International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

Design and Implementation of a Simple HMC6352 2-Axis-MR Digital Compass

C. K. Agubor[1], G. N. Ezeh[2], M. Olubiwe[3], O.C. Nosiri[4]

Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Nigeria.

Abstract— **This paper deals with the design and implementation of a simple HMC6352 2-axis digital compass. Most compasses have been of the analogue type with magnetic needles as pointers. Replacing the "old" magnetic needle compass or the gyrocompass by an electronic solution offers advantages like having a solid-state component without moving parts and the ease of interfacing with other electronic systems. In this work, the aim is to design and implement a digital compass. To realize this, we made use of HMC6352 which is a 2-axis MR (magneto-resistive) sensor from Honeywell, Arduino Uno board with an onboard ATmega328 microcontroller chip, and a 16x2 character Liquid Crystal Display (LCD).We adopted the magneto-resistive (MR) technology as compared to flux-gate sensors common in most electronic compasses which has the disadvantage of making the device bulky. The trial test carried out with the completed HMC6352 digital compass showed a reading of *232.8 degrees West* indicating its effectiveness in direction finding.**

Keywords—**ATmega328, Compass, Earth's magnetic field, HMC6352, Magneto-resistive, LCD.**

I. INTRODUCTION

A compass is a navigational instrument that measures direction in a frame of reference that is stationary relative to the surface of the earth. It is a device used to determine or find geographical directions. Angle markings in degrees are usually shown on a compass. North corresponds to zero degrees, and the angles increase clockwise. East is 90 degrees, south is 180 degrees, and west is 270 degrees. These numbers allow the compass to show azimuths or bearings, which are commonly stated in this notations. The compass relies on the earth's magnetic field to provide heading that is, angle (in degrees) and direction. It works on the principle that a suspended magnet remains in the north-south direction under the influence of the Earth's magnetic field. Most compasses are analogue devices.

This work focuses on the design and implementation of a simple digital compass. It is a low-cost, hand-held digital device. It uses HMC6352 which is a 2-axis MR (magneto-resistive) sensor from Honeywell, an Arduino Uno board with an onboard ATmega328 microcontroller chip, and a 16x2 character Liquid Crystal Display (LCD).

Digital compasses find application in several areas. Its module can be integrated into a wireless consumer's electronics such as handheld devices (e.g. cell phones, watches,etc). In a communication link set-up, the device can be used in transmitter-receiver antenna alignment. It can be used for the determination of the relative position during time intervals, where GPS signals cannot be received (e.g. when driving between high buildings). Like its analogue counterpart the digital compass can be used as a direction-finding instrument by miners in a tunnel.

A. Objective of the study

The main objective of this study is to design and implement a simple digital compass using the 2-axis MR sensor compass module with low power requirement and capable of providing heading accuracy in a static application environment to as low as 0.3 degrees RMS error.

B. Significance of the study

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 indispensable 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 applications where such applications require embedded sensors to determine a broader picture of the surrounding environment.

II. LITERATURE REVIEW

The 1490 sensor by Dinsmore was only designed to show direction of the horizontal pattern of the earth's field, which made it to be a compass. This sensor provides eight directions of heading information. The 1490 sensor was internally designed to respond to directional change similar to a liquid filled compass. It will return to the indicated direction from a 90° displacement in approximately 2.5 seconds with no over-swing.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

It magnetically indicates the four (N, E, S, W) cardinal points, and by overlapping the four cardinal points, showed the intermediate (NE, NW, SE, SW) directions. The 1490 can operate tilted up to 12° with acceptable error [1].

The design had the advantage of being simple, easy to construct and cost effective. However, the compass could indicate only eight directional headings, which cannot be used effectively in navigation. The slow response of the sensor when the compass is repositioned to about 90^0 makes the compass not suitable for fast moving objects. The device is sensitive to tilt, and any tilt greater than 12^0 will create directional errors [2].

The E Gizmo electronic compass was designed primarily to serve as navigational aid for autonomous robot systems. It can be used as well for other navigational applications with little or no additional hardware circuit. It has a 0.5 degree output resolution, serial I/O interface, and small footprint [3].

