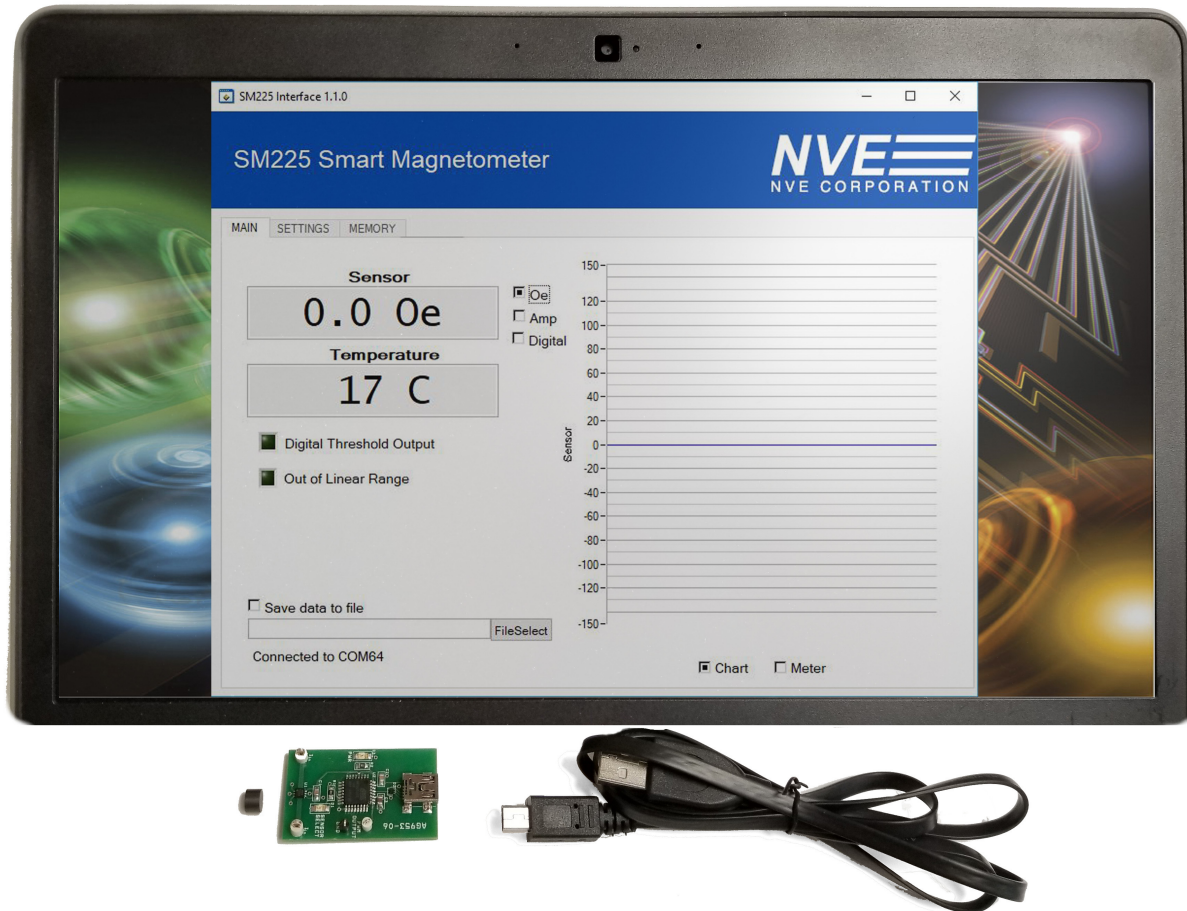


## **AG953: SM225 TMR Smart SPI Magnetometer Evaluation Board**



### ***Summary***

The AG953 Evaluation Board provides a sophisticated user interface for the SM225-10E Smart Magnetometer. The evaluation kit includes:

