The **GY953** module

User Manual V3.4

Overview

The GY953 is a low cost AHRS module.

The working voltage of 3-5v low power consumption, small size.

The working principle, is by the gyroscope and

Acceleration transmission, magnetic field sensors by data fusion

The algorithm finally get direct angle data.

This module, there are two ways to read the data, i.e.
Serial (TTL level) or SPI (4 lines)

The means of communication. The products of high precision, high stability.

To obtain accurate angle at any position,

The serial baud rate with 9600bps and 115200bps

A continuous output and ask the output in two ways,

To adapt to different working environment.

Connected with the single chip microcomputer and computer all
(1), small size
(2), high performance price ratio
(3), serial communication format
(4), SPI communication format

Three, product application

(1), handheld instrumentation
(2), robot navigation, positioning
(3), sailing aero-modeling system
(4), the balance of the car
(5), antenna elevation positioning

Pins

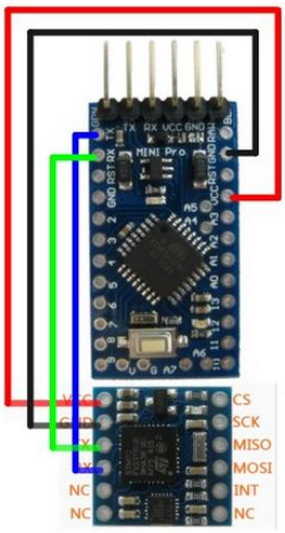
Pin1 VCC power + (3v-5v)
Pin 2 GND power supply
Pin3 TX serial data transmission
Pin 4 RX serial data receiver
Pin 5 SWD for internal use, do not need to connect, hanging
Pin 6 SWC for internal use, do not need to connect, hanging
Pin 7 B0 for internal use, do not need to connect, hanging
Pin 8 INT data interrupt pin, the output
Pin 9 MOSI SPI data
Pin 10 MISO SPI data
Pin 11 SCK SPI clock
Pin 12 CS SPI chip select

Byte2 0x15 0x25 0x35 0x45 0X55 0x65 0x75 0x85 (note there are 8 items below)

Meaning:

0x15, acceleration
0x25, The original number of gyroscope
0x35, The original number of magnetometer
0x45, Euler angles, repeat
0x55, Data retention: Euler angle
0x65, four Quaternion elements
0x75, Data sensors, all 3 in Degrees, plus frequency
0x85, sensor Ranges
0x95 Get one Euler angle
\

Communication protocol



Serial port

(1), serial port communication parameters (the default baud rate value of 115200 BPs, through the software setting)
The baud rate: 9600 BPS parity bits: N data bits: 8 stop bit: 1
The baud rate: 115200 BPS parity bits: N data bits: 8 stop bit: 1

(2), the format of the output module, each frame contains 11-13 bytes (sixteen m):
The.Byte0: 0x5A frame head logo
The.Byte1: 0x5A frame head logo
The.Byte2: 0X45 data type of the frame (reference meaning description)
The.Byte3: 0x06 data volume (6 following 3 data groups as an example)
The.Byte4: 0x00~0xFF data of 1 high 8
The.Byte5: 0x00~0xFF data of 1 low 8
The.Byte6: 0x00~0xFF data of 2 high 8
The.Byte7: 0x00~0xFF data of 2 low 8
The.Byte8: 0x00~0xFF data of 3 high 8
.Byte9: 0x00~0xFF data of 3 low 8
The.Byte10: 0x00~0xFF checksum (front of data accumulation and, leaving only the lower 8 bits)

(3), the data calculation method

Euler angle calculation method: angle = high 8 <<8| low 8 (results for the actual angle multiplied by 100)
Example: a frame data
<0x5A -0x5A -0x45-0x06 -0x00-0x64-0x03-0XE8-0x27-0x10-0x85>
Representation of Euler angle: Roll=1.00 degrees, Pitch=10.00 degrees, Yaw=100.00 degrees. These numbers are in 360 format, where positive number are to the left and minus numbers are to the right, -170 = 180+10 or 190 degrees.
The calculation method of gyro magnetic acceleration: original data the original data = high 8 <<8| low 8

Example: a frame data
<0x5A -0x5A -0x15-0x06 -0x00-0x64-0x03-0xE8-0x27-0x10-0x55>
That acceleration of original data:
0x0064, Y=0x03E8, Z= 0x2710 X=
Calculation method of four elements: data = high 8 <<8| low 8 (results for actual multiplied by 10000)
Example: a frame data
<0x5A -0x5A -0x65-0x08 -0x00-0x64-0x03-0xE8-0x03-0xE8-0x03-0xE8-0x46>
Said the four element data:
Q0=0.01, q1=0.1, q2=0.1, q3=0.1
WARNING: see detail about Q numbers below, high byte requires special treatment, and detection of the sign bit.