This device has a better resolution of 0.5 degrees and a wider range of 0 - 359.5 degrees, unlike the 1490 that can only measure eight directions. It is not tilt compensated and as such, it must be mounted on a level surface to get accurate headings. Large metal objects, motors and transformers nearby can disrupt the magnetic field, causing the electronic compass to give a false reading.

Another digital compass with R1655 sensor was designed to receive two signals related to the earth's magnetic field. The device, with an analogue-to-digital conversion (ADC) used an extensive calibrated TV screen that decodes the direction relative to the earth's magnetic field. Magnetic declination features were added to enable the compass display the true north as a function of current location. It has a wider range of operating temperature (i.e.-40^0C to $+85^0$C). The sensor is damped to show a return from a 90^0 displacement in approximately 0.5-1.0 sec. It has a range of $0\text{-}359^0$. The major problem with this device is its inaccuracy. Sometimes, the inaccuracy comes from the sensor itself. It outputs an inaccurate voltage because of its inefficiency [2].

Various types of digital compasses were built using different kinds of sensors. One type was constructed by Parallax Incorporated using Hitachi HM55B compass module. The Hitachi HM55B chip is a sensor on the compass that is sensitive to directions of the earth magnetic field [4]. Honeywell designed another kind of compass using HMC1052 magnetic sensor [5]

III. Research Methodology

The design takes on an overall top down modular approach. Each top module has a defined function and is further divided into sub-modules. Figure 1 shows the functional blocks of the digital compass. The complete system is broken down into three units/modules: the sensing unit, processing unit, and display unit. Each module was designed separately from the others before coupling them to realize a complete digital compass system.

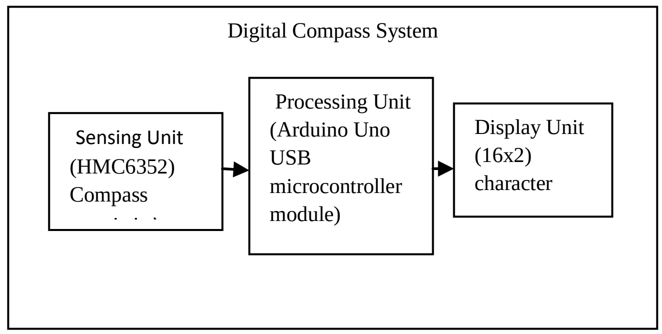

Fig 1: The block diagram of the digital compass

The sensing unit consists of a digital compass sensor, HMC6353. The sensor helps to translate the magnetic field of the earth (the physical quantity to be evaluated by the compass) into values that the microcontroller can use.

The processing unit is an Arduino Uno USB microcontroller module. It is an open-source hardware and software platform, which uses a microcontroller. It is used here to control the liquid crystal display (LCD). The display unit interfaces with and controlled by the Arduino board. It is a 16x2 character LCD and uses the HD44780 series LCD driver/controller from Hitachi.

A. Design considerations

The following factors were considered:

(i) Cost and ease of hardware implementation. Use of easily interfacing parts.

(ii) Use of an Arduino board, which contains features that will help in programming the on-board ATmega328 microcontroller chip without the use of any other external programmer.

(iii) Use of HMC6352 compass module because of it affordability.

IJETAE EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering

Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

(iv) The 16x2 character LCD was chosen to be the digital readout because, it could display alphanumeric characters and has lower power requirement than the conventional 7-segement LED displays.

(v) For the casing, a composite material was used instead of metallic casing, so as to prevent soft and hard iron anomalies or magnetic interferences that could affect the overall performance of the compass.

B. Design specifications

Table 1 gives the design specifications for the digital compass built with the HMC6352 compass sensor.

