DIGITAL COMPASS

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ABSTRACT

As information gathering becomes critical to a new information based economy, it is vital to have the tools necessary to collect information about our environment. One key environmental aspect to location awareness and geospatial data gathering is one's bearing within a frame of reference. Orientation and bearing are key to understanding our location and interpreting data from that environment. The most reliable and reproducible form of determining orientation is through measurement of Earth's magnetic field. With accuracy and precision being of upmost importance, it is crucial to implement a magnetic compass through digital equivalents to produce increased precision, accuracy and reducibility.

As navigation and orientation becomes necessary in a new information age, it is vital to have a precise and accurate digital compass. The primary function of the compass would be for navigation and orientation. This device has numerous markets it can be manufactured for. In a consumer market, it would be an indispensible aide for hikers, sailors, and for other outdoor activities where navigation is necessary. A digital compass also has viable market necessity in commercial and military application where such application require embedded sensors to determine a broader picture of the surrounding environment. Example of such parallel application are automotive, aerospace, satellite and troop management and movement.

The digital compass is[1] implemented via the ATMEGA 2560 microcontroller on an Arduino board and sparkfun LSM303 COMPASS module is both accurate and fairly easy to implement. The LSM303outputs values of the magnetic field and accelerometer reading to the arduino using I2C communication protocol, where these values are mathematically processed to find the Heading in degrees i.e. the location of the North in degrees. This is then displayed on an LCD. An arrow on a motor rotates according to the heading to point to the North.

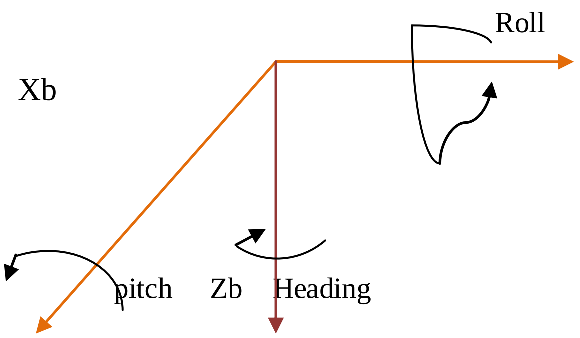
INTRODUCTION

COMPASS THEORY BASICS

A tilt compensated electronic compass [2]system requires a 3-axis magnetic sensor and a 3-axis accelerometer sensor. The accelerometer is used to measure the tilt angles of pitch and roll for tilt compensation. And the magnetic sensor is used to measure the earth's magnetic field and then to determine the heading angle with respect to the magnetic north. If the heading with respect to the geographic north is required, the declination angle at the current geographic location should be compensated to the magnetic heading.

DEFENITIONS

For compass application in a handheld device such as a cell phone or PDA, the aircraft convention is widely used to define the device body coordinates and three attitude angels pitch, roll and heading.



YbFig.1. Digital Compass

From figure the device body coordinates Xb/Yb/Zb are defined as forward/right /down based on the right-hand rule. Three attitude angles are referenced to the local horizontal plane which is perpendicular to earth's gravity-

Heading – defined as the angle between the Xb axis and the magnetic north on the horizontal plane

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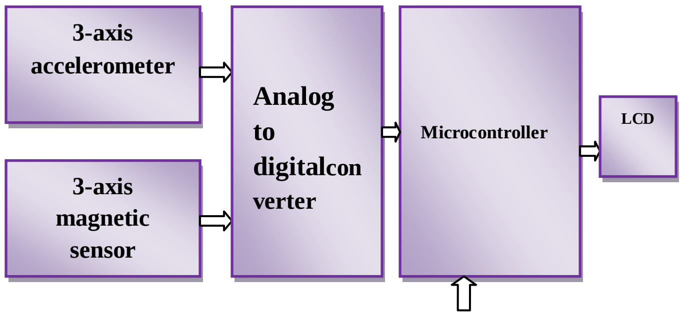
measured in a clockwise direction when viewing from the top of the device (or aircraft).

Pitch-defined as the angle between the Xb axis and the horizontal plane. When rotating the device around the Yb axis with the Xb axis moving upwards, pitch is positive and increasing.

Roll-is defined as the angle between the Yb axis and the horizontal plane. When rotating the device around the Xb axis with the Yb axis moving downwards, roll is positive and increasing.

THE ELECTRONIC COMPASS SYSTEM

Fig.2.below shows general block diagram of electronic compass system.



Pitch,Rolland Hearing calculations

A microcontroller (MCU) is used to collect the 3-axis accelerometer raw data for the pitch and roll calculation and collect the 3 axis magnetic sensor raw data for the heading calculation. The following procedure for building a working electronic compass system.

- Hardware design to make sure the MCU can get clean raw data from the accelerometer and the magnetic sensor.
- Accelerometer calibration to obtain parameters to convert accelerometer raw data to normalized values for pitch and roll calculation.
- Magnetic sensor calibration to obtain parameters to convert magnetic sensor raw data to normalized values for the heading calculation.
- Test performance of the electronic compass system.