- USB-powered Evaluation Board with:
  - an SM225-10E sensor
  - a microcontroller connected to the sensor via SPI
  - a regulated 3.3 volt supply to power the SM225-10E
  - a 10 amp current-carrying trace under the sensor for current-sensing evaluating
- A small ceramic magnet for evaluating as a proximity sensor
- USB cable to connect the Evaluation Board to a computer
- A powerful, intuitive graphical user interface

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## 1. Overview

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### This Evaluation Kit Includes:

- An evaluation board including:
  - An SM225-10E Smart Magnetometer
  - A microcontroller
  - A USB computer interface
  - A PWM analog output
- Easy to install Windows-compatible software and graphical user interface
- A disk magnet
- USB to mini-B cable

### SM225-10E Features:

- Tunneling Magnetoresistance (TMR) for precision and low power
- SPI communication interface
- In-plane sensitivity—more usable than Hall effect sensors
- Factory calibrated
- Programmable offset and gain correction
- Internal temperature compensation
- Optional magnet temperature calibration
- 1.7 to 3.6V supply
- $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  operating range
- Ultraminiature 2.5 x 2.5 x 0.8 mm TDFN6 package

### SM225-10E Key Specifications:

- Wide 0 to 150 Oe (0 to 15 mT) linear range
- $\pm 2\%$  of full-scale accuracy from 0 to  $125^{\circ}\text{C}$
- $\pm 4\%$  of full-scale accuracy for  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Fast 15000 samples per second update rate

## 2. Quick Start

- 2.1. Download the AG953 software installer from GitHub (<https://github.com/NveCorporation>).
- 2.2. Install the software on a Windows PC.
- 2.3. Connect the Evaluation Board to the computer via the USB cable.
- 2.3. Launch the application.
- 2.4. The user interface will show the applied field, which can be changed by moving a magnet relative to the sensor:

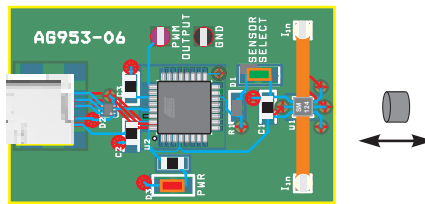


Figure 1. Measuring the field from a magnet with the SM225 Evaluation Board.

### 3. The Evaluation Board

#### 3.1 Board Layout

The evaluation board interfaces an SM225 Smart Magnetometer via SPI with a host computer via USB:

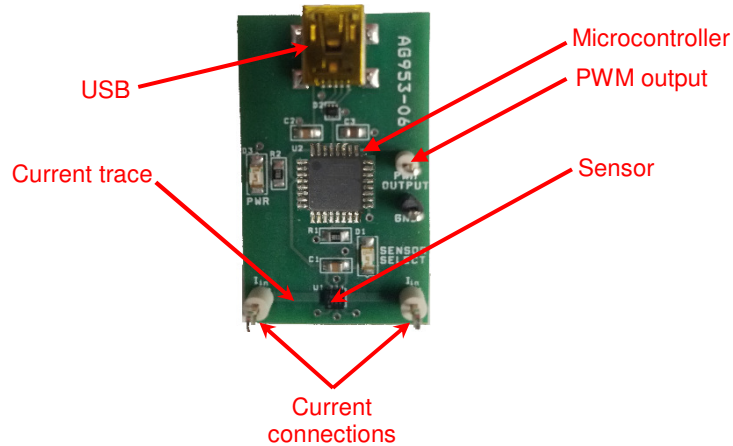


Figure 2. The Evaluation Board (actual size).