(4), by an external controller command byte, sent to the GY953 module (sixteen m)

1, the frame header: 0xa5,

Instruction format: frame head + Command + checksum (such as automatic reading of Euler angle instruction =0xa5+0x45+ The checksum byte is the additive of the a5 and next byte, then truncated to 8 bits.

2, the command instructions:

The serial baud rate setting instruction: (after each modification need to power on the entry into force, with the power down save)
0xa5+0xaf+0x54----------115200 (default value)
0xa5+0xae+0x53----------9600

The sensor configuration instructions:
0xa5+0x51+0xF6----------ON/OFF accelerometer sensor
0xa5+0x52+0xF7----------ON/OFF gyro sensor
0xa5+0x53+ 0xF8----------ON/OFF magnetic field sensor
Note: ON/OFF means send once, turn on, second time turns off.

54,56 maybe missing, no documentation.

0xa5+0x57+ 0xFC---------- gyro calibration, calibration data automatic storage
0xa5+0X58+0xFD----------magnetic field calibration, calibration data automatic storage

The magnetic field calibration will be complete when the indicator light comes back on. It goes out when calibration starts.

0xa5+0X59+0xFE---------- restore factory settings (after each modification need to electric force)(cycle power) FR does not change the state of the repeat commands.

0xa5+0xa4+ 0x49---------- data output rate of 50Hz
0xa5+0xa5+ 0x4A---------- data output rate of 100Hz
0xa5+0xa6+ 0x4B---------- data output rate of 200Hz

Note: no command to change the gyro, accelerometer or magnetic ranges.
1. Save automatic output flag settings:
After the automatic output instruction (A5 45 EA)is sent on, then the protection is sent. Save automatic output flag settings(A5 AD 52).Next time you get on the phone, just go straight is automatic output mode, no instructions need to be sent. In this mode, the original automatic output instruction switch function will not work.
2. Clear automatic output flag settings:
When in the "auto output flag setting", the data will be output automatically every time the power is turned on. To turn off auto output, use query mode, you need to send instructions. When it is powered on again, it is no longer in automatic output mode.

0xA5 0xAD 0x52 ---------- Saving the Auto Output Flag Setting (Power Saving)
0xA5 0xAC 0x51 ---------- Clear Auto Output Flag Setting (Power Saving)

Automatic repeating output commands: (with switch function, the first transmission to open, second send off):

Note: first send starts repeat, second send turns it off.
Be sure to turn off a particular data stream type BEFORE sending the command for another type. “Data automatic storage” is not clear as to what it means.

The repeating(15-65) original raw data of:
Acceleration of 0xa5+0x15+0xBA
Gyroscope of 0xa5+0x25+0xCA
Magnetic field of 0xa5+0x35+0xDA

0xa5+0x45+0xEA ---- the Euler angles (default 50HZ), repeating.
0xa5+0x55+0xFA ---- Euler angle ASCII character form (with serial assistant selection character display) NOTE: output is in: #RPY+010.72,+007.59,-145.81
0xa5+0x65+0x0A ---- four Quaternion number

The single query (75-E5) output instructions:
The accuracy of:

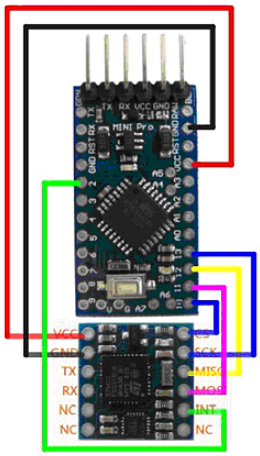
0xa5+0x75+0x1A ---- three sensor, the output frequency
0xa5+0x85+0x2A ---- obtain gyroscope range, plus range, the magnetic field range
See the SPI for the range information.