Design and Implementation

There is only a few kinds of magnetometers able to read a weak magnetic field strength:

- Mechanical magnetic sensors
- Fluxgate sensors
- Hall-effect sensors
- Magneto resistive sensor

TheLSM303DLH from STMicroelectronics is a 6D sensor module [3] that contains a 3D accelerometer and a 3D magnetic sensor. It has an I2C digital interface so that the analog to digital converter is avoided. The MCU can collect 6D sensor data directly through the I2C interface.

Microcontroller-(ArduinoMega board) Atnega2560

The Arduinomega is [4] a microcontroller board based on the ATmega2560. It has 54 digital input/output pins(of which 14 cab be used as PWM outputs), 16 analog inputs, 4 UARTs(hardware serial ports), a 16MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer witha USB cable or power it with a AC-to-DC adapter or battery to get started.

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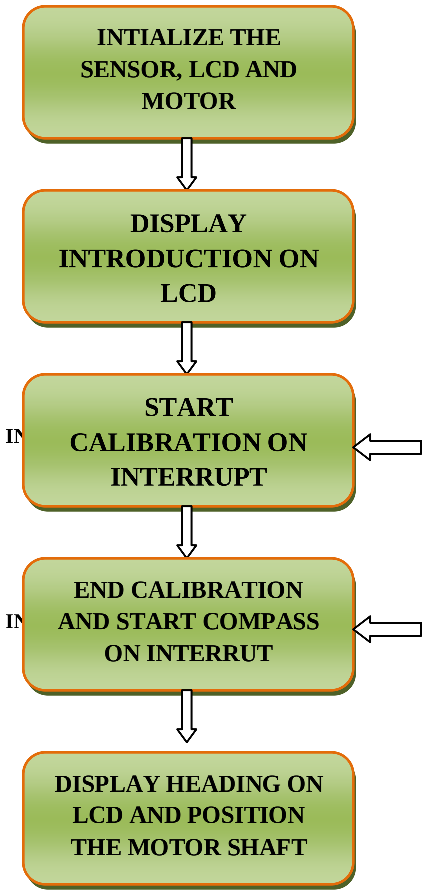
Fig.3. SOFTWARE DESIGN



CALIBRATION:

LSM303DLH accelerometer calibration

To reach a heading accuracy of below 2^o, an easy calibration procedure is described.

After the LSM303DLH is installed in the handheld device, it is necessary to calibrate the accelerometer part again at the handheld device's manufactures in order to determine the offset, the scale factor, and the misalignment matrix with respect to the device body axes Xb/Yb/Zb.

RESULTS:After the calibration parameters for the accelerometer and the magnetic sensor of the LSM303DLH have been determined, it is necessary to check the performance of the electronic compass. This could be carried out with accurate lab testing and rough field testing. The expected pitch/roll/heading accuracy is shown below.

Parameter	Value
Heading accuracy	$<2^o$ RMS , range: 0^o ~ 359.9^o
Pitch and roll accuracy	$<1^o$RMS,range:-90^o~ $+90^o$
Resolution	$0.1^o$for heading, pitch, and roll

- Absolute heading testing.
- Tilt compensation testing.
- Relative heading testing.
- Tilt compensation testing

FUTURE IMPROVEMETNS AND FUTURE SCOPE

Advantages of the compass

- Can be used in circuits in spite of the soft and hard iron interference after it is calibrated.
- The compass reading can be further used in navigation of ships, aircrafts or anywhere auto positioning (on basis of the 4 directions) is needed.
- Can be integrated to mobile systems like cell phones.
- As it is always calibrated before use, there is no chance of the instrument losing its calibration unlike a needle compass. Needles in magnetic compass can depolarize or the poles may interchange due to external magnetic fields.

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- High accuracy. Can be used with GPS to find magnetic north automatically.

DISADVANTAGES

- The compass board built is bigger than a normal needle compass. But this can be reduced by integrating it on an IC.
- Seems complicated to use when compared to needle compass.
- Costly.

APPLICATIONS

- ✓ Navigation and navigators. Ships, Aircrafts use a digital compass for its accuracy and reliability. Private trekkers also can use this for accurately determining their orientation.
- ✓ Integrated to electronic circuits.
- ✓ Robotics – robots which are used in Warfield's, or the puzzle solving robots which has AI all use digital compass inputs to orient themselves in the field.

FUTURE SCOPE

With the magnetic sensors becoming cheaper(according to an IEEE spectrum article, they are now available at $1.5) and almost all smart phones having accelerometer, many of them these days can run a digital compass. An example is the Iphone. This takes smart phones to another new level, making them a traveller's or an adventurer's aid. Since smart phones have GPS, it can also be used. This is a new rage in the smart phone market these days. Also highly accurate and precise standalone compass units which use other sophisticated method of measuring the Earth's magnetic field can be used for navigation of ships and aircrafts.

CONCLUSION

Implementing a digital compass can range from the simple to the complex. This is determined by how sophisticated an application is required. A low cost digital compass application requires mid-level design experience. Application requirements are the driving factors behind the level at which it is developed. Some of these factors include accuracy, speed, features and size.

References

[1]AN3192 Application note-using LSM303DLH for a tilt compensated electro ionic compass.

[2] Arduino Mega 2560 data sheet.

[3] Mitsumi motor datasheets.

[4] JHD204a data sheet.

[5] Internet.

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