Part Number	Designator	Manufacturer	Qty	Description
<b>Board-Level Components</b>				
SM225-10E	U1	NVE	1	SMART TMR SPI MAGNETOMETER SENSOR, 150 OE
ATMEGA16U2-AU	U2	Microchip Technology	1	IC MCU 8BIT 16KB FLASH 32TQFP
APT3216LZGCK	D1	Kingbright	1	LED GREEN CLEAR 1206 SMD
APT3216LSECK	D3	Kingbright	1	LED RED CLEAR 1206 SMD
	R1, R2	Generic	2	RES 3K OHM 1% 1/4W 0805
TPD2E001DRLR	D2	Texas Instruments	1	TVS DIODE 5.5V SO T5
885012207016	C2	Würth Electronics Inc.	1	CAP CER 0.1UF 10V X7R 0805
GRM21BR71C105KA01L	C1, C3	Murata Electronics North Amer	2	CAP CER 1UF 16V X7R 0805
690-005-299-043	J1	EDAC Inc.	1	CONN MINI USB RCPT RA TY PE B SMD
500x	3.3V, GND, PWM_OUT	Keystone Electronics	3	TEST POINT PC MINI .040"D
5007	Iin	Keystone Electronics	2	TEST POINT PC COMPACT .063"D WHT
<b>Package-Level Components</b>				
12216	N/A	NVE	1	6 MM DIA. X 4 MM THICK DISK MAGNET
	N/A	Generic	1	3ft FLAT USB 2.0 480Mbps Type A Male to Mini-B/5-Pin Male Cable

### 3.2 Schematic

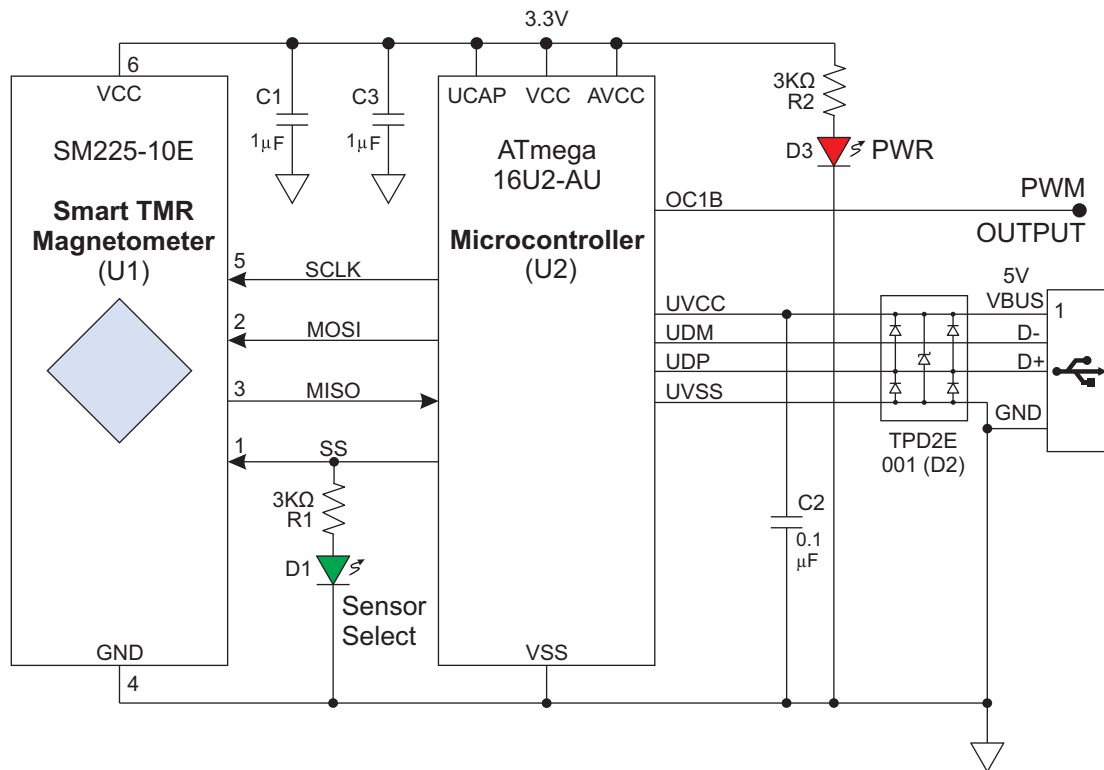


Figure 3. Evaluation Board Schematic.

