #	Pin Name	Cable color	Motherboard Pin
1	DAT3/CS	Red	B5
2	CMD/DI	Brown	B3
3	VSS1	Black	Ground
4	Vdd	White	3.3V
5	Clock	Grey	B2
6	Vss2	Purple	Ground
7	DAT0/D0	Blue	B4
8	DAT1/IRQ	Green	-No connection-
9	DAT2/NC	Orange	-No connection-

Table 9: SD card pin connections.

6.9.2 Gps pin connections

Pin #	Pin name	Cable color	Motherboard Pin
1	Enable/Disable	Grey	C2
2	Ground	Purple	Ground
3	RX	Blue	C6
4	TX	Green	C7
5	VCC	Yellow	3.3V

Table 10: Gps pin connections

6.9.3 Display pin connections

Pin #	Symbol	Color	Motherboard Pin
1	VSS	Red	Ground
2	VDD	Brown	3.3V
3	V0	Black	Ground
4	RS	White	D0
5	R/W	Grey	D4
6	E	Purple	D1
7	DB0	Yellow	E0
8	DB1	Orange	E1
9	DB2	Red	E2
10	DB3	Brown	E3
11	DB4	Blue	-No connection-
12	DB5	Green	-No connection-
13	DB6	Yellow	-No connection-
14	DB7	Orange	-No connection-
15	A	" No connection needed"	-No connection-
16	K	" No connection needed"	-No connection-

Table 11: Display pin connections

6.9.4 Accelerometer pin connections

Pin #	Pin name	Color	Motherboard Pin
1	ST	-No connection-	-------------
2	Z	Green	A0
3	X	Grey	A1
4	Y	Blue	A2
5	GND	Black	Ground
6	VCC	Red	3.3V

