Application Note

AS5510

10-bit Linear Absolute Field Sensor with Digital Output

Initialization and Application using a PSoC3

Content Guide

1 General Description

A project has been created under PSoC Creator 3.0 for a PSoC 3 microcontroller to guide a user through the process of initialization and communication with an AS5510. The main.c file is portable to any microcontroller – 8051, ARM Cortex Mx, or other – which either has an integrated IIC engine, or for which the user can write GPIO-driven IIC code to utilize an I/O to communicate with the IIC-connected AS5510.

2 Application Statement

The AS5510 requires initialization, and then read commands to obtain the data it is gathering.

A PSoC3 Project was created in PSoC Creator 3.0, targeting the CY8CKIT-030, and has been Archived – Allowing users of PSoC devices to extract the Project, bring it into PSoC Creator 3.0 or later, connect an AS5510-AB via a simple 4-wire jumper (Vdd, GND, SDA, SCL) to the Eval board, and begin testing – utilizing the PSoC 2-line x 20 Character display to show device information.

Non-PSoC users can fashion their hardware after the interface used to connect the AS5510-AB to the PSoC eval board, and can use the main.c file of the project as the base code and structure for their own test application.

3 Hardware Description

The following Resources/Items can be used for the test process:

PSoC Based Processor Solution:

1) CY8CKIT-030
2) PSoC Creator 3.0
3) Keil Compiler (Free Version) for PSoC3
4) AS5510-AB and Simple Reference Magnet
5) 4-wire jumper – See connection diagram

OR

Other Processor-Based Solution:

1) Designer’s preferred Development Platform
2) Designer’s preferred Development Environment
3) Designer’s preferred Compiler
4) AS5510-AB and Simple Reference Magnet
5) 4-Wire Jumper – Connect Dev-Board-End per Development Platform interface

4 Detailed Hardware Description

Hardware used for development/proof-of solution included the following items: – AS5510-AB board , Magnet-Carrier Strip, AS5000-MA4X2H-1 axially magnetized bar magnet, CY8CKIT-030 eval board, and connecting cable as shown in Figure 1.