### 3.3 Circuit Description

#### *The Sensor*

The SM225 (U1) has six pads: power (VDD and GND) and SPI (SCLK, MOSI, MISO, and SS).

#### *Microcontroller*

The SM225 is compatible with almost any microcontroller. This board uses a popular ATMEGA16U2 8-bit microcontroller (U2), which has integrated SPI and USB interfaces. The microcontroller also has an internal 3.3-volt regulator that is used to power the board.

#### *LEDs*

Red LED D3 shows the sensor is powered, indicating the board is connected to a powered USB port, and that the microcontroller power supply is operating. Green LED D1 indicates the sensor is selected as a slave.

#### *SPI*

SPI links the sensor and microcontroller. The SM225 is an SPI Slave, and the microcontroller is configured as the Master. The SM225 SPI interface is compatible with 3.3 or five-volt microcontrollers. The evaluation board uses 3.3 volts for both the sensor and microcontroller.

In accordance with industry standards, the SM225 SCLK, MOSI, and SS lines are open-drain, and the microcontroller's internal pull-up resistors are activated in software. When external pull-ups are used with different power supplies, they should be connected to the lower supply voltage.

#### *PWM Analog Output*

A PWM output from the microcontroller tracks the field magnitude measured by the sensor, and can be connected to a multimeter or data acquisition system. The output is scaled to 0.01 volts/oersted (0.1 V/mT), or 1.5 volts at the full 150 Oe (15 mT) linear range. The output is referenced to board ground and ratiometric with the 3.3 V regulated supply. PWM resolution is eight bits over 3.3 volts, or about one part in 100 over the sensor's linear range. The PWM output is generated by the microcontroller, not directly by the sensor. The PWM output cannot go negative.

#### *USB*

The microcontroller has an integrated USB UART. A Transient Voltage Suppressor (D2) protects the microcontroller.

#### *Current-Sensing Trace*

The board has a current trace under the sensor IC (the  $I_{in}$  connections) for evaluating the magnetometer as a current sensor. The trace is 0.05 inches (1.3 mm) wide and one-ounce copper, and can carry up to seven amps continuously with a safe temperature rise, or up to 10 amps typically for a few minutes.

Since the SM225 is bipolar it provides positive and negative outputs and can measure AC current.

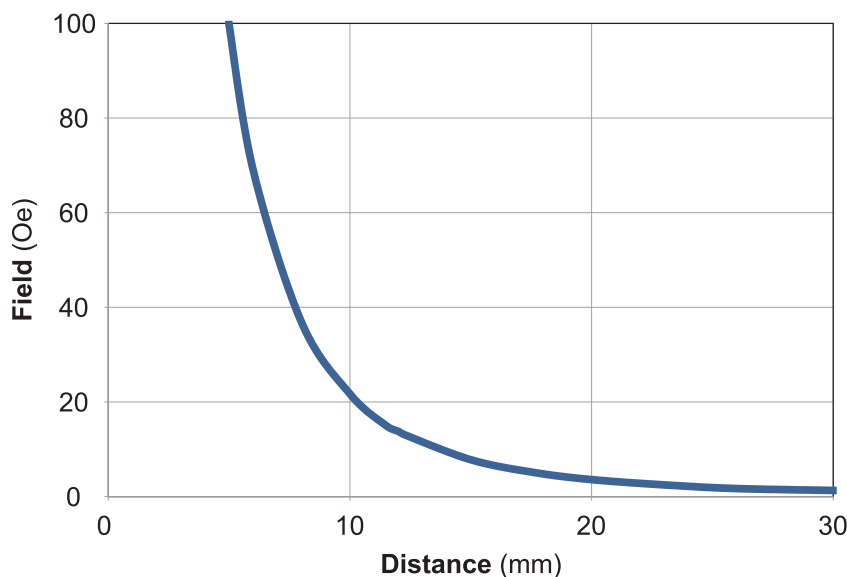
Fields generated by clip leads can affect the sensor, so for precise measurements the lead positioning should be fixed, and ideally at right angles to the trace to minimize their effect on the sensor.