TABLE 1
HMC6352 Specifications

Characteristics	**Conditions**	**Min**	**Type**	**Max**
Field range	Total applied field	0.1 gauss		0.75 gauss
Supply voltage	Vsupply to GND	2.7V	3.0V	5.2V
Supply current	Vsupply to GND steadymode (Vsupply=3V) steadystate(Vsupply=3V) steadystate(Vsupply=5V)		1µA 1mA 2mA	10mA
Operating Temperature	Ambient	-20°C		70°C
Heading accuracy	HMC6352		2.5°C	
Heading resolution			0.5°C	
Heading repeatability			1.0°C	
Distorting field	Sensitivity starts to degrade.Set/reset function restores sensitivity	20 gauss		
Max exposed field	No permanent damage, set/reset function restores performance			1000 gauss
Storage temp	Ambient	-55°C		125°C
Moisture sensitivity			MSL 3	240°C
Output	Heading, Mag X, Mag Y			
Size (casing)	10cm x 10 cm x5cm			

C. Hardware design

The schematic diagram in Figure 2 shows the basic HMC6352 application circuit. From Figure 2, the host microprocessor (µP) controls the HMC6352 via I2C serial data interface lines for data (SDA) and clock (SCL). Two external 10kΩ pull-up resistors to the nominal +3 volt DC supply create normally high logic states when the interface lines are not in use. The 0.01µF supply decoupling capacitor is added near the HMC6352 for optimum circuit stability.

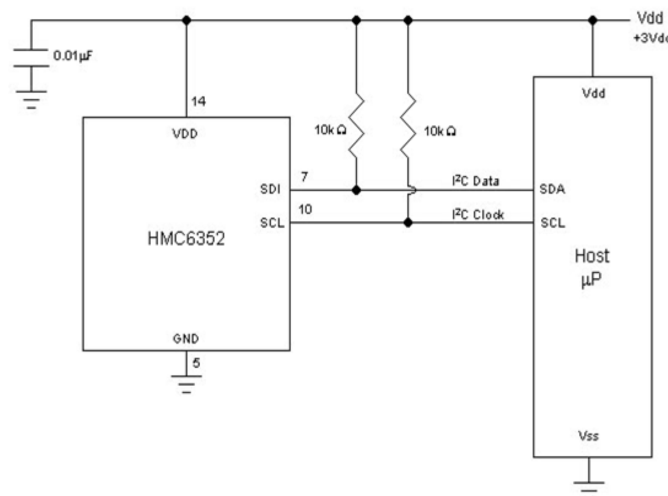

Fig 2: Design schematic of the HMC6352 compass sensor

The HMC6352 Serial Clock (SCL) and Serial Data (SDA) lines do not have internal pull-up resistors, and require resistive pull-ups (Rp) between the master device (usually a host microprocessor) and the HMC6352. Pull-up resistance values of about 10kΩ are recommended with a nominal 3.0 volt supply voltage.

The Processing Unit consists of the Arduino Uno board and its on-board ATmega328 microcontroller chip. Its features/ratings are tabulated in Table 2.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

TABLE 2
FEATURES/RATINGS OF THE ARDUINO UNO BOARD

Items	Features/Ratings
Microcontroller	ATmega328
Operating Voltage	5V
InputVoltage (recommended)	7-12V
Input Voltage (limits)	6 – 20V
Digital I/O pins	14 (6 provide PWM output)
Analog Input pins	6
DC current per I/O pin	40mA
DC current for 3.3V pin	50mA
Clock Speed	16MHz
Flash Memory	32Kbits (0.5 Kbits used by bootloader)
SRAM	2Kbits
EEPROM	1Kbit

The Arduino Uno was powered via a USB connection.. The board operates on an external supply of 6 to 20 V. If supplied with less than 7V, the 5V pin may supply less than 5V resulting to the board being unstable. More than 12V causes the voltage regulator to overheat which may damage the board. The recommended range is 7 to 12V.

The ATmega328 has 32KB of flash memory for storing codes (with 0.5KB used for the boot loader). It also has 2Kbits of SRAM and 1Kbit of EEPROM (which can be read and written with the EEPROM library).

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5V. Each pin can provide or receive a maximum of 40mA and has an internal pull-up resistor (disconnected by default) of 20-50KΩ. In addition, some pins have specialized functions as listed in Table 3.