Figure 1: **Hardware**

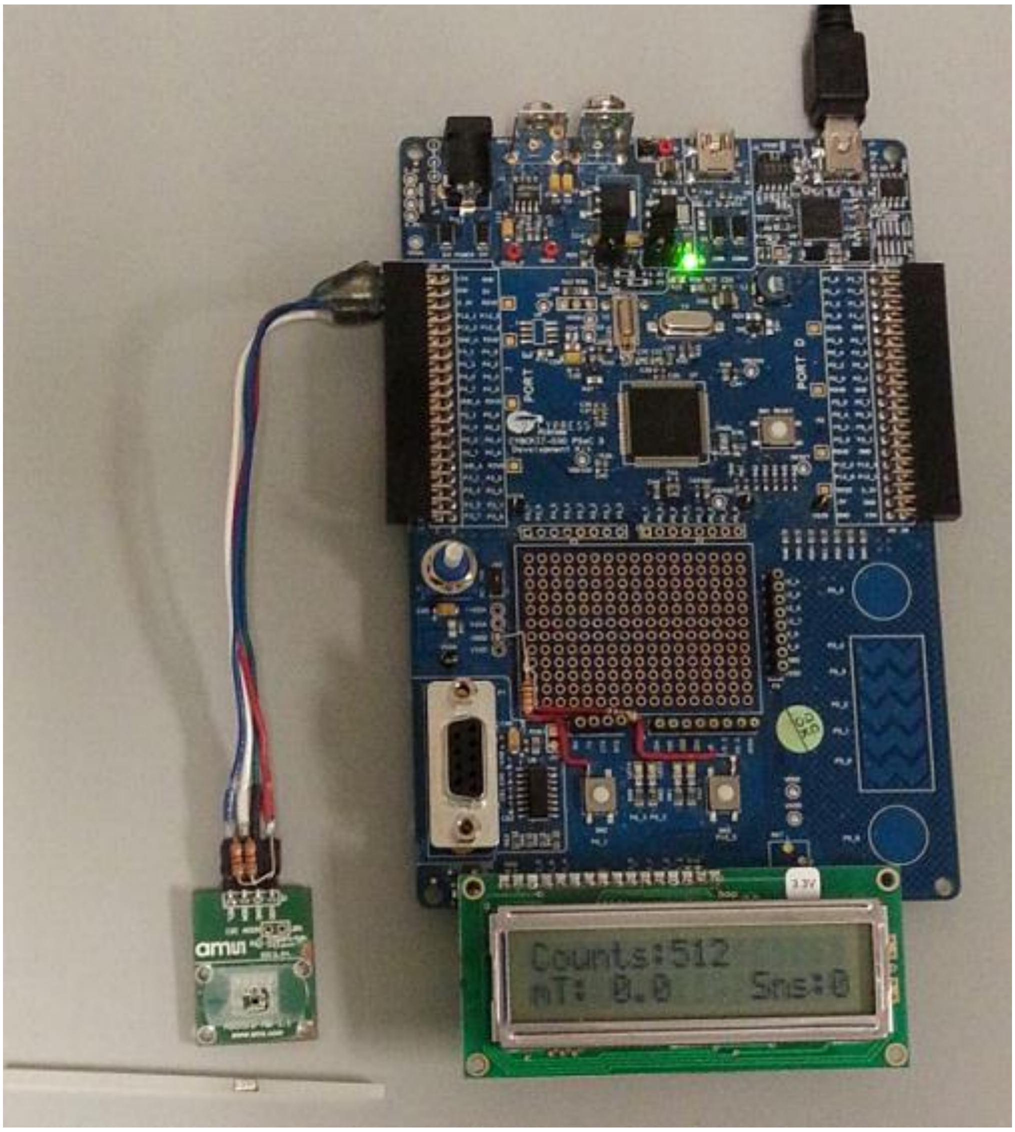


Figure 2 shows the Eval-Board-to-AS5510-AB Connecting Cable Schematic information. The Eval-Board end can be modified to match the User’s Eval board as-needed.

Figure 2: **Connecting Cable Schematic**

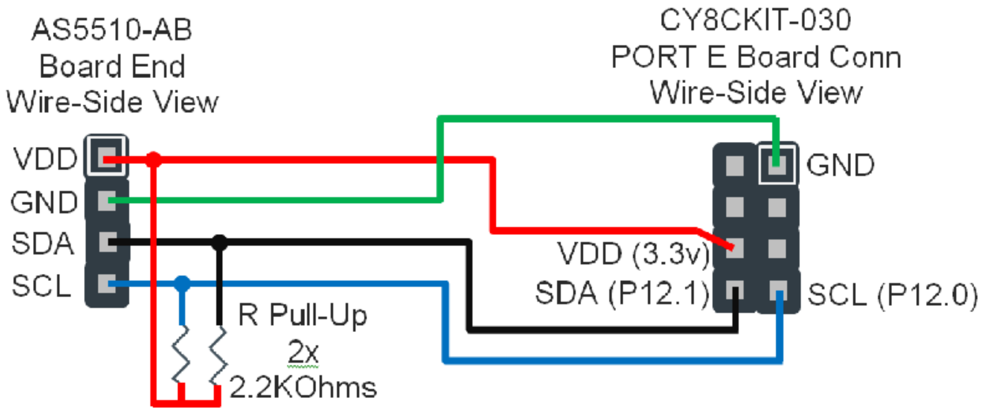
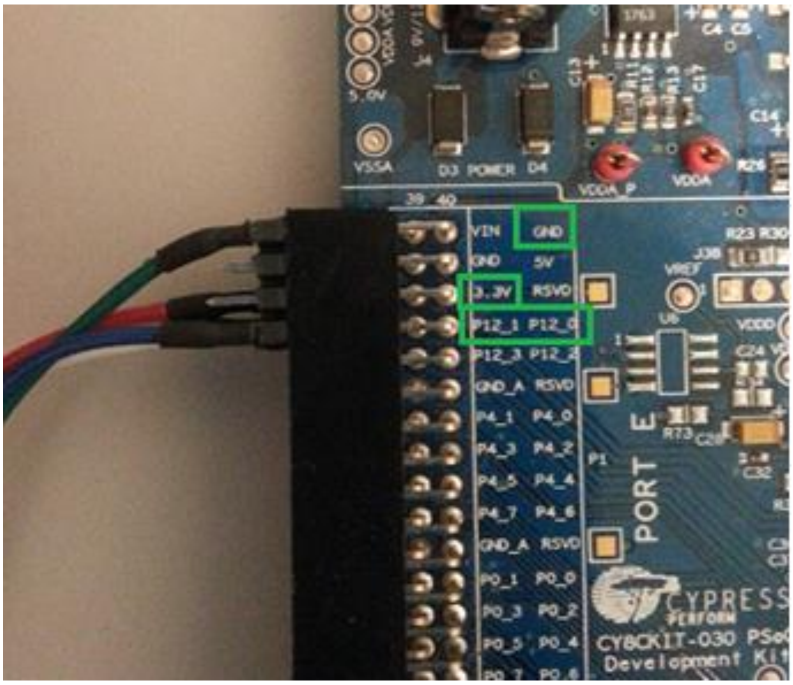


Figure 3 shows a close-up view of CY8CKIT-030 PORT E Connector with Jumper Connected. Key signals Highlighted – VDD, GND, SDA, SCL (P12.1 = SDA, P12.0 = SCL).