#### *Decoupling Capacitors*

The board has 1  $\mu$ F decoupling capacitors (C1 and C3) as recommended for the sensor and the microcontroller. There is also a 0.1  $\mu$ F decoupling capacitor (C2) as recommended for the USB bus supply.

#### 4. Magnets and Magnetic Operation

The Evaluation Kit includes a popular ferrite disk magnet. The magnetic field from the magnet at the center of the sensor is shown in this graph:



**Figure 4. Magnetic field from the 6 mm dia. x 4 mm thick ferrite magnet**  
(referenced to the center of the sensor).

Larger and stronger magnets allow farther operate and release distances. For more calculations, use our axial disc magnetic field versus distance Web application at:

[www.nve.com/spec/calculators.php#tabs-Axial-Disc-Magnet-Field](http://www.nve.com/spec/calculators.php#tabs-Axial-Disc-Magnet-Field).

##### 4.1 Magnetic Thresholds

Typical thresholds for proximity sensing with the magnet included in the kit are shown in the following table:

Magnetic Threshold	Magnet Distance
100 Oe*	5 mm
20 Oe	10 mm
5 Oe	18 mm
2 Oe	24 mm

\*Factory default

Table 1. Typical magnetic thresholds.



## 5. Current Sensing

SM225-10E sensors can measure the current through a circuit board trace by detecting the magnetic field generated by the current through the trace. In this application, the digital output can be used for current threshold detection or overcurrent protection.

The evaluation board includes a current-sensing trace:



Figure 5. Current trace (top view).

The board trace is on the top side of the circuit board for high current sensitivity, but traces can also be run on the bottom side of the PCB for higher currents. The magnetic field generated in either case can be approximated by Ampere's law:

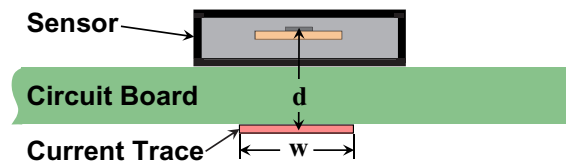


Figure 6. Current-sensing over a circuit board trace (side view).

$$H = \frac{2I}{d} \quad [\text{"H" in oersteds, "I" in amps, and "d" in millimeters}]$$

For the trace on the top of the circuit board, "d" is the distance from the bottom of the sensor package to the sensor element, which is 0.7 millimeters. The field is therefore approximately 3 Oe/A.

Typical overcurrent thresholds are summarized in the following table:

Magnetic Threshold	Current Threshold
28 Oe	10 A
20 Oe	7 A
10 Oe	3.5 A
3 Oe	1 A

Table 2. Typical overcurrent detection settings.

## 6. User Interface Software Installation

---

### 6.1 System Requirements

The software system requirements are:

- Windows 7 or later
- 100 MB system memory
- A USB 2.0 port

### 6.2 Software Installation

- 6.2.1. Download the software installation executable from <https://github.com/NveCorporation>.
- 6.2.2. Run the executable to begin installation.
- 6.2.3. Follow prompts for installing the NVE software and supporting National Instruments files.

### 6.3 USB driver installation

- 6.3.1. Disconnect any AG953 boards from the PC.
- 6.3.2. Locate the USB driver *NVESmartSensor.inf* in the “*C:\Program Files (x86)\NVE*” folder.
- 6.3.3. Right click on *NVESmartSensor.inf* and click “Install.”
- 6.3.4. Restart the computer to complete the installation.
- 6.3.5. Connect the AG953 board to a USB port.
- 6.3.6. The connection can be verified by checking for “NVE Smart Sensor” under “Ports (COM & LPT)” in the Device Manager.