TABLE 3
SPECIALIZED FUNCTIONS OF THE ARDUINO UNO I/O PINS

Pins	Functions
Serial: 0 (RX) and 1 (TX).	Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL serial chip.
External Interrupts: 2 and 3.	Configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
PWM: 3, 5, 6, 9, 10 and 11.	Provide 8-bit PWM output with the analogueWrite() function
SPI:10(SS), 11(MOSI), 12 (MISO), 13 (SCK).	These pins support SPI communication using the SPI library.
LED: 13	There is a built-in LED connected to digital pin13. HIGH pin value - LED on, LOW pin value - LED off.
TWI	A4 or SDA pin and A5 or SCL pin. Support communication using the wire library
AREF	Reference voltage for the analogue inputs. Used with analogueReference().
Reset	To reset the microcontroller

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual COM port to software on the computer. The 16U2 firmware uses the standard USB COM drivers, and no external driver is needed. The ATmega328 also supports I2C (TWI) and SPI communication. Figure 4 shows the pin mapping of the ATmega328 with the Arduino Uno board.

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

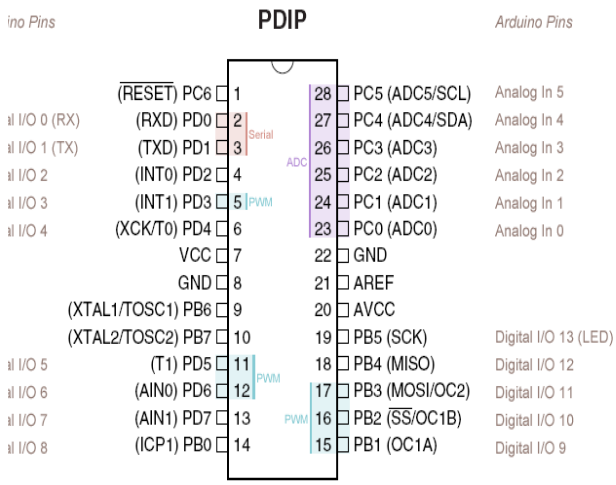

Fig 4: ATmega328 pin mapping with the Arduino Uno board.

Arduino digital pins default to inputs, so they don't need to be explicitly declared as inputs with pinMode(). Pins configured as INPUT are said to be in a high-impedance state. There are also convenient 20KΩ pullup resistors built into the Atmega chip that can be accessed in the following manner:

- pinMode(pin, INPUT); // set 'pin' to input.
- digitalWrite(pin, HIGH); // turn on pullup resistors.

Pins configured as OUTPUT are in a low-impedance state and can provide 40 mA of current to other devices/circuits. This is enough current to brightly light up an LED, but not enough current to run most relays, solenoids, or motors.

To prevent the Atmega chip from damage due to short circuiting and excessive current, OUTPUT pin 13 was connected to an external device in series with a 220Ω resistor (Figure 5).

Fig 5: Arduino output connection for an LED

The input is governed by two possible states: on or off. When the switch is closed the input pin will read HIGH and turn on an LED and when switch is open (Figure 6), input pin is on LOW state, the LED is turned off.

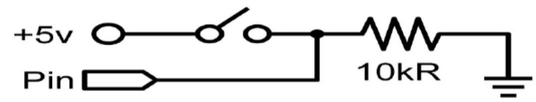

Fig 6: Arduino input connection with a switch.

A 10KΩ potentiometer was used as potentiometer input for contrast adjustment of the character LCD (Figure 7)..

Fig 7: Arduino potentiometer connection

D. Design of the Display Unit

The LCD uses a standard 16 contact interface as shown in Figure 8. The pin description is given in Table 4.

