HMC5843 based digital compass: Direction Change Detector

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1.Introduction

With the development and improvement of integrated circuit technology, people use the principle that the changes of the magnetic field can affect the inductive circuit to produce a magnetoresistive sensor. an electronic compass can be produced by using magnetoresistive sensors,which makes compass development enter a new era. to better understand the principle behind. In this project. Honeywell's magnetoresistive sensor HMC5843 has been used to collect the magnetic field strength of a certain direction and upload the output data to Microprocessor MSP430. after being processed, the data would be sent to and displayed on OLED screen.

2.Hardware System Module

- MSP430
- Code Composer Studio
- HMC5843
- OLED

2.1Microprocessor——MSP430

Texas Instruments ultra-low power MSP430™ micro-controller Value Line offers superior 16-bit MCU performance and industry leading ultra-low power consumption for cost sensitive applications that have traditionally depended on low cost 8-bit micro-controllers. TI MSP430 Value Line ensures 8-bit developers no longer need to sacrifice performance, power efficiency or scalability because of price. The MSP430G2xx Value Line is an ideal fit for a broad range of cost sensitive applications, including, safety and security, low cost touch pads, remote controls and intelligent sensors. The roadmap includes more than 100 MCUs to be released over the next 15 months, providing developers with a broad portfolio to best fit their memory, peripheral and packaging configuration needs[1].

Features

Up to 10X performance, including true 16 MIPS operation
Five power modes with ultra-low standby power of 0.4 μA and <1μs wake-up time
Integrated intelligent peripherals
Up to 2KB Flash and 128B RAM - future devices will include up to 16KB Flash and 512B RAM
Full code compatibility across MSP430 platform

Applications

Consumer Electronics
Personal Health & Fitness
Intelligent Sensors
Touch Pads
Safety & Security
Lighting

2.2 Code Composer Studio™ - Integrated Development Environment

Code Composer Studio serving as an integrated development environment (IDE) has been used to develop 、 the function. Both TI's Micro-controller and Embedded Processors portfolio can be supported by CCS. it also contains a suite of tools which can help develop and debug the applications of embedded system. several parts:an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features have been included in CCS. The intuitive IDE provides a single user interface taking you through each step of the application development flow. Familiar tools and interfaces allow users to get started faster than ever before. Code Composer Studio combines the advantages of the Eclipse software framework with advanced embedded debug capabilities from TI resulting in a compelling feature-rich development environment for embedded developers[2].

2.3 Axis Digital Compass IC HMC5843

The Honeywell HMC5843 is a surface mount multi-chip module designed for low field magnetic sensing with a digital interface for applications such as low cost compassing and magnetometry. The HMC5843 includes our state of the art 1043 series magneto-resistive sensors plus Honeywell developed ASIC containing amplification, strap drivers, offset cancellation, 12-bit ADC and an I2C serial bus interface.the inner structure and the connection to Host CPU can be found below[3]:

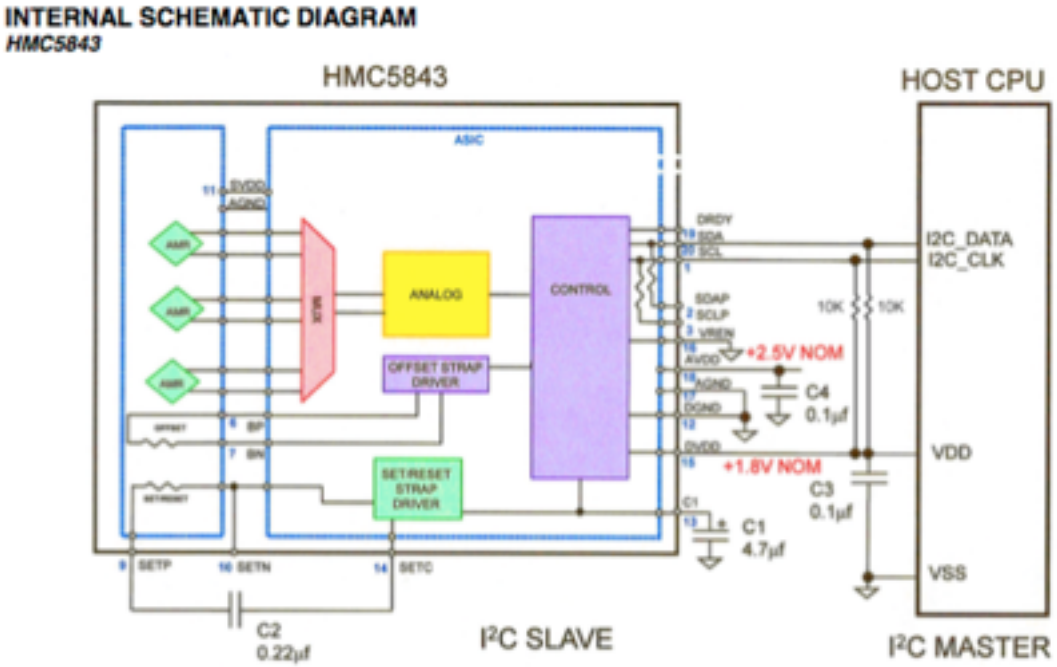

Figure 1

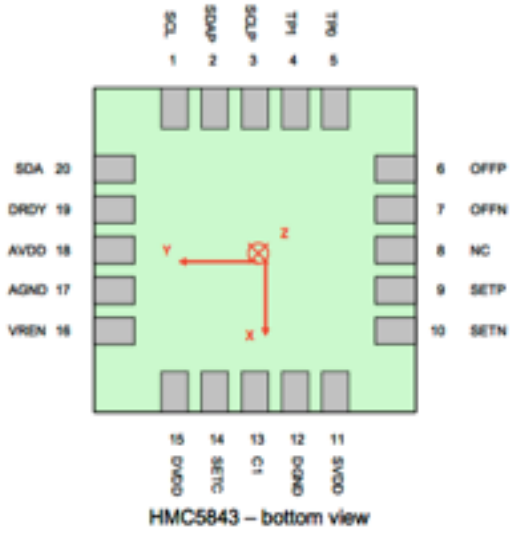

Figure 2

The HMC5843 utilizes Honeywell's Anisotropic Magnetoresistive (AMR) technology that provides advantages over other magnetic sensor technologies. The sensors feature precision in-axis sensitivity and linearity, solid-state construction with very low cross-axis sensitivity designed to measure both direction and magnitude of Earth's magnetic fields, from tens of micro-gauss to 6 gauss. Honeywell's Magnetic Sensors are among the most sensitive and reliable low-field sensors in the industry[3].

Features:
- 3-Axis Magnetoresistive Sensors and ASIC in a Single Package
- Low Cost
- 4.0 x 4.0 x 1.3mm Low Height Profile LCC Surface Mount Package
- Low Voltage Operations (2.5 to 3.3V)
- Built-In Strap Drive Circuits
- I2C Digital Interface
- Lead Free Package Construction
- Wide Magnetic Field Range (+/-6 Oe)
- Available in Tape & Reel Packaging
- Fast 116 Hz Maximum Output Rate

Benefits:
- Small Size for Highly Integrated Products. Just Add a Micro- Controller Interface, Plus Two External SMT Capacitors
- Designed for High Volume, Cost Sensitive OEM Designs
- Easy to Assemble & Compatible with High Speed SMT Assembly
- Compatible for Battery Powered Applications
- Set/Reset and Offset Strap Drivers for Degaussing, Self Test, and Offset Compensation
- Popular Two-Wire Serial Data Interface for Consumer Electronics
- Complies with Current Environmental Standards
- Sensors Can Be Used in Strong Magnetic Field Environments
- High Volume OEM Assembly
- Enables Pedestrian Navigation and LBS Applications

2.4 Display OLED

OLED (Organic Light Emitting Diode) is a self light-emitting technology composed of a thin, multi-layered organic film placed between an anode and cathode. In contrast to LCD technology, OLED does not require a backlight, the display unit can be self-luminous
. OLED possesses high application potential for virtually all types of displays and is regarded as the ultimate technology for the next generation of flat-panel displays[4].