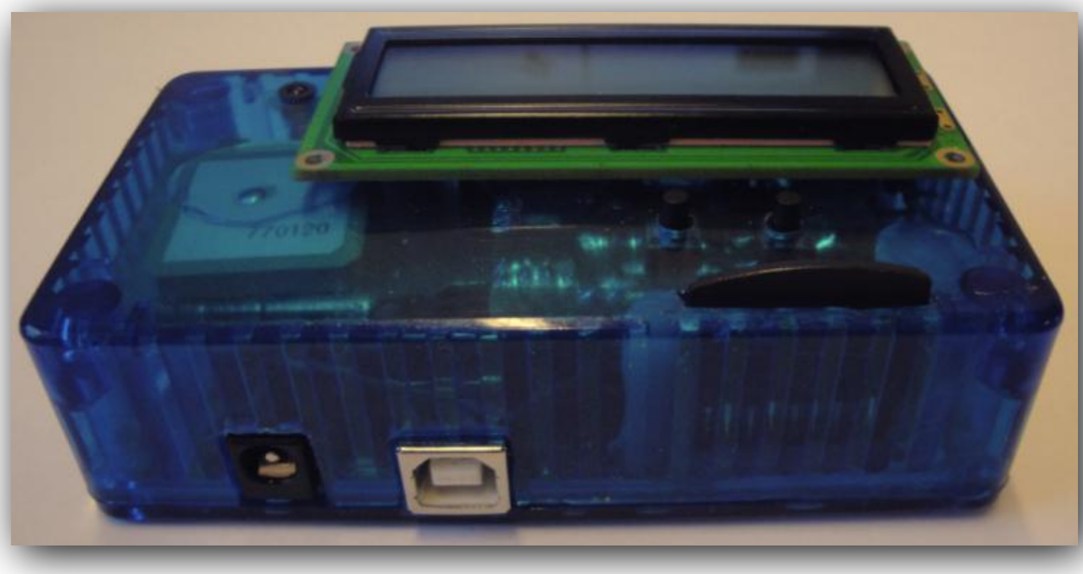
Table 12: Accelerometer pin connections

6.9.5 Switches connections

	Color	Motherboard pin
Switch 2	Purple	RB6
Switch 3	Green	RB7

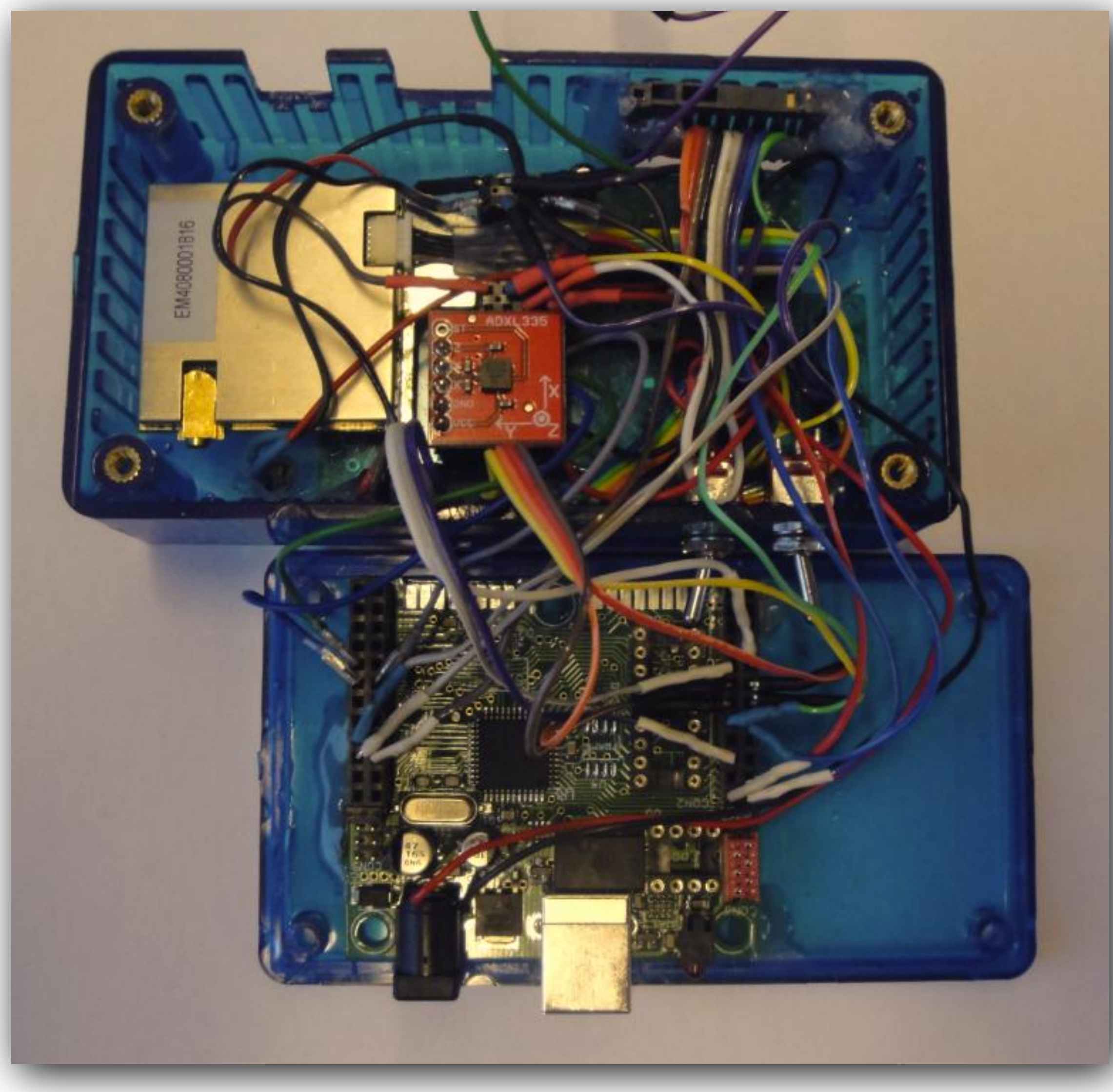
Table 13: Switches pin connections.