## **7. User Interface Operation**

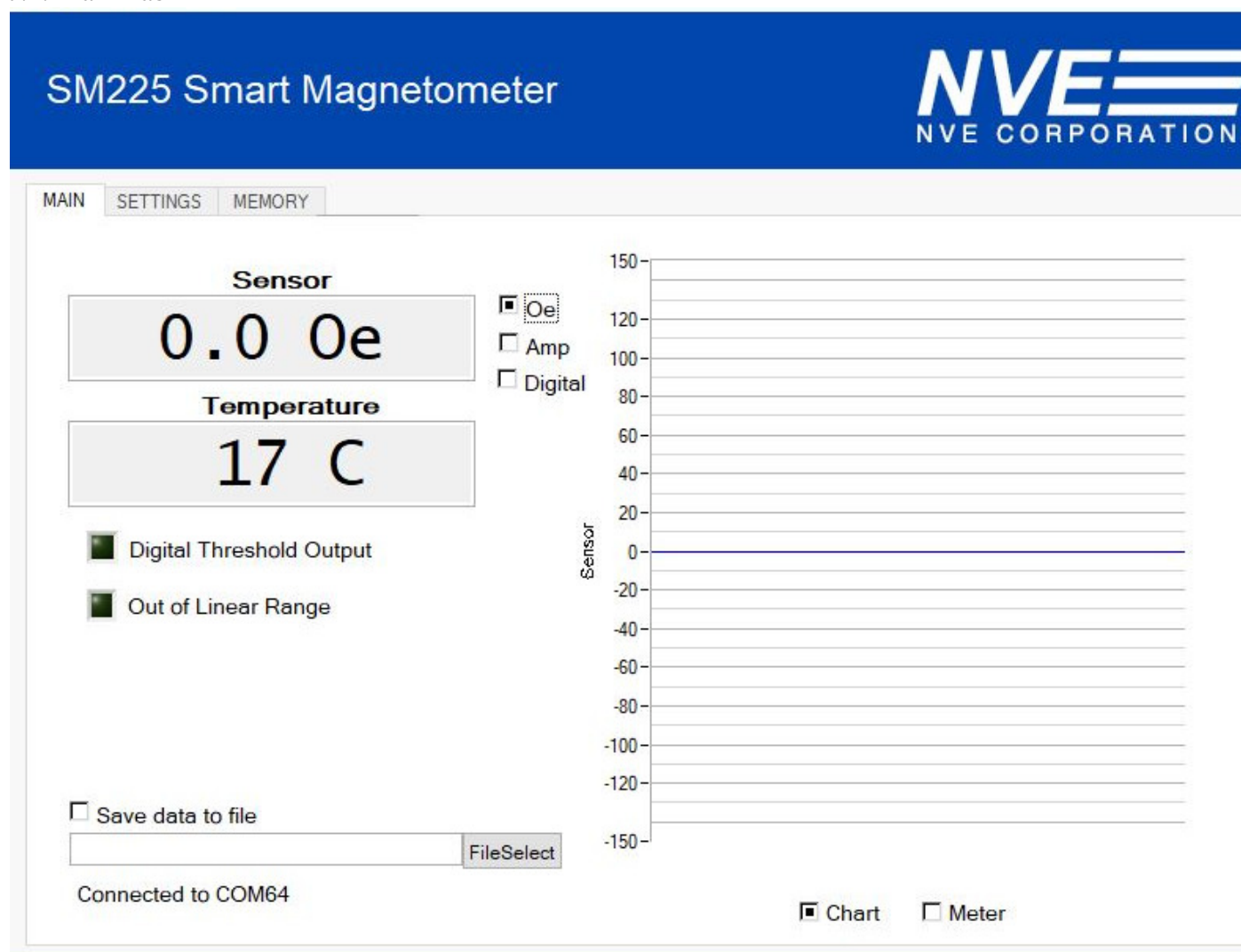
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The User Interface allows reading sensor data, setting the digital output threshold, and reading and writing the nonvolatile sensor parameters and calibration constants.