0xa5+0x95+0x3A ---- Euler angle (single data return), returns data type 45, not 95

a4,a5,a6 used to set frequency.
0xa5+0xb5+0x5A ---- four Quaternion number, returns data type 65, not B5
0xa5+0xc5+0x6A ---- raw accelerometer data, returns data type 0x15
0xa5+0xd5+0x7A ---- raw gyro data, returns data type 0x25
0xa5+0xe5+0x8A ---- raw magnetic field, returns data type 0x35

This is some C code for combining the bytes for the yaw. Where the buffer is unsigned short(16 bit). This is not completely portable.

```
 i = (signed short)inBuf[6]<<8;    // hang onto the sign bit
 j = (unsigned short)inBuf[7];
head = (i | j);    // or-ing is more portable than adding.
 head = (head+5)/100;    // round up then divide.
```



SPI interface

static byte _gy953reg_a = 0x08; //0b001000 set (refresh) data

static byte _gy953reg_b = 0x11; //0b010001 calibration functions

WARNING: most of the documentation for SPI must be deduced from the code example, listed here and in the references. https://github.com/sumotoy/GY953

Send a byte command with one of three commands: set data, calibrate, interrogate.
Send a byte of data to indicate sensor or type of data wanted.
Assume the S? register is a Status Register and the CR? Register is the Control Register layout.
A request for data(interrogate) returns 41 bytes of data. The description follows.
The CR? Byte is the first byte.
Number 2 byte specifies, read or write?
The S? Bytes 0x23, 0x24 are accuracy and range info bytes.

CR7 1: restore factory settings (0x80)
CR5 this bit must be 0 (0x20)
CR4 this bit must be 1 (0x10)
CR3 1: the field to start the calibration; automatic data storage (0x08)
CR2 1: self inspection and calibration of accelerometer and gyro meter; automatic data storage (0x04)
CR0 this bit must be 1 (0x01)
The above works out to 0x9d

CR6 (0x40)
CR7 this bit must be 0 (0x80)
The default CR6 CR6=1, when CR6=0 is closed magnetic field meter sensor, 1 open (0x40)
The default CR5 CR5=1, when CR5=0 is off the gyro sensor, 1 open (0x20)

The default CR4 CR4=1, when CR4=0 is closed and meter sensor, 1 open (0x10)
CR3 this bit must be 1 (0x8)

For instance set sensor enables:
0x73+8=0x7b. 3-6 set on, 50hz in 0-2, bit 7 is zero.

CR2 to CR0 set the data output rate: 3:50hz, 4:100hz, 5:200hz

CR2 CR1 CR0 data output rate
011 50Hz (default)
100 100Hz
101 200Hz

There are 41(0x29) bytes in the status registers.

B control register CR7 CR6 CR5 CR4 CR3 CR2 CR1 CR0

0x02 (write / read) delivered 001 CC self 01

ACC_X_H D15-D8
0x03 X axis acceleration and high 8 bit data
ACC_X_L D7-D0
0x04 X acceleration low 8 bits of data

ACC_Y_H D15-D8
0x05 Y axis acceleration and high 8 bit data
ACC_Y_L D7-D0
0x06 Y axis acceleration and low 8 bit data

ACC_Z_H D15-D8
0x07 Z axis acceleration and high 8 bit data
ACC_Z_L D7-D0
0x08 Z axis acceleration and low 8 bit data

NOTE: 0x09to 0x0xE were missing (6 dec.) Most likely GYRO
The COMPASS stuff was missing, filled in by guessing.

GYRO_X_H D15-D8
0x09 X gyro high 8 bits of data
GYRO_X_L D7-D0
0x0A X gyro low 8 bits of data

GYRO_Y_H D15-D8
0x0B Y gyro high 8 bits of data
GYRO_Y_L D7-D0
0x0C Y gyro low 8 bits of data

GYRO_Z_H D15-D8
0x0D Z gyro high 8 bits of data

GYRO_Z_L D7-D0
0x0E Z gyro low 8 bits of data

COMPASS_X_H D15-D8
0x0F X shaft magnetic high 8 bits of data
COMPASS_X_L D7-D0
0x010 X shaft magnetic low 8 bits of data

COMPASS_Y_H D15-D8
0x11 Y shaft magnetic high 8 bits of data
COMPASS_Y_L D7-D0
0x12 Y shaft magnetic low 8 bits of data

COMPASS_Z_H D15-D8
0x13 Z shaft magnetic high 8 bits of data
COMPASS_Z_L D7-D0
0x14 Z shaft magnetic low 8 bits of data

ROLL_H D15-D8
0x15 roll angle high 8 bit data
ROLL_L D7-D0
0x16 roll angle the low 8 bits of data

PITCH_H D15-D8
0x17 pitch high 8 bit data
PITCH_L D7-D0
0x18 pitch low 8 bits of data

YAW_H D15-D8
0x19 heading angle high 8 bit data
YAW_L D7-D0
0x1A heading lower 8 bits data

WARNING: see detail about Q numbers below, high byte may require special treatment.