6.10 Prototype Pictures



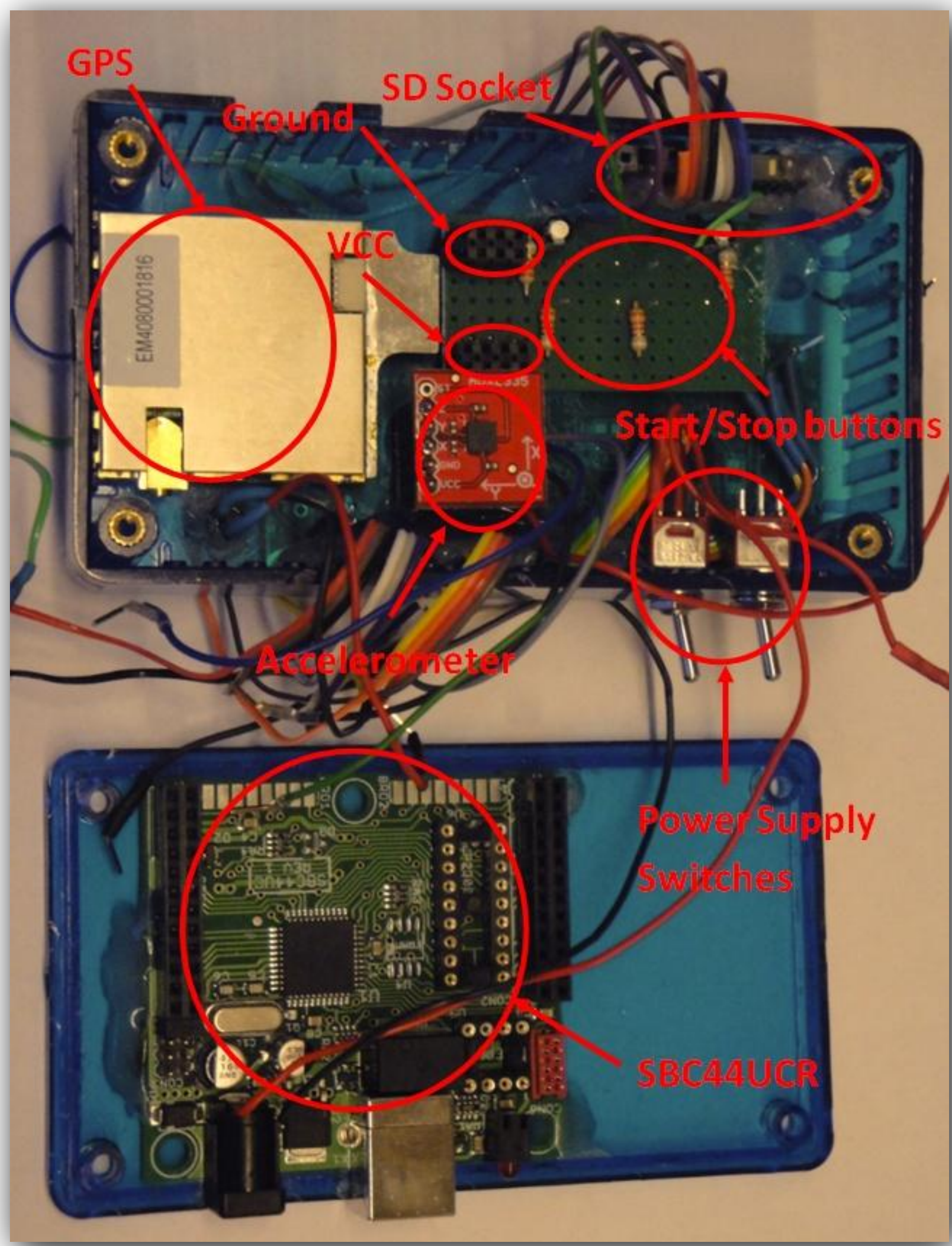
Picture 5: USB and the power supply connections.

Picture 6: Two switches for manage the power supply.



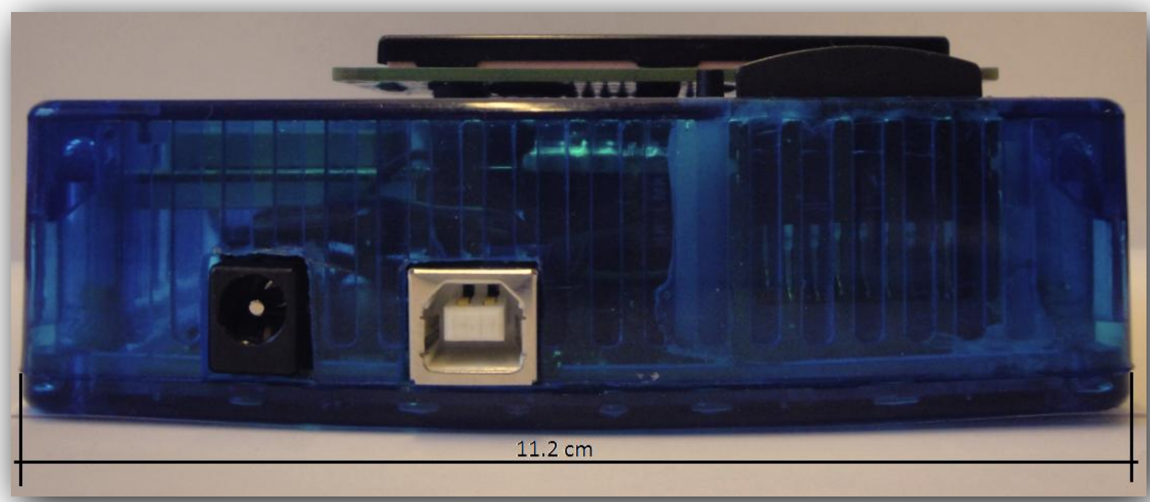
Picture 7: Connections inside the device.

