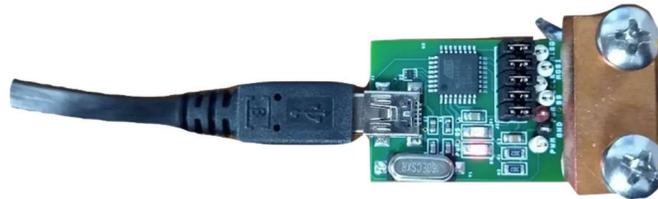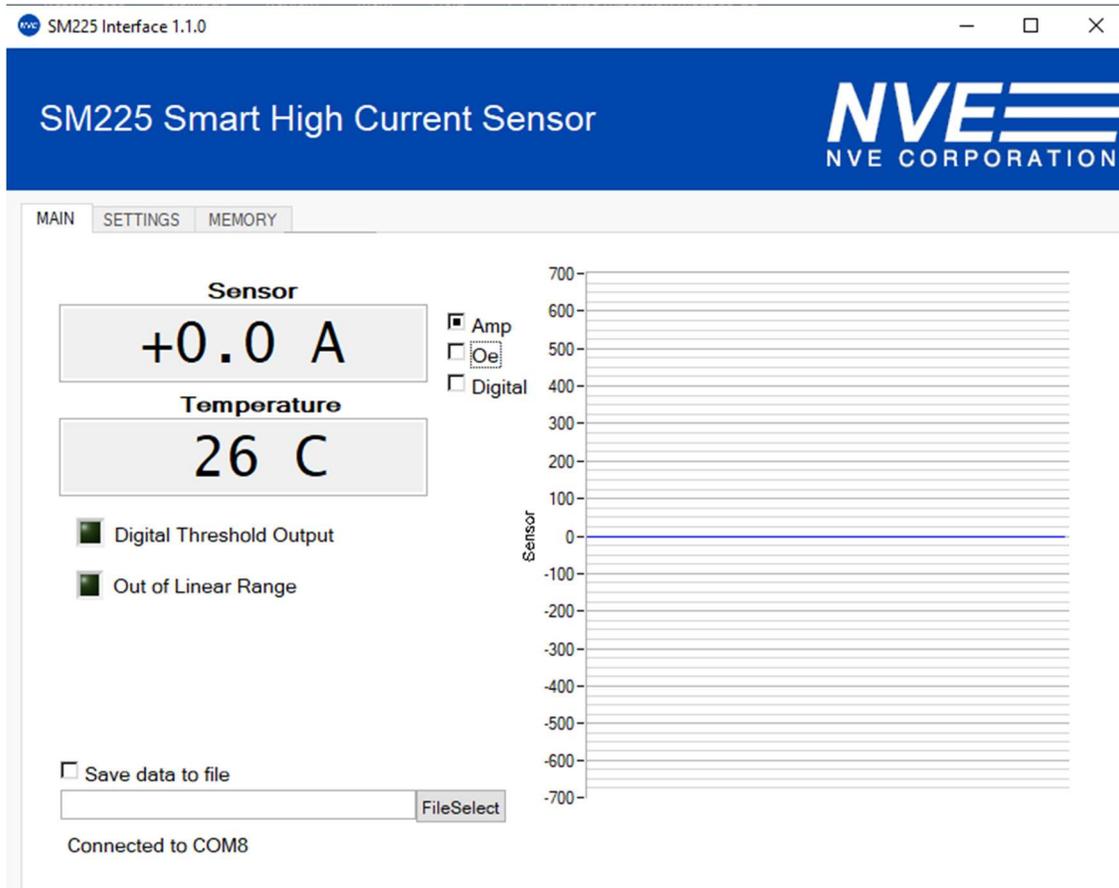# AG953H-07E: SM225 TMR Smart Sensor High Current Demonstration Board

Summary

The AG953H-07E Demonstration Board provides a sophisticated user interface for the SM225-10E Smart Magnetometer. Based on the AG953H-07E Evaluation Kit, this demonstration features a busbar for high current sensing. The demonstration includes:

- USB-powered Demonstration 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 6.35 mm x 12.7 mm copper busbar
- USB cable to connect the Evaluation Board to a computer
- A powerful, intuitive graphical user interface

Contents

1. Overview

This Demonstration Includes:
- A demonstration 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

- 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°C to 125°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
- ±2% of full-scale accuracy from 0 to 125°C
- ±4% of full-scale accuracy for −40°C to 125°C
- Fast 15000 samples per second update rate

2. Quick Start

2.1. Download the AG953H software installer from GitHub (*https://github.com/NveCorporation*), or access via provided USB stick.

2.2. Install the software on a Windows PC.

2.3. Launch the application.

2.4. The user interface will show the measured busbar current in amps. The calibration coefficient should be adjusted based on the vertical placement of the busbar.

Figure 1: The demonstration board.