Q0_L D7-D0
0x1C four element Q0 low 8 bits of data
Q0_H D15-D8
0x1B four element Q0 high 8 bit data

Q1_L D7-D0
0x1E four element Q1 low 8 bits of data
Q1_H D15-D8
0x1D four element Q1 high 8 bit data

Q2_L D7-D0
0x20 four element Q2 low 8 bits of data
Q2_H D15-D8
0x1F four element Q2 high 8 bit data

Q3_L D7-D0
0x22 four element Q3 low 8 bits of data
Q3_H D15-D8
0x21 four element Q3 high 8 bit data

0x23 Byte = accuracy levels, per following format.
S7 1: data update, automatic reset after reading
S6 reserves
S5 to S4 to obtain the accelerometer calibration accuracy is highest, lowest, 11: 00
S3 to S2 to obtain the gyro meter calibration accuracy, the highest, lowest 11: 00
S1 to S0 to obtain the field calibration accuracy, the highest, lowest 11: 00

0x24 Byte = range levels per following format.
S7 to S6 reserves
S5 to S4 0: acceleration range; 2G; 1: 4G 2:; 8g; 3: 16g
S3 to S2 0:+250dps; 1:+500dps; gyroscope scale; 2:+1000dps; 3:+2000dps
S1 to S0 magnetic field range (0.6; 0:14bit t 4915; 1:16bit (selection) selection t 0.15) 4915

NOTE: 0x23, 0x24 were missing. 23 is most likely ACC, and 24 is GYRO
These 23 and 24 byte blocks need confirmation.

ACC_SUM 8bit: acceleration data accumulation and 6 data registers (0x03~0x08)
0x23 ACC _X_H+ ACC _X_L+... ACC _Z_L
0x23 00001101

GYRO_SUM 8bit: gyro data accumulation and 6 data registers (0x09~0x0E)
0x24 GYRO _X_H+ GYRO _X_L+... GYRO _Z_L
0x24 new 0 acceleration gyro magnetic field

NOTE: 0x25 out of sequence

C status register S6 S5 S4 S7 S3 S2 S1 S0

COMPASS_SUM 8bit: magnetometer data accumulation and 6 data registers (0x0F~0x14)
0x27 COMPASS _X_H+ COMPASS _X_L+... COMPASS _Z_L

RPY_SUM 8bit: Euler angle 6 data register data accumulation and (0x15~0x1A)
0x28 ROLL _H+ ROLL _L+... YAW_L

D status register S6 S5 S4 S7 S3 S2 S1 S0

ACC_SUM 8bit: accelerometer data accumulation and 6 data registers (0x03~0x08)

0x25 ACC_X_H+ ACC_X_L+... ACC_Z_L

GYRO _SUM 8bit: gyroscope 6 data register data accumulation and (0x09~0x0E)
0x26 GYRO _X_H+ GYRO _X_L+... GYRO _Z_L

NOTE: 0x27 to 0x28 are in C status register, above.

Q_SUM 8bit: four Quaternion number 8 data registers the data accumulation and (0x1B~0x22)
I 0x29 Q0_H Q0 _L+... Q3_L

Note: the magnetic field accuracy, can be used as magnetic field calibration complete flag

Methods of using module

1, module data update frequency:
The output frequency is 50Hz by default, such as the need for higher output frequency, with the corresponding serial port or SPI please read corresponding instruction

The configuration, if the module initialization is successful, the indicating lamp will light up, interrupt pin appear on the L update along the existing data represents a module, this time also represents a module has been initialized. (see specific incidental reference program.)

2, data output module:
Please use interrupt pin reads data after the rising edge updates in the data. A large amount of data read in serial.