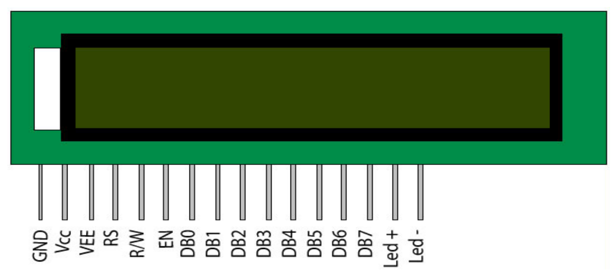

Fig 8: Pin diagram of a 16x2 character LCD module

TABLE 4
PIN DESCRIPTION OF THE 16x2 CHARACTER LCD MODULE

Pin No	Symbol	Level	Description
1	Vss	0 V	Ground
2	V_{DD}	5.0V	Supply voltage for logic
3	V o	variable	Operating voltagefor LCD
4	RS	H/L	H data/L instruction code
5	R/W	H/L	H/Read (MPU-module) L/write (MPU-module)
6	E	H, H-L	Chip enable signal
7	DB0	H/L	Data bit 0
8	DB1	H/L	Data bit 1
9	DB2	H/L	Data bit 2
10	DB3	H/L	Data bit 3
11	DB4	H/L	Data bit 4
12	DB5	H/L	Data bit 5
13	DB6	H/L	Data bit 6
14	DB 7	H/L	Data bit 7
15	A		Power supply for LED backlight (+)
16	K		Power supply for LED backlight (-)

Figure 9 shows the interface between the LCD and the Arduino Uno board.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

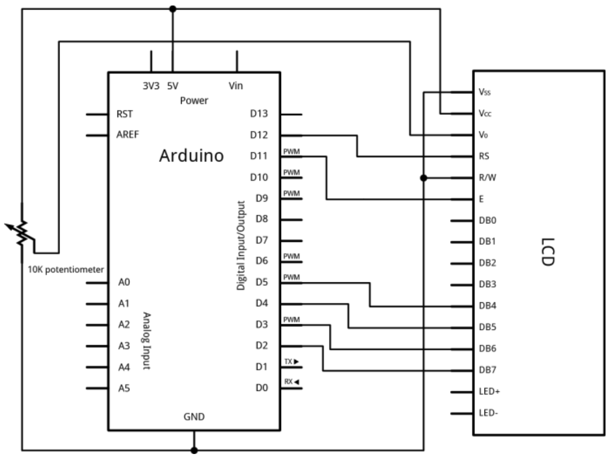

Fig 9: LCD to Arduino Uno interface

Figure 10 shows the block diagram of the 16x2 character LCD driver/controller, HD44780.

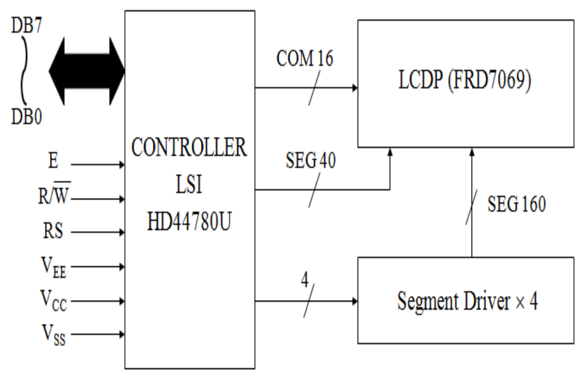

Fig 10: HD4478 LCD driver/controller.

E. Software Design

The Arduino Uno (or hardware) was programmed with the Arduino software using a wiring-based language (syntax and libraries), similar to C++ with some slight simplifications and modifications, and a processing-based integrated development environment. The open-source Arduino environment makes it easy to write codes and upload them to the I/O board.

The software consists of a standard programming language compiler and the bootloader that runs on the board [6]. It runs on Windows, Mac OSX, and Linus. The environment was written in Java and the code flow diagram is shown in Figure 11.