Figure 3: **CY8CKIT-030 PORT E Connector**



Figures 4, 5 and 6 show the AS5510-AB Board with a Spacer added to support a Carrier Strip which will place the magnet at the proper distance from the device for evaluation under these circumstances. The User can configure the mechanical solution to duplicate the physical structure of the intended application for test and evaluation, and then with the carrier strip with the magnet in-view, and finally with the carrier strip in evaluation-position over the AS5510.

Figure 4: **AS5510-AB with added spacer**

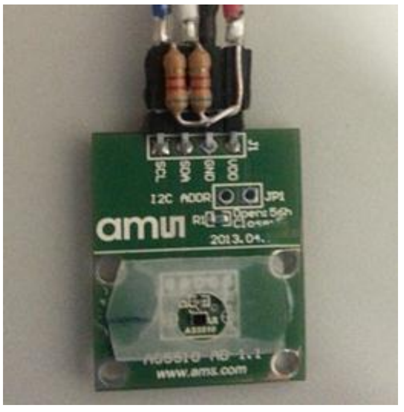


Figure 5: **AS5510-AB with AS5000-MA4x2H-1 magnet mounted in a carrier-strip**

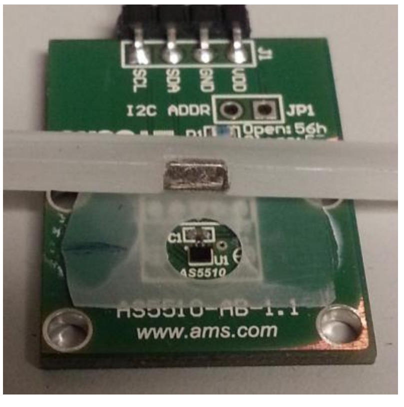
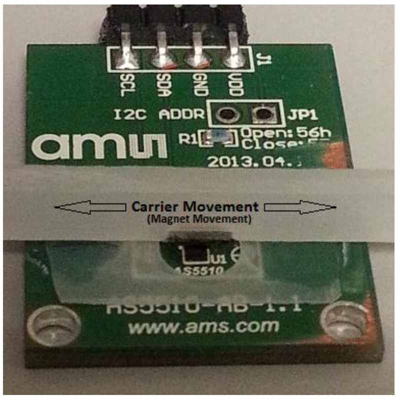


Figure 6: **Carrier-strip positioned over the AS5510-AB, ~0.8mm air-gap**



5 Hardware/Firmware Description

The AS5510 includes an I²C slave engine which complies with the NXP UM10204 specification. Because of the requirement for properly placed Start and Stop conditions in the IIC data stream to meet this specification, it is recommended that Buffer-Type IIC Engines be employed on the IIC Master that is communicating with the AS5510.

Figure 7 shows the communication structure that is required by the AS5510 for a Register Write. Please refer to the AS5510 datasheet for further information/detail.

Figure 7: **Register Write Communication Structure**

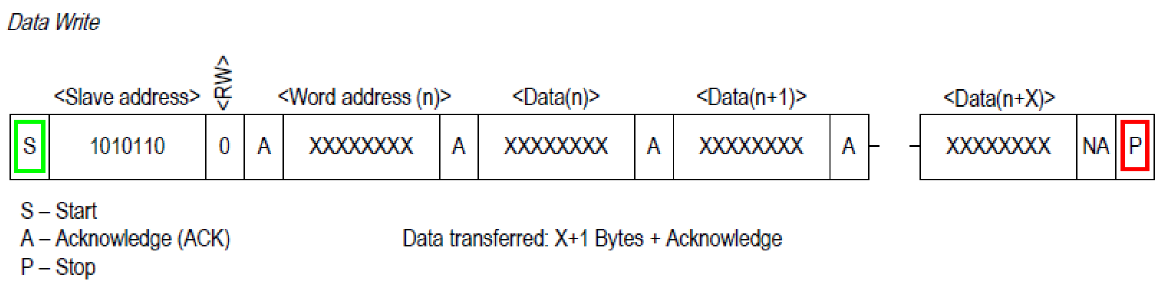
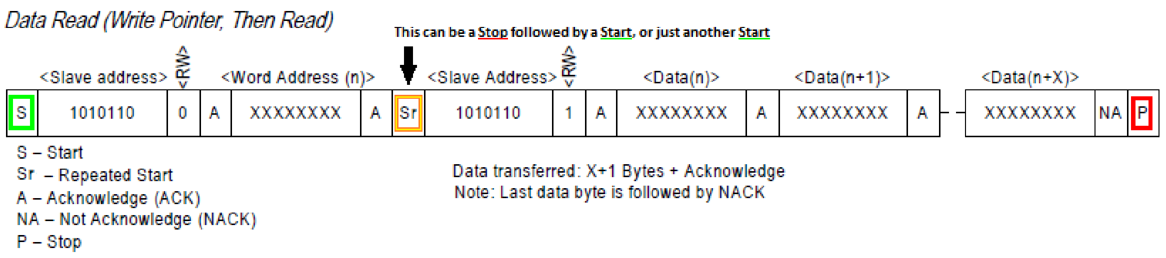