Calculation of a good serial data transmission time, please try to ensure that the data transmission time is less than the data update cycle, to avoid data transmission Impact of module. If the serial baud rate is 115200, then 115200/1000=115.2, said 1ms can transmit 115.2 Bit, serial transmission of a byte with start and stop bits 10bit, 115.2/10 said on 1ms serial port baud rate 115200 can transmit 11.52 bytes, the module of ACC, GYRO, MAG, RPY frame data are 11 bytes,

That is a data frame transmission need to 1ms, if the frequency of update module for 50Hz (20ms update), then the user in an update cycle can output all data frames; if 100Hz (10ms update), users can output all the number according to the frame; if 200Hz (5ms update), users can output four data frame, because the number of serial data four Quaternion

The frame consists of 13 bytes, the need to 1.12ms and data processing module itself also needs time, so the proposal in the baud rate of 115200,
Data update frequency is 200Hz, a data update user period output data frame as the 3 best. The baud rate 9600, please use corresponding calculations.

The transmission speed of SPI can be simply calculated in accordance with the SPI clock, if the SPI clock frequency is 125Khz, a clock transmission 1bit,
The 1ms can transmit 15.62 bytes of data, the module consists of 41 registers (41 bytes), 41/15.62 = 2.62ms,
So SPI data read time less than the highest periodic update data module (5ms), you can read all the register.
Module serial port and SPI data output are check and output, serial port for frame check and output, SPI is the register number

According to the accumulation and the output, the user can receive in the data, do the check and the corresponding test, it can avoid the data transmission by the system Transmission error disturbance generated (refer to attached program) (missing).

3.

4, restore factory settings:

Send the instruction after the restore factory settings, module will clear the calibration data preservation, MCU needs to reset force.

5, module three sensor status
The module comprises a gyro sensor, accelerometer and magnetometer, if the user does not need to use the heading angle, can send corresponding commands to close the magnetic sensor.

The module does not support all the sensors off, default of three sensors are on.

6, the gyro calibration:
The accelerometer and gyroscope itself may exist error, have a certain influence on the accuracy and precision of the pitch, roll angle, Therefore, before use of accelerometer gyro calibration, avoid the error caused by the sensor.

Calibration method:

As far as possible ensure that module is placed level, and then send the instructions (by PC send calibration instructions), wait for Angle stability, after calibration can check the calibration precision. When the accelerometer and gyro calibration accuracy is 3 indicates Gyro calibration is successful.

7, the magnetic field calibration:
Due to the fact that the module environment around the magnetic field is complex. This has a certain influence on the accuracy of course angle, so before use do the calibration, Calibration of module in the field will help to avoid the influence of the environment on the module.

Calibration method:

Do not place objects in the area surrounding the magnetic sensor when calibrating the module. Set the module placement level, then send the calibration instruction. (through Host computer sends instruction), the calibration module indicator light is off, the magnetic field calibration accuracy will be set to 0, pick up the module and slowly move around the X, Y, Z (i.e., left and right, before and after in situ) three axis around, until the indicator lights up, completion of calibration, calibration precision of magnetic field will be 3,

The user can send corresponding instructions to check the calibration accuracy. If the calibration, the indicating lamp has not been lit, or use the module, magnetic 9

If field calibration accuracy is 0, check around the module whether there exist hard iron or magnetic objects.

Note: This module has the ability to automatically detect the surrounding magnetic field, if there exist large objects with magnetic, then calibration of the magnetic module is necessary. Accuracy will be set at 0, the module course angle will appear error. When the module is far away from the magnetic object, magnetic field calibration precision module Recovery after calibration accuracy 3, this time heading angle will resume.

8, sensor

Acceleration measuring range module for 2G gyroscope; +2000dps; magnetic field range: range: 4915 t selection

(1), Module power on self correction, need to keep more than 3 seconds rest state, is not recommended to take module by hand

(2), Module with magnetometers, as far as possible from the iron, magnet, electromagnetic field interference, etc..

(3), The angle of Euler angle has a universal lock problem(gimble lock), roll, pitch will influence each other at 90 degrees or more.

(4), I/O module is the TTL level, can be directly connected with the serial interface, can be directly connected with PL2303, CH340, FT232 and other chips, but not with the computer serial port directly connected to nine (volts?).

Addition :

ARDUINO SPI CONNECT
ARDUINO serial port terminal wiring diagram

Notes

WARNING: Quaternion numbers x, y, z, the high byte requires special treatment. If high byte is signed, then subtract the entire integer from 0xFFFF or do an inversion with the C operator '!" If the high bit is set, the parameter is negative: set a flag and be sure to account for the sign before converting to Euler, as below.

In order to compute the yaw from the Q number takes special processing. The logic is as follows. If the sign bits for Q0 and Q3 are 0,1 or 1,0 then use the heading. If Q0 and Q3 are 0,0 or 1,1 then the heading is: 3600-heading.