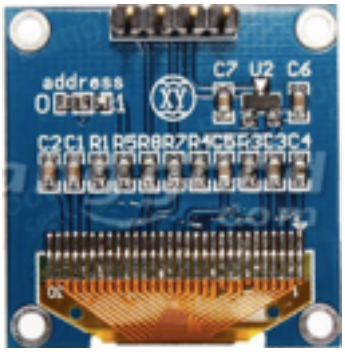

Figure 3

Features:

- No backlight, High resolution: 128 x 64
- Viewing angle: >160°
- Supports many control chip: fully compatible with Arduino, 51 series, MSP430 series, STM32 / 2, CSR chip, etc.
- Ultra-low power consumption: full screen lit 0.08W, 0.06W normal full-screen display of Chinese characters
- Wide voltage support: without any modification, directly supports 3V ~ 5V DC
- Working temperature: -30°C ~ 70°C
- Module volume (generous): 27.0 x 27.0 x 4.1mm
- Minimum occupancy on Earth IO port display: The IIC/I2C communication, as long as the two IO ports will be able to drive!
- Driver IC: SSD1306

2.5 I2C Serial Transmission

in this project, I2C bus has been applied to conduct the transmission and control of HMC5843. usually there are two types of device: master device(usually the microprocessor or micro-controller),slave device(different types of sensors). HMC5843 will be connected to this bus as a slave device under the control of a master device-MSP430.This device shall be compliant with I2C-Bus Specification because HMC5843 is an I2C compatible device,it has a 7-bit serial address and supports I2C protocols. it also can support standard and fast modes, 100kHz and 400kHz respectively, but cannot support the high speed mode (Hs). Depending on the application, the internal pull-ups may be used to support slower data speeds than specified by I2C standards.

Table 1 shows the Characteristics of the SDA and SCL I/O stages for I2C-bus devices".

Table 1

Characteristics	Conditions*	Min	Typ	Max	Units
I2C Address	7-bit address 8-bit read address 8-bit write address		0x1E 0x3D 0x3C		hex hex hex
I2C Rate	Controlled by I2C Master	-10		+10	%

Table 2 shows the pin information of HMC5843

Table 2

Pin	Name	Description
1	SCL	Serial Clock – I2C Master/Slave Clock – up to 400kbps I2C Speed
20	SDA	Serial Data – I2C Master/Slave Data – up to 400kbps I2C Speed
12	DGND	Digital Supply Ground/Return

The whole hardware system has been shown in figure 4. There are mainly three parts: MSP430 micro controller,OLED,and HMC5843.

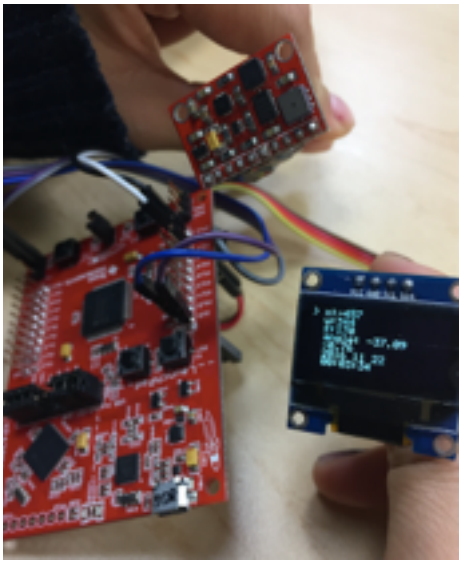

Figure 4

3. Software Design

As to software part, C language has been used to to conduct MCU programming to control register addresses and finally achieve the real function of detecting direction change.