Figure 8 shows the communication structure for a Register Read. It is important to note that a Register Read requires that the Start-Register Address for the Read (the first byte in the read sequence) be written to the device before initiating the Read. Please refer to the AS5510 datasheet for further information/detail.

Figure 8: **Register Read Communication Structure**



6 Setup and Operation

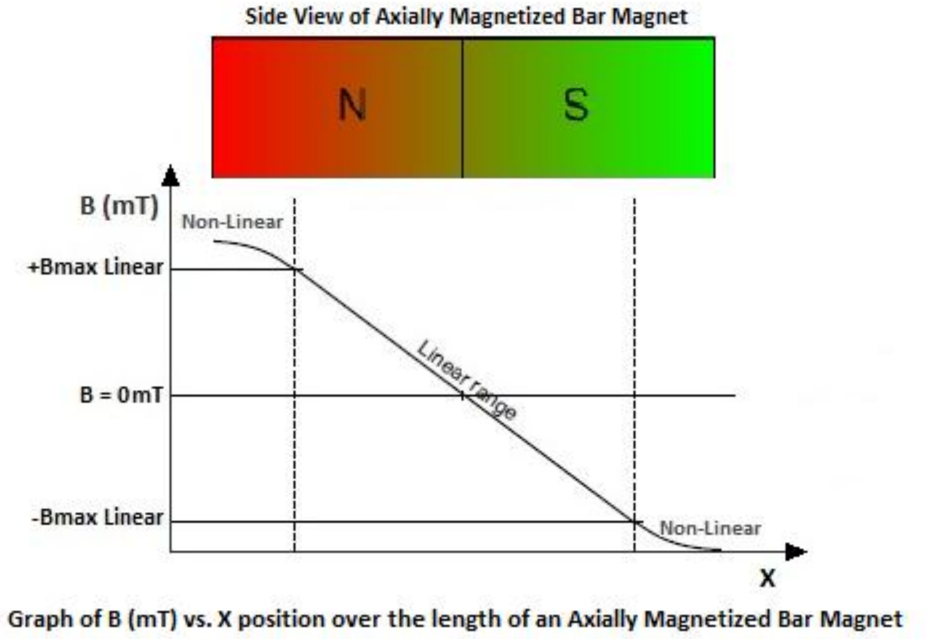
6.1 Magnet Selection – Magnet Length, Linear Measurement Range

Selection of a magnet to function with the AS5510 can be a very simple process.

For this example, an Axially Magnetized Bar Magnet [Bar Magnet] will be used since this is a common style, recommended magnet to use with the AS5510 for linear position measurements.

A Bar Magnet produces a field that looks like the graph in Figure 9 where a portion of the magnet's field offers a linear response moving along the X axis, and normally the field becomes non-linear toward the ends of the magnet as shown in Figure 9.

Figure 9: **B (mT) vs. Magnet X-axis (length of Axially Magnetized Bar Magnet)**



The AS5510 device has a Sensitivity setting that allows measurement of fields ranging from +/- 50mT down to +/-12.5mT in 4 predetermined ranges (See datasheet, Table 9, Register 0x0Bh, for Sensitivity settings).

This means that +Bmax Linear and –Bmax Linear field values to be measured can be: +/-50mT, +/- 25mT, +/-18.75mT, and +/-12.5mT.

The AS5510 output provides 10 bits of data resolution (0 to 1023 counts output) over these field values.