After starting the application, a single window with three tabbed panels is displayed. The three tabs are:

1. **Main** – Displays measurement results in digital and graphical formats.
2. **Settings** – Sets the digital output threshold, hysteresis, offset, and digital filter constant. Parameters are changed by entering a number and hitting “Enter.” This tab also allows changing between omnipolar, unipolar, and bipolar digital outputs by selecting either the desired image or the corresponding radio button.
3. **Memory** – A table shows the sensor’s data, parameters, and calibration constants. Data and parameters are displayed in rel time, and can be changed by entering the desired value in the write address.

## 7.1. Main Tab



Main tab elements are described below:

**Sensor** – Displays the output of the device in oersteds, amps, or the sensor’s integer digital output as selected by the radio buttons. Double right-clicking the display changes oersted or amps precision.

**Temperature** – Displays the calibrated temperature from the sensor in degrees Celsius. The sensor’s maximum operating temperature is 125°C.

**Digital Threshold Output** – A virtual LED turns on when the sensor’s virtual comparator is HIGH. The threshold, hysteresis, and configuration can be set in the Settings Tab.

**Out of Linear Range** – Warns that the sensor field exceeds its linear range, so the reading may be inaccurate.

*Chart* – Displays a “strip chart” on right side of the tab with the measurement on the y-axis. The chart is updated approximately 10 times per second.

*Meter* – Displays a virtual meter on the right side of the tab.

*Save Data to File* – Checking this box saves data points (date, time stamp, elapsed time, temperature, and sensor field or current output) to a file chosen under the *File Select* button. The box can be checked and unchecked while the demo is running. Data are updated every 100 milliseconds when the box is checked.

*File Select* – Opens a pop-up window to select a csv format data file. Data are continuously added to the file whenever the “Save data to file” box is checked.

## 7.2. Settings Tab

The Settings Tab allows setting parameters for the Threshold Output, the Current Sensing Sensitivity, and the Digital Filter Constant. Parameters can be entered into the appropriate boxes.

An error popup will indicate the user is attempting to set a parameter out of range.

Note that the values in the boxes do not always reflect the values in the sensor because they are not read back from the sensor, rather they are a way of programming the sensor.

SM225 Smart Magnetometer

MAIN
SETTINGS
MEMORY

Threshold Output

On

Off

Field

HYST1 TRSH1

HYST2 TRSH2

Threshold Output

On

Off

Field

HYST1 TRSH1

Threshold Output

On

Off

Field

HYST1 TRSH1

☒ Omnipolar
☐ Unipolar
☐ Bipolar

**Set Threshold**

TRSH1 (Oe)

TRSH2 (Oe)

Current Sens (Oe/Amp)

**Set Threshold Hysteresis**

HYST1 (Oe)

HYST2 (Oe)

**Digital Filter Constant**

Cutoff Frequency (Hz)

**Sensor Offset**

Offset Value (Oe)

*Omnipolar* (the default configuration) – The output turns on when the magnitude of a field of either polarity exceeds the threshold. The field can be. Uses both TRSH and both HYST parameters.

*Unipolar* –The output turns on when one pole is applied, and turns off when the field is reduced or reversed. Only requires TRSH1 and HYST1;  $HYST1 < |TRSH1|$ .

*Bipolar* – The output will turn on when the field exceeds the threshold and off with the opposite field. Only requires TRSH1 and HYST1;  $\text{HYST1} > |\text{TRSH1}|$ .

*Sensor Offset* – Sets the sensor offset, which can be used to zero background magnetic fields.