3.1Mode status

For the continuous transmission of data, Continuous-Measurement Mode need to applied. During continuous-measurement mode, the device continuously makes measurements and places measured data in data output registers. Settings in the configuration register affect the data output rate (bits DO[n]), the measurement configuration (bits MS[n]), and the gain (bits GN[n]) when in continuous-measurement mode. To conserve current between measurements, the device is placed in a state similar to idle mode, but the mode is not changed to idle mode. That is, MD[n] bits are unchanged. Data can be re-read from the data output registers if necessary; however, if the master does not ensure that the data register is accessed before the completion of the next measurement, the new measurement may be lost. All registers maintain values while in continuous-measurement mode. The I2C bus is enabled for use by other devices on the network in while continuous-measurement mode[3].

3.2 Data Analysis

HMC5843 can measure data from X, Y, Z three directions. the three directions are orthogonal, the magnetic field angle can be gained by processing the data from these three directions. each direction has two eight-bit data register A and B. register A stores the upper data in a measurement result, and register B stores the low-order data of a self-measurement result. The values in these registers are sixteen bits in the form of two's complement ranging from 0XF800 to 0X07FF. Because the Z axis perpendicular to the magnetic field, which is theoretically equal to zero, only X, Y value can be used to calculate angle, the formula for the angle = arctan (X / Y)[3].

3.3 System Work-flow

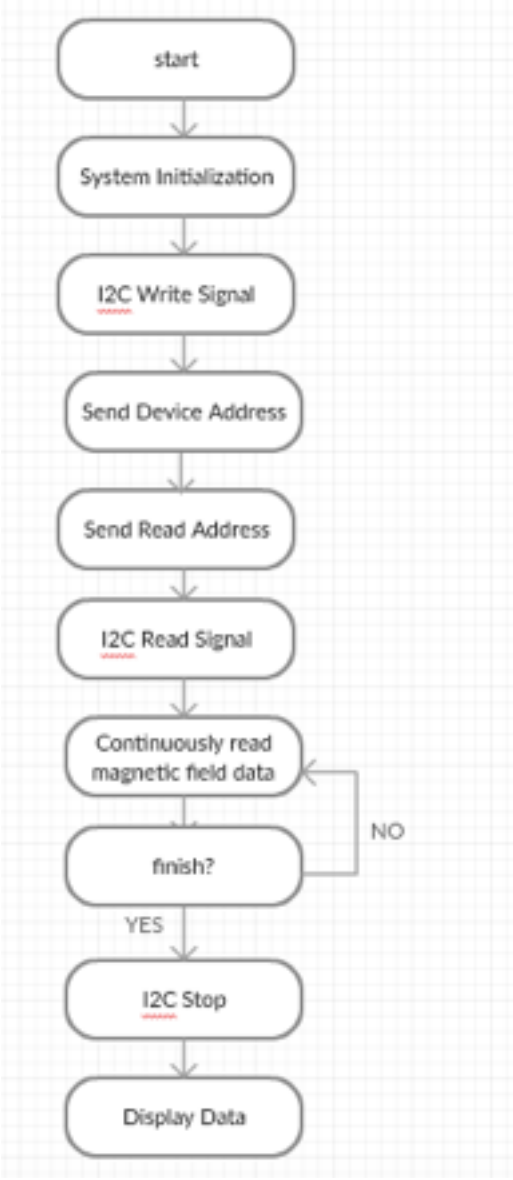

Figure 5

4. Result Analysis

After the selection of hardware components and the setup of the whole hardware system, the C code has been used to conduct the initialization of the whole programming environment and the achievement of the functions. Finally, the result can be found on OLED screen. one thing that cant be avoided is that the accuracy of HMC5843 will certainly be influenced by the magnetic field in surrounding environment

4.1Display Components

There are several parts shown on OLED screen: x,y,z direction data derived from magnetic filed, direction angle(ranges from -90 to +90). y/x(to check the property of the result(for testing purpose)),the current time of system, and the running time of the whole system.