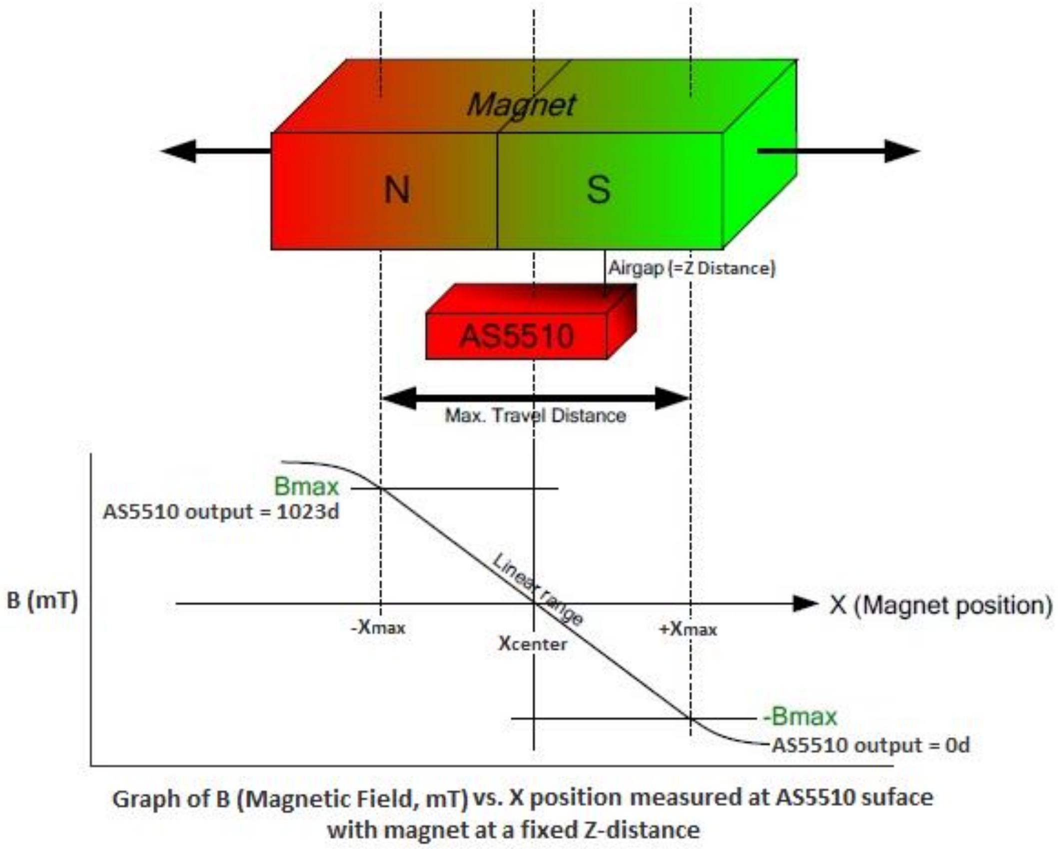
Simply stated:

> If the AS5510 is configured for +/- 12.5mT Sensitivity, it will output 0 counts to 1023 counts over a magnetic field strength range of -12.5mT to +12.5mT.
>
> Likewise, if the AS5510 is configured for +/- 50mT Sensitivity, it will output 0 counts to 1023 counts over a magnetic field strength range of -50mT to +50mT.

If a magnet were selected which provided exactly -50mT at one end of its linear field area, and exactly +50mT at the other end of its linear field area (See Figure 10), and the Sensitivity Register

(Register 0x0B) were set to 0x00h (see Table 9 of datasheet) the part would output 0 counts at one end of travel, and 1023 counts at the other end of travel (See Figure 10).

Figure 10: **AS5510 Position vs Output Values (Ref: B vs X Graph, Figure 9)**



Therefore, if the example magnet produced a +/-50mT field over a 2mm segment of the magnet-body, the distance measured per-LSB would be:

Distance-per-LSB = 2mm/1024 = 0.00195mm/LSB

If the example magnet produced a +/-50mT field over a magnet length of 10mm, the distance measured per-LSB would be:

Distance-per-LSB = 10mm/1024 = 0.00977mm/LSB

The distance-per-LSB is directly related to the length of the magnet and the strength of the magnet combined with the Sensitivity setting and mechanical arrangement of the total solution.

The same calculation method applies when the Sensitivity (Register 0Bh) is set to one of the other 3 values – +/-25mT, +/-18.75mT, and +/-12.5mT.

NOTE: Exceeding the maximum field energy does no harm, but the output of the device saturates at the maximum + or – count such that the output will stop at either 0 or 1023 counts even if the field exceeds the maximum selected field strength per the Sensitivity setting.

Below find Figure11 showing the output values from the AS5510 relative to the Sensitivity (Register 0Bh) setting and the strength of the Magnetic Field. Refer to Table 9 in datasheet for further detail.