6.11 Sub-devices location inside the TT Race Date

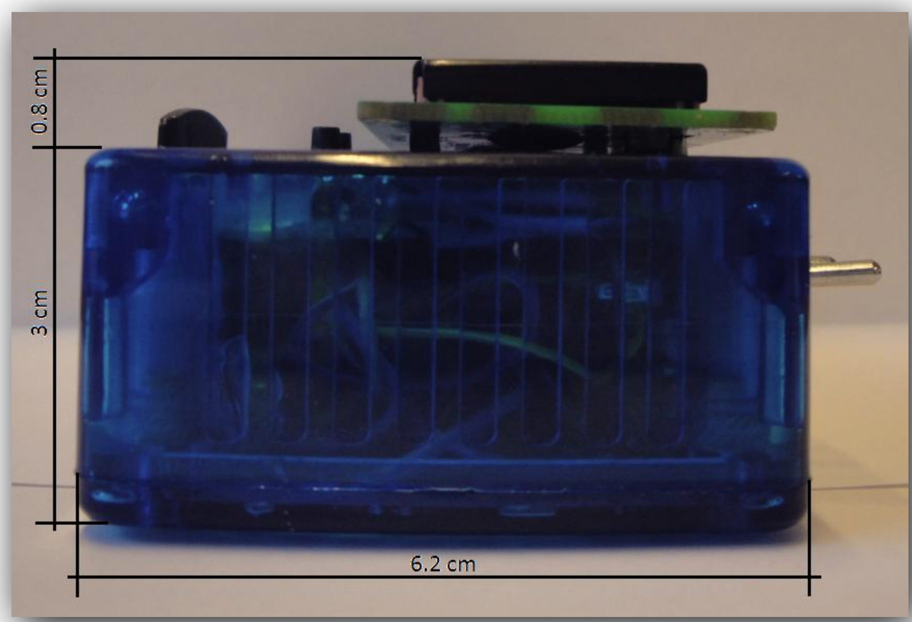


Picture 8: Location of the sub-devices

6.12 Dimensions & Orientation

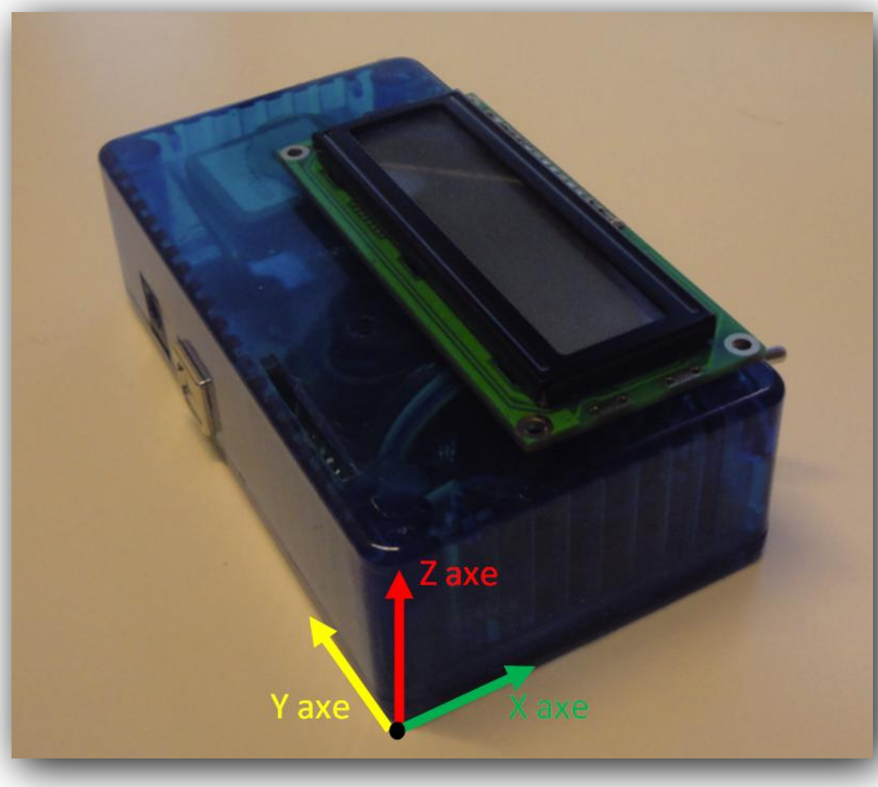


Picture 9: Frontal view.



Picture 10: Lateral view.

6.12.1 TT Race Data Logger location and position on the motorbike



Picture 11: The arrow shows the operation direction.

On the previous picture, is shown the direction of the motorbike movement, for place the device correctly it has to be behind the pilot, because the accelerometer, the device has to be positioned parallel with the road. The Y axe is marking the straight direction of the motorbike.

6.13 Tools

The complete project is designed with MPLAB IDE v8.46 and C18 compiler.

Is used a boot loader driver included in PIC18F4550 to program and erase the microchip. The program used to flash the PIC is PDFSUSB.exe “Microchip USB Wizard Program”.