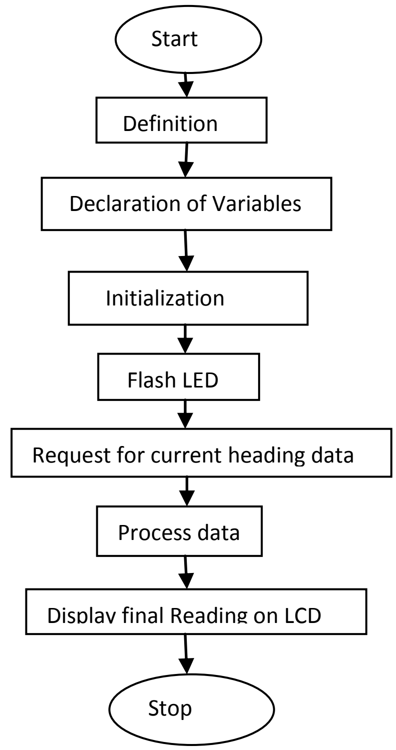

Fig 11: Code flow diagram

Figure 12 shows the complete system diagram. The compass module serves as a slave device to the microcontroller (the host device). The speed of the transmitted data is about 100Kb/s. The host microcontroller controls the compass module through the interfaced two wired lines. Serial Clock (SCL) and serial Data (SDA) lines are the two-wire I^2C bus systems that require an external pull-up resistor to keep the line in a high logic state. 8-bit of data transmitted along these lines are controlled by the host microcontroller, which issues start and stop command by pulling the serial data line low. It pulls the same line high for a stop condition. The microcontroller does the processing of the input signal (current heading) from the compass module through its stored program.

Finally, the measured azimuth has to be indicated to the user by a display. A 16x2 character LCD was used for this purpose. With the aid of its serial kit, it is able to receive the heading signal from the microcontroller serially and then converts it to parallel. By its driver/controller, the right segments to display the heading are activated.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

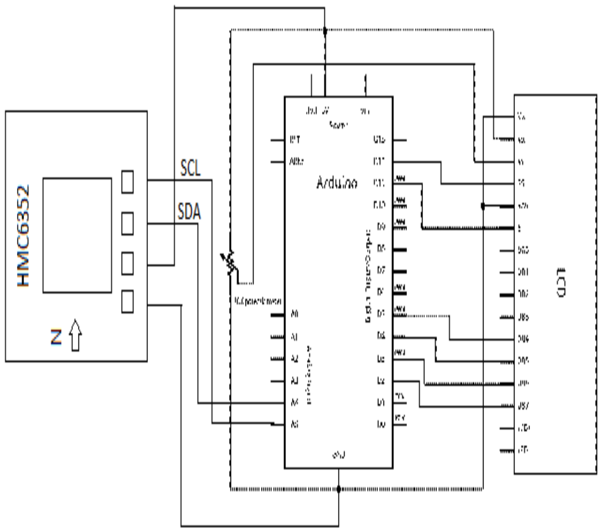

Fig 12: The complete design diagram

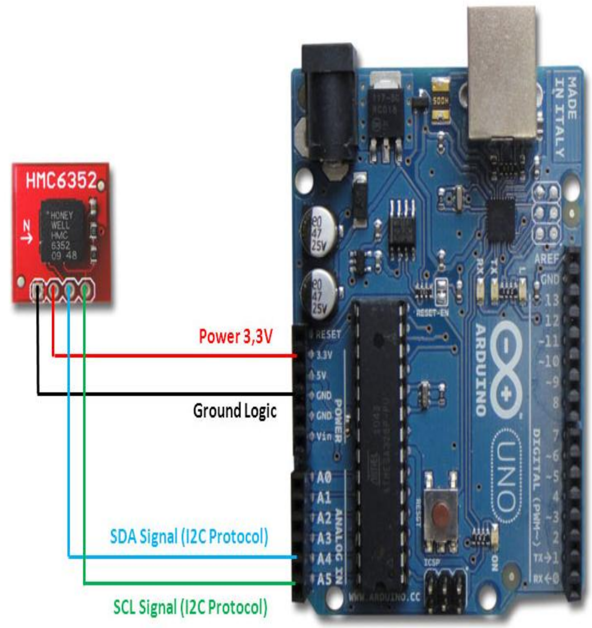

Fig 13: Connection of the HMC6352 compass sensor to the ATmega328 microcontroller on the Arduino

IV. IMPLEMENTATION

The following tools and materials were used:

- HMC6352 compass module (Honeywell).
- Arduino Uno board (Sparkfun DEV-09950).
- 16x2 character LCD module.
- USB programming cable.
- 9V battery (for stand-alone operation).
- Host PC running the Arduino development environment.
- DC power plug.
- Solderless breadboard for prototype.
- Veroboard for permanent soldering.
- Soldering iron and soldering lead.
- Digital multimeter for voltage, current, and resistance measurements.
- Needle nose pliers and cutters.
- 10KΩ potentiometer.
- Jumper wires.
- Plastic casing.