*Set Threshold* – Sets the sensor's digital output (DOUT) turn-on threshold.

*Set Threshold Hysteresis* – Used to change the magnetic threshold differential in the sensor's nonvolatile memory. The digital output will turn off at *Threshold – Hysteresis*.


*Digital Filter Constant* – Sets the filter constant which will change the cutoff frequency of the internal filter. The cutoff frequency will be updated and displayed to the right. The range is 1 to 127 (dec). The factory-default sensor constant is "1," which disables the filter.

*Factory Reset* – Sets the calibration constants back to the factory defaults.

## 7.3. Memory Tab

This tab allows direct access to the sensor's internal memory:

SM225 Smart Magnetometer



MAIN
SETTINGS
MEMORY

Address (Hex)	Name	Value (Hex)	Value (Dec)	Description
0	Sensor	0000	0	Sensor (Read Only) (% of 100 Oe /10 mT)
1	temp	0019	25	Temperature (Read Only) (°C)
2	tout	0000	0	Threshold output (Read Only)
10	TRSH1	FF9C	-100	Threshold one (Read Only)
11	HYST1	000A	10	Hysteresis one (Read Only)
12	TRSH2	0064	100	Threshold two (Read Only)
13	HYST2	000A	10	Hysteresis two (Read Only)
14	TOUT_Invert	0000	0	Threshold invert (Read Only)
15	Sensor_Offset	FFFF	-1	Sensor offset (Read Only)
16	m	0001	1	Digital filter constant (Read Only)
30	TRSH1	0000	0	Threshold one (Write Only)
31	HYST1	0000	0	Hysteresis one (Write Only)
32	TRSH2	0000	0	Threshold two (Write Only)
33	HYST2	0000	0	Hysteresis two (Write Only)
34	TOUT_Invert	0000	0	Threshold invert (Write Only, high to invert TOUT)
35	Sensor_Offset	0000	0	Sensor offset (Write Only)
36	m	0000	0	Digital filter constant (Write Only)

Data are written to and read from different addresses. Addresses 0 to 16 hex are read addresses, while addresses 30 to 36 hex are write addresses. For example the Sensor Offset is written to address 35 hex and read from address 15 hex.

Data in the Read Addresses are updated continuously as the software is running, and reflect changes made in the write address table or the Settings Tab. Write address table values may not always reflect the actual values in the sensor, however, since they are not written until a value is entered and committed with the enter key.

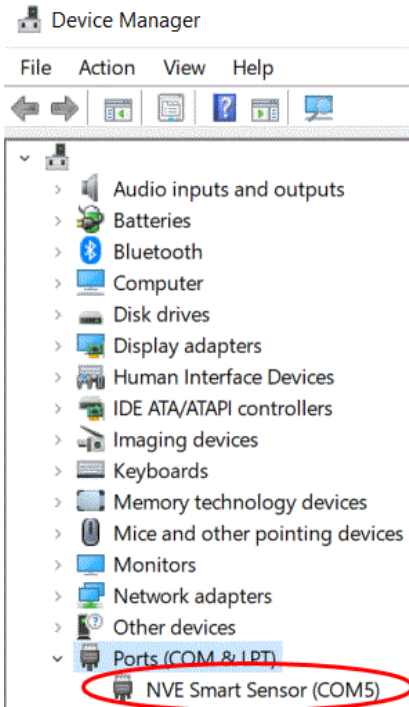
Data and parameters are all two-byte signed integers, although the allowable range of values is different for different parameters. Note that calibration constants are set at the factory and vary from part to part.



## 8. Troubleshooting

### No communications

1. Check the USB cable.
2. Verify the USB port under Windows Device Manager:



3. Reinstall the USB driver.

## **9. Revision History**

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**SB-00-080-A**

June 2019

**Change**

- Initial Release

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SB-00-080—AG953 Evaluation Kit Manual

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