Figure 11: **Field Strengths at Sensitivity Settings vs. AS5510 output**

Reference	Field Strength				AS5510 Output
<-Bmax	<-12.5mT	<-18.75mT	<-25mT	<-50mT	0
-Bmax	-12.5mT	-18.75mT	-25mT	-50mT	0
B = 0mT	0	0	0	0	~512
+Bmax	+12.5mT	+18.75mT	+25mT	+50mT	1023
>+Bmax	>+12.5mT	>+18.75mT	>+25mT	>+50mT	1023
Sensitivity Setting:	Reg 0Bh = 10h (Sens = +/- 12.5mT)	Reg 0Bh = 11h (Sens = +/- 18.75mT)	Reg Bh = 01h (Sens = +/- 25mT)	Reg 0Bh = 00h (Sens = +/- 50mT)	

The length of the magnet is not limited.

Measurement produces 10 bits of resolution over the field range selected using the Sensitivity Register (0Bh, bits 1 and 0).

The output of the AS5510 ranges from 0 counts to 1023 counts over the full range of B specified by the Sensitivity Register.

6.2 Hardware

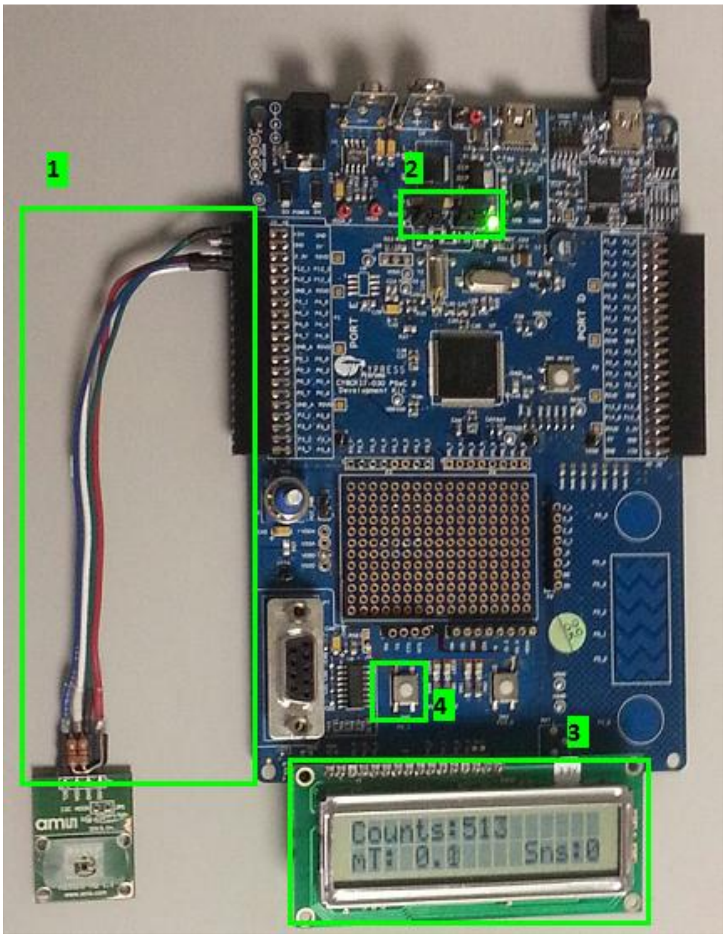
For PSoC: The cable (1) shown in Figure 12 is connected between the CY8CKIT-030 and the AS5510-AB board.

Set J10 and J11 per marking (2) on Figure 12 to operate at VDDD and VDDA of 3.3V.

Install the 2x20 Character LCD Display (3) on Figure 12 below that came with the CY8CKIT-030.

Note the location of SW2 (4) on the board. It will be used as the Sensitivity Mode Select Button – each press of the button increments through the successive sensitivity modes for the device. See the datasheet for Sensitivity Mode specifics.

Figure 12: **Key Items per Setup Instructions**



For non-PSoC: An appropriate jumper with VDD, GND, SCL, SDA (with Pull-Up R's as-necessary) is connected between the IIC Master and the AS5510-AB board.

The AS5510-AB board should be supplied 2.5V to 3.6V for operation.

6.3 Software/Firmware Setup

6.3.1 For PSoC:

- Unzip the Archived Project into a working directory.
- Open PSoC Creator 3.0 or later.
- Select "File", "Open Project" and point to the working directory into which the project was unzipped. Select the Project file, and open it.
- Perform a "Clean and Build" to confirm that the Project is current, and is behaving properly in your PSoC Creator/Compiler combination setup.

- If any issues with PSoC Creator or the Compiler arise, resolve those before moving forward.