This Schema represents the procedure of flashing the microchip with the PIC18f4550 boot loader and PDFSUSB.exe. The driver files needed by the Operating system are: MCHPUSB.sys and MPUSBAPI.dll provided by Microchip.

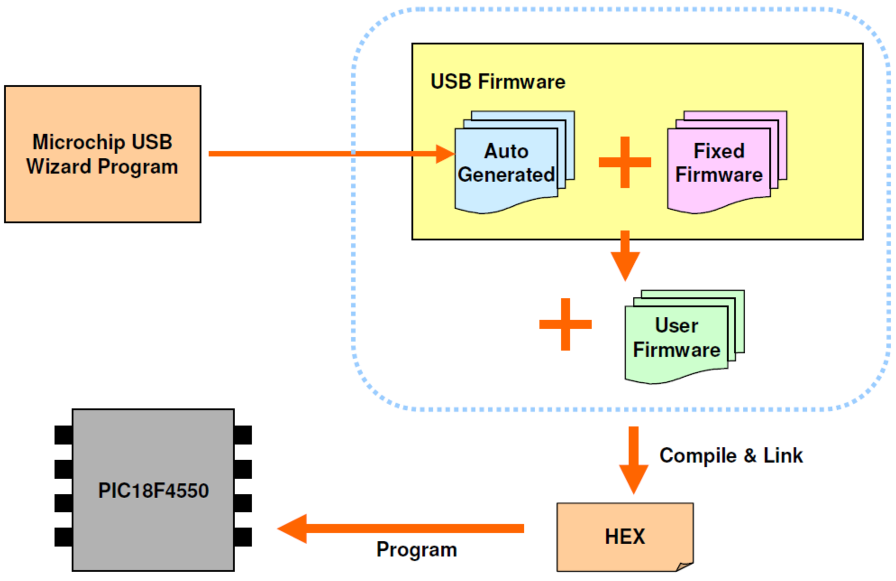


Figure 5 – Microchip’s Bootloader

6.14 Components

6.14.1 Mother Board

Model SBC44UC with PIC18F4550 Controller

Features

- Human Interface Device (HID) class firmware
- Communication Device Class (CDC) firmware (virtual serial port)
- Mass Storage Class Firmware
- Microchip Bootloader
- Microchip Custom Driver
- PIC18F4550 Controller
- 32 KByte FLASH program memory, 2048 Byte SRAM, 256 Byte internal EEPROM
- 33 user-programmable in- and outputs
- 13 user-programmable, 10-Bit analog to digital-converter inputs
- 2 programmable 10-Bit CCP-modules (PWM or Capture/Compare functions)
- 1 USART-module
- 1 I2C/SPI interface
- 2 comparators
- 4 Timer (1x 8-Bit and 3x 16-Bit)
- socket for an external I2C EEPROM
- optional expandability for a 8-Pin Ramtron SPI FRAM Chip (e.g. FM25246)
- Micro Match connecting socket with I2C and SPI-Bus
- red LED (user-programmable) on Port pin RB6
- dimensions: 58mm x 54mm
- current supply by USB-Bus or external 9-12V by a 2.1mm jack plug (reverse battery protection)
- high class quality components (e.g. electrolyte capacitors with extra long durability, high class 20ppm crystals...)
- optional ICSP-interface(In Circuit Serial Programming)

The SBC44UC can be provided with current by the USB-Bus or by an external wall power supply. The Board possesses a socket for an optional extension with a MCP23008 I/O Expander switching circuit or an externalI2C EEPROM. Also a FRAM chip as the 32 kB big FM25246 can be soldered optionally on the board.

Observations

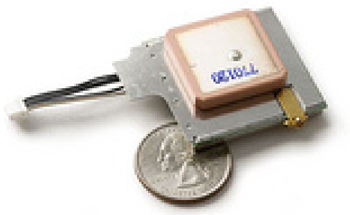
SBC44UC offers to us all the performance and reliability that we can ask to a prototyping board. It has all the I/O, A/D that we need for all our sensors, also supports USART and I2c protocols, these ‘re the protocols used by the GPS unit and the Memory cards . That board has the whole power supply system and main connections with the Inputs and Outputs already made. Is programmable with C for assembled microcontrollers and compatible with Mass Storage class Driver.

6.14.2 GPS Unit

20 Channel EM-408 SiRF III Receiver with Antenna/MMCX

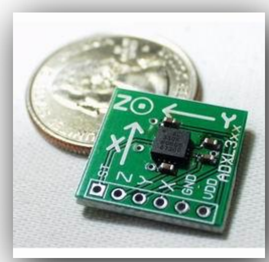
Features:

- Weight**:** 16g including cable
- 20-Channel Receiver
- Extremely high sensitivity : -159dBm
- 10m Positional Accuracy / 5m with WAAS
- Hot Start : 1s
- Warm Start : 38s
- Cold Start : 42s
- 70mA at 4.5-6.5V
- Outputs NMEA 0183 and SiRF binary protocol
- Smallest complete module available: 30mm x 30mm x 10.5mm



Observations
Good sensitivity, positional accuracy and use NMEA protocol compatible with USART and provides an external output for optional antenna.