3. The Demonstration Board

3.1 Board Layout

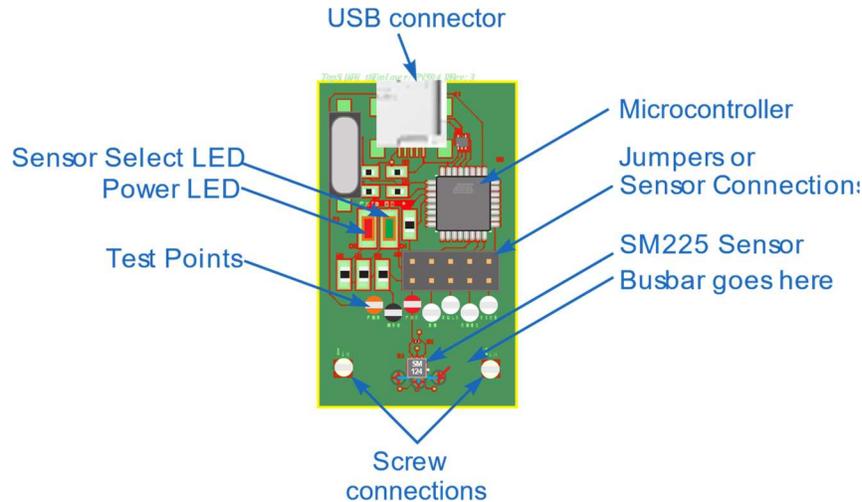The demonstration board interfaces an SM225 Smart Magnetometer via SPI with a host computer via USB:

Figure 2. The demonstration board with busbar removed.

Part Number	Designator	Manufacturer	Qty	Description
Board-Level Components				
SM225-10E	U1	NVE	1	SMART TMR SPI MAGNETOMETER SENSOR, 15 mT
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
	R3	Generic	1	RES 1M OHM 1% 1/10W 0603
TPD2E001DRLR	D2	Texas Instruments	1	TVS DIODE 5.5V SOT5
GRM033C71C104KE14D	C1	Murata Electronics	1	CAP CER 0.1UF 16V X7S 125C 0201
LMK107BBJ106MAL	C2,C3	Taiyo Yuden	2	CAP CER 10UF 10V X5R 0603
GRM21BR71C105KA01	C4	Murata Electronics	1	CAP CER 1UF 16V X7R 0805
CL10C200JB8NNNC	C5, C6	Samsung Electro-Mechanics	1	CAP CER 20PF 50V C0G/NP0 0603
ECS-160-20-5PX-TR	Y1	ECS Inc	1	CRYSTAL 16.0000MHZ 20PF SMD
690-005-299-043	J1	EDAC Inc.	1	CONN MINI USB RCPT RA TYPE B SMD
TSW-105-07-T-D	J2	Samtec	1	CONN HEADER VERT 10POS 2.54MM
500x	Various	Keystone Electronics	7	TEST POINT PC MINI .040"D
5007	Iin	Keystone Electronics	2	TEST POINT PC COMPACT .063"D WHT
Package-Level Components				
12216	N/A	NVE	1	6 MM DIA. X 4 MM THICK DISK MAGNET
	N/A	NVE	1	USB stick with Windows user interface installation software
	N/A	Generic	1	3ft FLAT USB 2.0 480Mbps Type A Male to Mini-B/5-Pin Male Cable