A. Wiring connections/soldering methods

Using a low wattage (40W) soldering iron, connections were made as shown in Figures 13 and 14.

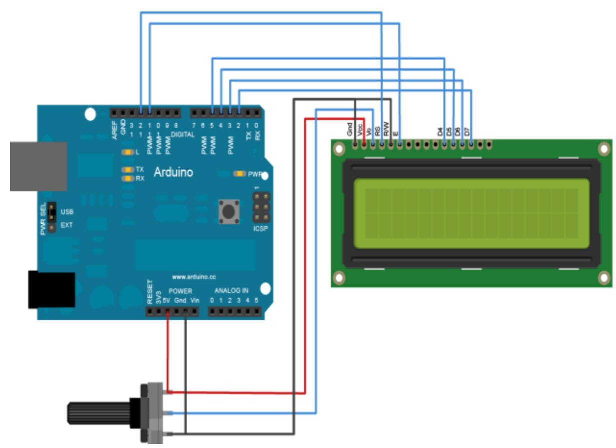

Fig 14: 16x2 character LCD module on the Arduino board

The LCD pin to Arduino connections are tabulated in Table 5.

IJETAE
EXPLORING RESEARCH AND INNOVATIONS

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 3, March 2015)

Table 5.
Lcd Pin To Arduino Connection Description

LCD pin	Connection to
1 (V_{SS})	GND Arduino pin
2 (V_{DD})	+5V Arduino pin
3 (Contrast)	Resistor or potentiometer to GND Arduino pin
4 (RS)	Arduino pin 12
5 (R/W)	Arduino pin 11
6 (Enable)	Arduino pin 10
7, 8 & 9	No conections
11 (Data 4)	Arduino pin 5
12 (Data 5)	Arduino pin 4
13 (Data 6)	Arduino pin 3
14 (Data 7)	Arduino pin 2
15 (Backlight +)	Resistor to Arduino pin 13
16 (Backlight GND)	GND Arduino pin

B. Casing Design

The casing is a *10cm x 10cm x 5cm* rectangular box that houses all the component parts of the compass. It was completely made of a strong plastic material because it does not distort or affect the reading of the compass neither does it interfere with the earth's magnetic field unlike metallic or ferrous materials.

C. Test Result

It should be noted that, for this digital compass to give an accurate measurement of one's heading or true bearing, it must be placed parallel to the earth's magnetic field. This is because, the compass module is made up of 2-axis magneto-resistive sensor, meaning it can only measure the magnetic field components of the earth (X and Y components) lying on the horizontal plane.

The compass was tested and proved to be effective and efficient when used this way. In one of the tests a reading of *252.8 degrees West* was obtained as shown in Figure 16.

Fig 16: A picture of the completed digital compass

V. CONCLUSION

The HMC6352 2-axis MR digital compass was built and tested. It was seen to be efficient and effective. It is recommended for use in areas where the earth magnetic field together with other stray magnetic and local magnetic fields do not exceed 1000 gauss, so as to prevent it from permanent damage.

An improvement on this system can be achieved by using HMC6343 compass module; with 3-axis magneto-resistive (MR) sensors and 3-axis Micro Electromechanical System (MEMS) accelerometers.

REFERENCES

[1] 1490 Digital Sensor, (1993). Dinsmore Instrument. [Onliine]. Available:http://www.zagrosrobotics.com/files/dens1490.pdf.

[2] Zilog 8-Directional Digital Compass, (2008).[Online] . Available: http://www.zilog.com

[3] T. Stork. *Electronic Compass Design using KMZ51 and KMZ52.*Hamborg, Germany: Philips Semiconductors Systems Laboratory. 2004

[4] Hitachi HM55B Compass Module, (2005). [Online]. Available: http://www.parallax.com/dl/docs/prod/compshop/HM55B

[5] Honeywell sensor products, (2005). [Online]. Available: http://www.magneticsensors.com

[6] Arduino Microcontroller Guide, (2011). [Online]. Available: http://www.me.umn.edu/courses/me2011/arduino/