6.3.2 For non-PSoC-based solutions:

- Unzip the Archived Project into a Scratch directory.
- Create a new Project for your processor in your Development Environment of-choice.
- Utilize an existing (or structure a buffer-style) IIC Write function and a buffer-style Read function. (See figures 7 and 8 above specific to Start and Stop Condition points).
- Open the main.c file in the Scratch Directory, and copy all variables, functions, code, and comments. into your main.c file.
- Remove the sections labeled “Delete for Non-PSoC-Based Solutions”
- Adjust the Buffer Write and Buffer Read operation to utilize your native IIC engine/Buffer Write/Read functions.
- Adjust the LCD Display operation to utilize your data-display resource.
- Create your own Delay Function if your application needs to pause – No delays are required for the AS5510 interface to operate properly in normal program flow.
- Set up an I/O pin as an input, resistively pulled High, Active-Low, and either set up with an internal Pull-Up Resistor, or attach an external pull-up resistor as-required (This is for the Sensitivity Mode Select Button).

7 Software/Firmware Operational Description

The Software/Firmware operation is as-follows:

- Initialize Variables, Defines, Arrays, etc.
- Send Configuration Bytes to the AS5510 – Refer to the Datasheet and firmware for detail on Register values and resulting configuration adjustments that are impacted.
- Continuously loop performing the following functions:
  - Read the output from the device in Counts.
  - Calculate the Field strength based on Counts and Sensitivity Mode setting.
  - Display Counts, Field Strength, and Sensitivity Mode.
- Check SW2 every Cycle to determine if Sensitivity should be updated – Update as-required

Note: Other adjustable factors for the device can be managed at a firmware level, compiled into the code, and run to demonstrate/test their impacts. References and setup structures are in-place in the main.c file to support this kind of testing.

8 Firmware Sequence -- Initialization and Read of the AS5510

```
 #define I2C_SLAVE_ADDRESS   (86u) // Base address for AS5510 - 56h – AS5510 can also have
                                    address 87d = 57h, see datasheet
                                  //NOTE: "u" indicates unsigned value
#define Two_Byte_Buffer     (2u)  // Set the setup buffer length to be 16 bits or 2 bytes
#define One_Byte_Buffer     (1u)  //only need 1 byte sent by buffer-write

// NOTE: With no magnet present, Count = ~512 (1/2 of 0 to 1023 data range)

   uint8 Functional_Mode;         //Power state, speed, etc.
   uint8 Sensitivity_Mode;        //Sensitivity Mode for device, values 0 thru 3, refer to
                                  datasheet for information

   uint16 AS5510_Output;          //Full 16-bit AS5510 Raw output value
   uint16 AS5510_MSB;             //MSB of data
   uint16 AS5510_LSB;             //LSB of data

   uint8 AS5510_Setup_Buffer0[Two_Byte_Buffer];    //Set up Buffer for device config data
   uint8 AS5510_Setup_Buffer1[Two_Byte_Buffer];    //Set up Buffer for device config data
   uint8 AS5510_Value_Address[One_Byte_Buffer];   //Address at which 5510 output will be stored
   uint8 AS5510_Data_Buffer[Two_Byte_Buffer];      //Data Buffer for 5510 output

   uint8 AS5510_OCF_Process_Done;                  //Variable to use for OCF Flag Check

//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

//Initialize Variables
//    Functional Mode
//    UNCOMMENT the line/mode that you wish to select
      Functional_Mode = 0x00;    //FAST Mode, NORMAL Polarity, RUN - 000
//    Functional_Mode = 0x01;    //Device OFF - xx1
//    Functional_Mode = 0x02;    //FAST Mode, REVERSE Polarity, RUN - 010
//    Functional_Mode = 0x04;    //SLOW Mode, NORMAL Polarity, RUN - 100
//    Functional_Mode = 0x06;    //SLOW Mode, REVERSE Polarity, RUN - 110

//Sensitivity
      Sensitivity_Mode = 0x00;   //0x00 = +/- 50mT range, 97.66uT/LSB = Most Physical Movement
                                 Per LSB Change
//    Sensitivity_Mode = 0x01;   //0x01 = +/- 25mT range, 48.83uT/LSB
//    Sensitivity_Mode = 0x03;   //0x03 = +/- 18.7mT range, 36.62uT/LSB
//    Sensitivity_Mode = 0x02;   //0x02 = +/- 12.5mT range, 24.41uT/LSB = Least Physical
                                 Movement Per LSB Change
```

```
  AS5510_Setup_Buffer0[0] = 0x02u;              //Setup register (address = 0x02h) :
  AS5510_Setup_Buffer0[1] = Functional_Mode;    //Tell device: Speed, Polarity, On/Off

  AS5510_Setup_Buffer1[0] = 0x0bu;              //Sensitivity register (addr = 0x0bh) :
  AS5510_Setup_Buffer1[1] = Sensitivity_Mode;   //Sensitivity setting - for Mag Field calc

  AS5510_Value_Address[0] = 0x00u;              //Address for output LSB
  AS5510_Value_Address[1] = 0x01u;              //Address for output MSB (ref: datasheet)

  AS5510_OCF_Process_Done = 0x00u;              //initialize OCF flag variable

//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
//Configure Device -- Write setup data to the device
  Write AS5510_Setup_Buffer0 (Two_Byte_Buffer)  //Write Functional Mode Reg Data to device
  Write AS5510_Setup_Buffer1 (Two_Byte_Buffer)  //Write Sensitivity Mode Reg Data to device

//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

//Check to be certain Offset Compensation process is complete - Check OCF Flag to be sure == 1
//Position data not valid until OCF Flag = 1 – see datasheet

  while(AS5510_OCF_Process_Done == 0x00);       //Loop until OCF flag goes high
  {
    Write AS5510_Value_Address (One_Byte_Buffer); //Send 1 byte – Send Address for the read
    Read AS5510_Data_Buffer (Two_Byte_Buffer)     //Read 2 data bytes – IIC Read mode, bit 0

     AS5510_OCF_Process_Done = (AS5510_Data_Buffer[1] & 0x08u);  //Mask off unwanted bits -
                                                                  Only want the OCF bit,
                                                                  Bit 3 (Offset Comp Flag,
                                                                  which = 1 when
                                                                  compensation process
                                                                  completes) -- See
                                                                  datasheet for details
  }

  for(;;)
  {
    Write AS5510_Value_Address (One_Byte_Buffer);   //Send 1 byte -- Address for read
    Read AS5510_Data_Buffer (Two_Byte_Buffer)       //Read 2 data bytes

     AS5510_LSB = AS5510_Data_Buffer[0];
     AS5510_MSB = (AS5510_Data_Buffer[1] & 3u);     //Mask off unwanted bits - Only want 2 low
                                                     bits of MSB (= D8 and D9)
```

```
    AS5510_Output = ((AS5510_MSB<<8u) + AS5510_LSB);        //Combine Data bits to create
                                                              10-bit Output Value
  }
```