Valid data for Q numbers is from integers 0-10000, which when divided by 10000 results in valid floats of 0 to 1.0. No other numbers are valid. In practice the high byte can never be more than 0x27. This issue is related to the "excess digits" mode of data representation. This is not normal one or two's complement representations.
A historical note: this may have been implemented this way because of the added difficulty of writing zeros. See the Wikipedia articles on this subject.

This checking for sign and subtraction also applies to the raw sensor data for the accelerometer, gyro and magnetometer. The Raw Gyro and most likely the acc and mag data require:
If the high byte is negative(the high bit is set) then take the integer and subtract it from 0xFFFF, then multiply by -1 if you need the reverse. The degrees per second is most likely the integer divided by 100 or 1000.

There is an effective gimble lock for roll or pitch beyond about some point, likely about 60 degrees. Exceed this limit and the Euler yaw will return a completely new value. See sensor item (3).

The Serial and SPI interfaces are not completely equal. The SPI can be polled, but most of the Serial data comes by interrupt.
The SPI interface may be usable at faster than the default of 1mghz.

SPI: To begin communication, the bus master configures the clock, using a frequency supported by the slave device, typically up to a few MHz.

The Serial interface appears to be subset of the SPI/pin interface, a kind of high level interface.

It may be possible to query by Serial and SPI simultaneously.

Notes from Aliexpress

2016.8.1
Added two serial port instructions to facilitate the need to automatically power output that customers use:

A5 AD 52 ---------- Saving the Auto Output Flag Setting (Power Saving)
A5 AC 51 ---------- Clear Auto Output Flag Setting (Power Saving)

Description:
1. Save the automatic output flag settings:
After sending the automatic output command (A5 45 EA), the Save Automatic Output Flag setting is sent (A5 AD 52).
The next time the power is directly after the automatic output mode, do not need to send any instructions.
In this mode, the original automatic output of the command switch function will not work.

2. Clear the automatic output flag setting:
When in the "automatic output flag setting" time, every time power is automatically output data, in order to turn off the automatic power output,
Using the query mode, you need to send commands (A5 AC 51). When power is turned on again, it is no longer the automatic output mode.
---------- --------
Raw data is converted to the actual unit, note that there is ±:
Acceleration Sensors (g) = Acceleration Raw Data / 16383

Gyro sensor (deg / sec) = gyro raw data / 16.4

Magnetic field sensor (uT) = magnetic field raw data / 6.7

References

Here are some internet links.

The GY-953 appears to use the MPU-925x chip.

Documentation
https://invensense.tdk.com/products/motion-tracking/9-axis/mpu-9250/#product-documentation
Data Sheet
https://invensense.tdk.com/wp-content/uploads/2015/02/PS-MPU-9250A-01-v1.1.pdf
Register Map
https://invensense.tdk.com/wp-content/uploads/2017/11/RM-MPU-9250A-00-v1.6.pdf

JY901 and GY953 comparison paper
https://symbiosisonlinepublishing.com/robotics-automation/robotics-automation16.php

https://en.wikipedia.org/wiki/Serial_Peripheral_Interface

SPI, Serial code examples. Source of some documentation not available in this.
https://github.com/sumotoy/GY953
examples/basic/basic.ino is a Serial test program.
src/GY953.cpp and GY953.h contain routines to access the registers.
https://www.arduino.cc/en/Reference/SPI

The sumotoy code is based arduino.

https://is.muni.cz/th/mp860/

Comparing Gyroscopes
https://learn.adafruit.com/comparing-gyroscope-datasheets

Gyro Errors. Search: gyroscope error correction
https://www.researchgate.net/publication/301222605_Marine_Gyro_Compass
https://www.researchgate.net/publication/261395324_Estimating_MEMS_gyroscope_g-sensitivity_errors_in_foot_mounted_navigation

Calculation Gyro Error
http://collisionregs.com/Gyro.pdf

Gyro Calibration
https://cdn-learn.adafruit.com/downloads/pdf/adafruit-sensorlab-gyroscope-calibration.pdf

https://www.researchgate.net/publication/301222605_Marine_Gyro_Compass

Editing Notes

This document is based upon:
https://docs.google.com/document/d/1M3NA8EF-jvdfeZpuAe-RLQwVDurlY1n75bb-RodDKxc/edit#

And was edited by Michael P. Maurice. Sherwood, OR. May 2020
Some items were missing, I made guesses at what they were..
Fixed some grammar and made major changes to the format.