6.14.3 Accelerometer



Triple Axis Accelerometer Breakout – ADXL335

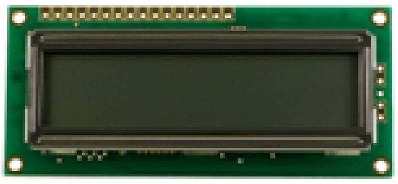
The ADXL335 is a triple axis accelerometer with extremely low noise and power consumption - The sensor has a full sensing range of +/-3g.

There is no on-board regulation, provided power should be between 1.8 and 3.6VDC.

Observations.

Easy Analog interface compatible with SBC44UC board with3 axis.

6.14.4 LCD 16x2 Display



Model.	**LCM-S01602DTR/A**
Lumex Opto/Components Inc	
Display Type	TN - Twisted Nematic
Display Mode	Reflective
Display Format	16 x 2
Character Format	5 x 8 Dots
Character Size	5.56mm H x 2.96mm W
Backlight	Without Backlight
Viewing Area	66.00mm L x 16.00mm W
Operating Temperature	0°C ~ 50°C
Voltage – Supply	5V
Dot Size	0.56mm W x 0.66mm H

Table 14: LCD characteristics

Complements

Daughter's board to expand buses and connections

Power supply AC to DC

Rechargeable Battery Li-On

SD Card Socket

Memory

Voltage Regulators

Buttons

Cables

7. Budget

Budget for our prototype and experimental equipment

Component	Cost (€)	
SBC44UC BOARD x 2	84.04 €	
GPS	44.17 €	
ACCELEROMETER	20.99€	
DISPLAY	12.35€	
DEVICE BOX	7.95€	
OTHER COMPONENTS (CABLES/CONNECTORS)	30€	
PROTOBOARD	19.95€	
No VAT included	**219.45€**	**TOTAL €**

Table 15: Empirical Budget

Budget for build a prototype

Component	Cost (€)	
SBC44UC BOARD	42.02€	
GPS	44.17 €	
ACCELEROMETER	20.99€	
DISPLAY	12.35€	
DEVICE BOX	7.95€	
OTHER COMPONENTS (CABLES/CONNECTORS)	10€	
LITTIUM BATTERY	25.00€	
SD CARD	20€	
No VAT included	**182.48€**	**TOTAL €**

Table 16: Ideal Budget

With an available budget of 1000 Euros and a maximum expenditure of 219.45 Euros we have managed to significantly reduce costs, and design a device only with that.

There are similar devices out in the market costs around 3000 Euros.

8. Observations & Evaluation

At this point, and without possibility of having been tested successfully the full algorithm designed for the prototype, we are satisfied with the done. We have not had the opportunity to change the design due to the short period of time which we have provided.
Design has been tailored to meet the demands of the contractor, we have made and studied a design for it, in theory the design is well implemented, but due to last minute problems on the size of the ROM of the microcontroller, it is not able to successfully perform the tests necessary to complete the final design.

Assessing the problems we had have, we concluded that the only way to solve these problems is to change the chosen microcontroller by one with more resources, enough to accomplish the needs of the program we have done.

9. Recommendations

9.1 Dimensions

This design is intended as a prototype, after the prototype is tested and getting the desired result, it's possible to redesign the board, designing a new board with all the components located in the same plane, making the design as small as the technology permits, it means less cost and less space.

9.2 Power Supply

TT Race Data Logger cans be fed by USB or external DC input, both at 3.3 Volts, but as we already said before, an internal an autonomous power supply with a battery and charging system will improve the complete design.
We offer a design for this system. Is not implemented but it could be easily to do it.

NOTE: Pins 1,2,16 are switching the state, IDLE, ON, OFF and are connected to the main Chip. It's not necessary to be exactly RB port, it could be another.