Figure 6

4.2 Operations

when you rotate or change the direction of sensor in x-y coordinate or change the direction of object which is attached with HMC5843. eg:a motorcycle's stick which is attached to HMC5843 sensor. Then, the x,y,z data which is derived from the magnetic strength will change accordingly. then the angle will change from -90 to +90. the change of angle will help you figure out whether the device turn left or right. in what degree that the deviation has been achieved.

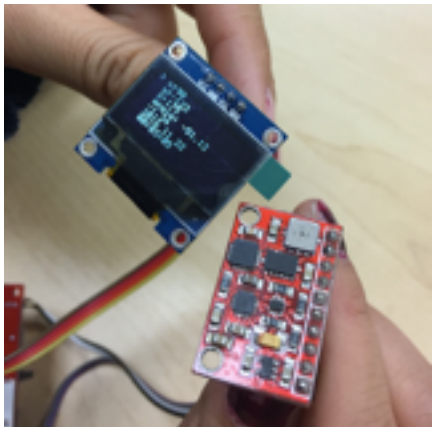

Figure 7

4.3 Future Improvement

To enable this system's ability of detecting the north south pole and serve as a real compass, other two sensors: ADXL345 (triple-axis accelerometer) and ITG3200 need to be added to get the roll, pitch and yaw. then a centralized filtering scheme will be chosen to filter and other mathematical knowledge will be used to do data analysis and get more precise and accurate angle of roll,pitch and yaw. The error source which affects the accuracy of the magnetic compass is analyzed. The corresponding compensation scheme will be given. The algorithm of calculating the heading angle is selected to improve the processing speed.

5. Summary

After taking ENPM609, which helps me lay a well-round foundation on different knowledges related to microprocessor such as fault detection, RAM, Bus, register and processor properties, This project not only serves as a good chance for me to apply what learnt from class into practical function design, but also it helps me get involved with the hardware components that have been used in real situation and even in the industry. Through this project, I get hands on coding platform (Integrated Development Environment-CCS) and microprocessor component that Texas instrument provides: MSP430. I also gain knowledge about HMC 5843(register and address) ,and OLED display,register/address operation, I2C serial bus, and data transmission between hardwares. I can write programs to the electronic compass and do debugging of the system hardware and software. the final function for this project is to detect the changes of direction by a more visual presenting way:the angle change in OLED screen.

However, what need to be noticed is that there are still some shortcomings that can or cant be improved. such as that: the signal noise is small, the accuracy is not high enough, when the driving direction does not change, the data display ability is very good; but when direction is changed, the system stability is relatively poor. The error sources of the whole system has been analyzed systematically. There are mainly three kinds of errors: systematic error, random error and coarse error. The main sources of error are: bridge bias, the reference voltage stability is poor, the inevitable existence of the manufacturing process errors Magnetic sensor can be impacted by magnetic substances,which results in errors in the heading data and angle. to enable it ability to find the north or south direction, more sensors such as ADXL345 (triple-axis accelerometer) and ITG3200 are needed to achieve the ultimate goal.

Specially thanks to Yueqian Zhang for the hardware environment and the suggestions he provided for me. Partial Microprocessor environment setup code is originated from him.

Reference

[1] "Ultra-Low-Power MSP430TM MCU Value Line",2010,Texas Instrument.

http://www.ti.com/lit/ml/slat122d/slat122d.pdf

[2] "Code Composer Studio (CCS) Integrated Development Environment (IDE)".Texas Instrument

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[3] "3-Axis Digital Compass IC HMC5843",Honeywell.

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[4] http://www.banggood.com/0_96-Inch-I2C-IIC-SPI-Serial-128-x-64-OLED-LCD-LED-Display-Module-p-922246.html