“ASS5510”_Output now holds a value between 0 and 1024 which represents the intensity of the magnetic field that the device is sensing.

Using this information, a system can be calibrated for positional management.

Is is also possible to calculate the actual value in mT that the device is sensing based on this “AS5510_Output” value and the Sensitivity Mode Setting (and associated factor – See datasheet for details)

9 Testing and Evaluation – What to expect

Under PSoC Creator, the application can be run in Debug mode, or can be downloaded and run on the board as a standalone application.

All variable functions can be set up within the code for test.

The raw Counts data displayed on the 2 x 20 LCD is the decimal value of 0 to 1024 counts indicating the level of magnetic field that the AS5510 is sensing.

With no magnet, the output will be ~512 counts (~1/2 of 1023).

With the magnet centered over the device, the output will be ~512 counts (~1/2 of 1023).

Moving the magnet in one direction across the AS5510 (starting with it centered) will decrease the output counts to 0.

Moving the magnet in the opposite direction will increase the output counts to 1023.

The Sensitivity Mode [Sns] is displayed as a decimal value of 0 to 3. (*NOTE: The sensitivity level is not sequential as the Mode value counts 0 through 3 – Refer to the datasheet for sensitivity relative to Mode).

The mT value is a decimal representation of the calculated Magnetic Field. Calculations are based on the raw Counts value, and the Sensitivity Mode Setting.

Because the AS5510 uses a pure field sense configuration, rather than the stray-field-tolerant ams differential-sense design, it is susceptible to stray field energies, so care in implementation is necessary with this device.

From this point, the user can utilize the basic setup and interface code, and the data gathered from the device to create their own application solution and/or to explore the additional functionality of the AS5510.

10 Contact Information

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12 Revision Information

Revision History

Revision	Date	Owner	Description
1.0	12.09.2013	N. Brown	Designer's Notebook – AS5510 Magnetic Field/Position Sensor
1.01	06.01.2014	N. Brown	Designer's Notebook – Revision - AS5510 AS5510 – Initialization and Application
1.02	30.07.2014	A. Zenz	Updated to new template
1.03	31.01.2014	R. Pichler	Minor Change