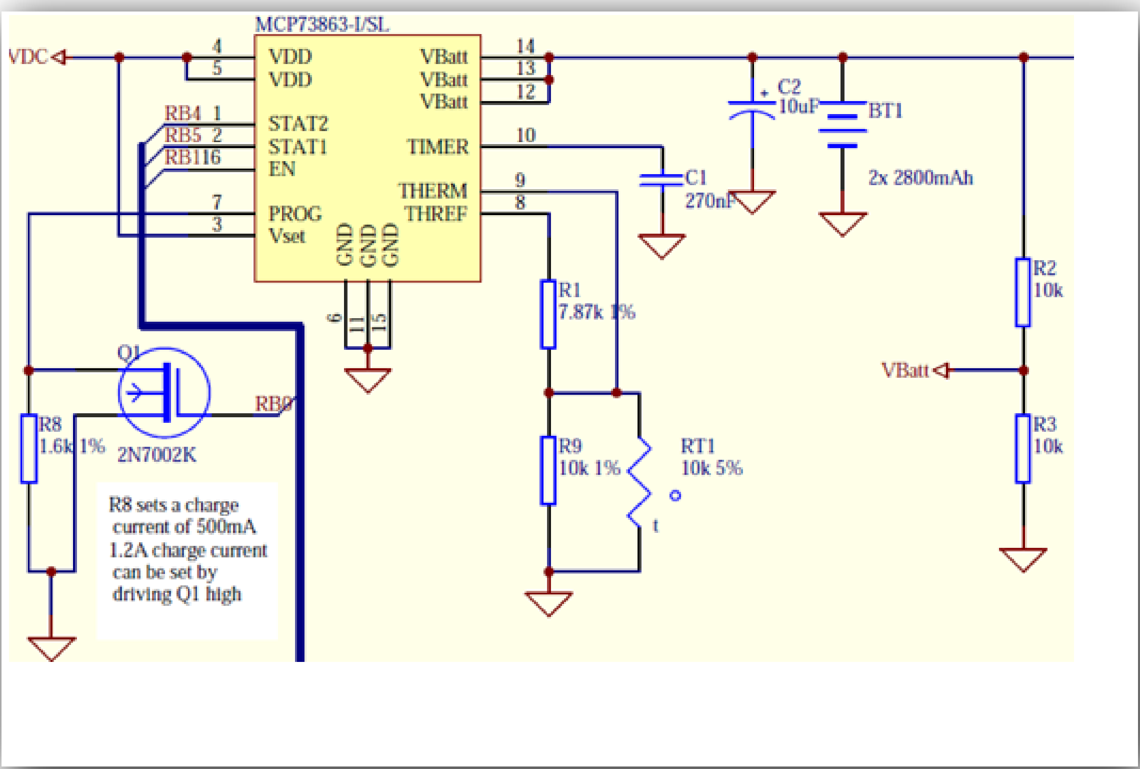


Figure 6: Battery management circuit schematic

9.3 SD Socket with USB chipset included

One of the issues encountered so far, was the lack of program memory space inside the CHIP used (PIC18F4550). One solution to minimize significantly the size of the entire program is use a better socket for SD card, with an USB/FAT16 interface chipset included. It offers the advantage to store the whole USB interface and FAT16 file system giving more freedom and space to the motherboard, offering the possibility to include more features to the TT Race Data logger.

Picture 11 – MicroSD Socket with USB/FAT16 interface included.

Model: DOSonCHIP FAT16/32 IC

9.4 Microprocessor

TT Race Data Logger needs a complex program to run, this means that this will use a lot of ROM memory to store it. During the study of the possibilities we found this problem, is caused because the main program is large to store it into the PIC18F4550, because of this our prototype is not running as well as we want.

We couldn't test it and know if the algorithm of the program is ok. During the part of the design we found several problems, we asked Microchip about this problems, they tried to solve it and found a solution, but finally, the best choice is change the microprocessor (PIC18F4550) for another with more capacity, and more resources.

PIC18F4550 has 32Kb of ROM memory, at least is needed the double, so minimum is needed a microcontroller with a memory ROM > 64 Kb. Is proposed one microprocessor for continue the project. PIC18F87J50 family should be enough with more than the double of resources. It has 3.800 Kbytes of Ram Memory.

To continue with this project will be necessary some changes in the wire connections and the code, to try to habituate for another chipset.

9.5 Data File Processing and Google Maps

TT Race Data Logger grants the position of the motorbike using a standard and international coordinate's format that could be read by some easy high level software. Actually Google offers very interesting software called "Google Earth/Maps API" that has the entire world mapped by their satellites stored in his database. This software is capable of, easily; make a remapping of the coordinates generated by the TT Race Data Logger showing them on a map with an incredible resolution and accuracy. This software is assembled by his own language; this compiler is made by Google and is open source but not for free. You can program your own functions and utilities inside your maps, designing tracers, routes and lots of more features, making it more interactive and easy to use. Also has a good behavior and compatibility with other languages like C, C++, java or flash and fits inside a mobile phone. It's easy, powerful and high recommended tool for further high level software design to process the data file generated by TT Race Data Logger.

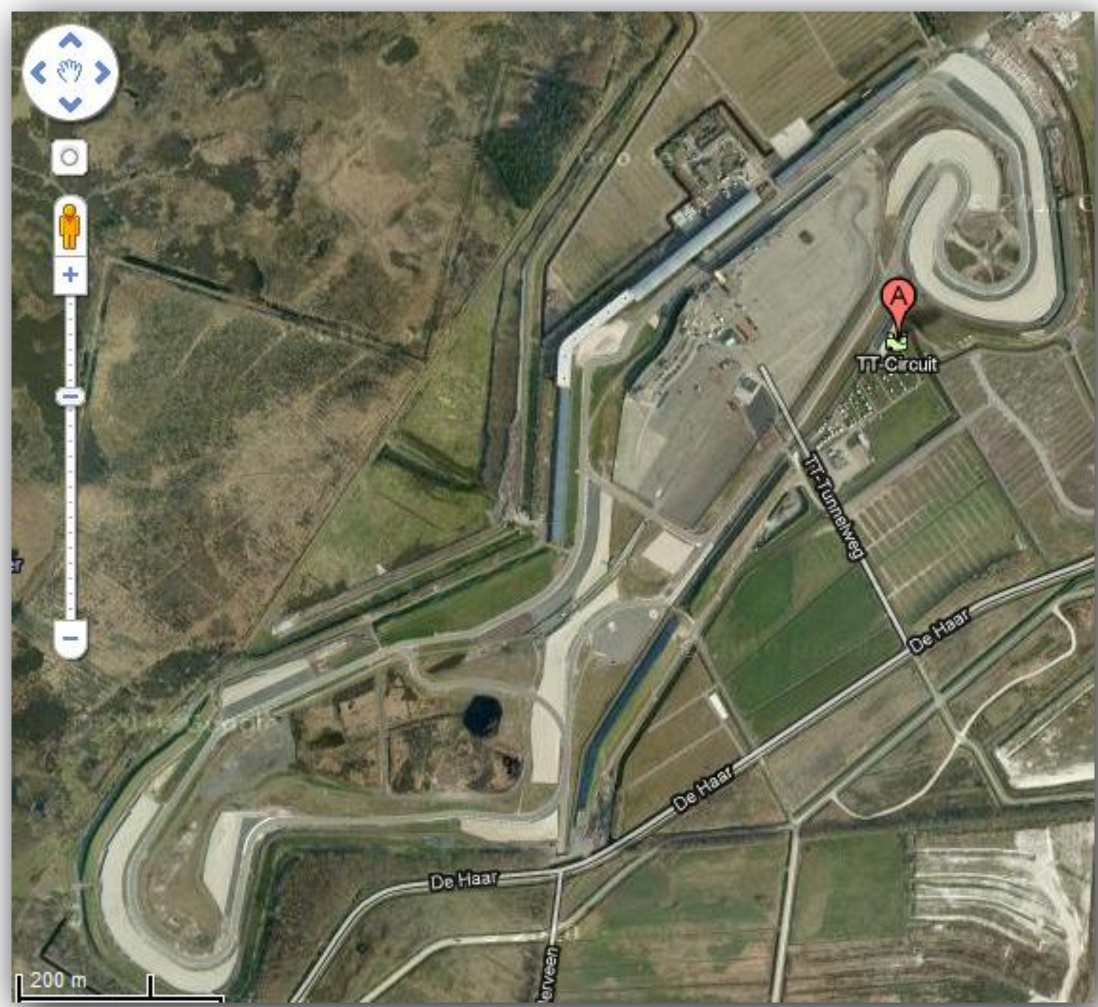


Figure 7: Example of Google Earth API Software, showing the TT Race Circuit in Assen - Netherlands

10. Literature

The next web links are some pages used for do our project

- http://www.aim-sportline.com
- http://www.gpsinformation.org/dale/nmea.htm
- http://en.wikipedia.org
- http://www.microchip.com/
- http://www.edaboard.com/
- http://www.xilinx.com/itp/xilinx10/isehelp/pim_c_introduction_spi_configuration.htm
- http://www.digitale-elektronik.de/shopsystem/
- http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1824&appnote=en532040
- http://elm-chan.org/docs/mmc/mmc_e.html
- http://mbed.org/projects/cookbook/wiki/SDCard
- http://www.vti.fi/midcom-serveattachmentguid-b469d17c67e60d4e3dbb25b0d099ad68/TN15_SPI_Interface_Specification.pdf

Books used

- Title: PIC Microcontrollers

  Author: Milan Verle

  Number of pages: 394

  Publisher: mikroElektronika; 1st edition (2008)

  Language: English

11. Annex

This report has to be followed by a CD where the user cans find the whole C Code and the necessary software tools for design it (MPLAB IDE, C18 Compiler and Firmware's Libraries). Also is included all datasheets about integrated components, no added to this report cause their size.