3.2 Schematic
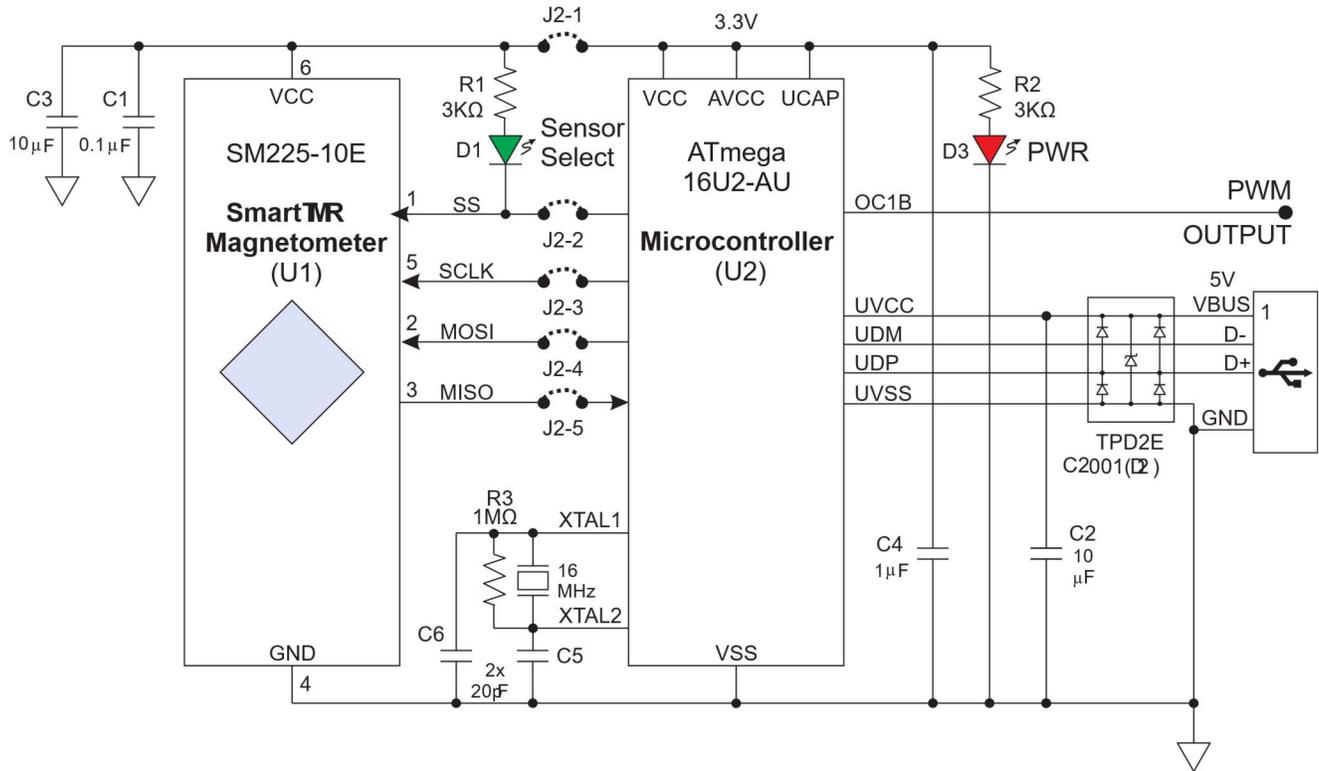

Figure 3. Demonstration Board Schematic.

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 demonstration 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-Carrying Busbar
The board has a height-adjustable copper busbar for evaluating the magnetometer as a current sensor. The busbar measures 6.35 mm x 12.7 mm and is rated to 360 amps for a 65°C temperature rise. The busbar can carry more than 500 amps for short periods of time.

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

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

4. Current Sensing

SM225-10E sensors can measure the current by detecting the generated magnetic field. This demonstration uses a busbar to carry large currents. In this application, the digital output can be used for current threshold detection or overcurrent protection.
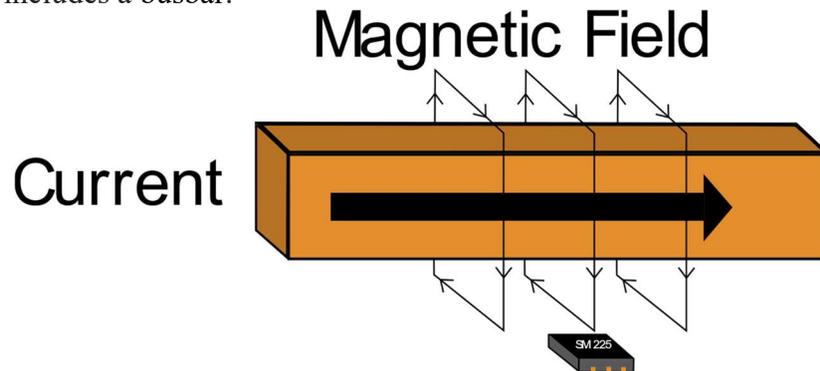
The evaluation board includes a busbar:

Figure 4. Reading the magnetic field of a busbar.

The magnetic field in this configuration can be calculated using our free web application:
https://www.nve.com/spec/calculators.php#tabs-Current-Sensing

At an airgap of four millimeters, the busbar produces 0.023 mT/amp, which corresponds to ±650 amps in the sensor's ±15 mT linear range.

5. User Interface Software Installation

5.1 System Requirements

The software system requirements are:
- Windows 7 or later
- 100 MB system memory
- A USB 2.0 port

5.2 Software Installation

    5.2.1. Download the software installation executable from ***https://github.com/NveCorporation*** or the provided USB stick*.*

    5.2.2. Run the executable to begin installation.

    5.2.3. Follow prompts for installing the NVE software and supporting National Instruments files.

5.3 USB driver installation

    5.3.1. Disconnect any AG953 boards from the PC.

    5.3.2. Locate the USB driver *NVESmartSensor.inf* in the "*C:\Program Files (x86)\NVE*" folder.

    5.3.3. Right click on *NVESmartSensor.inf* and click "Install."

    5.3.4. Restart the computer to complete the installation.

    5.3.5. Connect the AG953-06 board to a USB port.

    5.3.6. The connection can be verified by checking for "NVE Smart Sensor" under "Ports (COM & LPT)" in the Device Manager.

6. User Interface Operation

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.

6.1. Main Tab
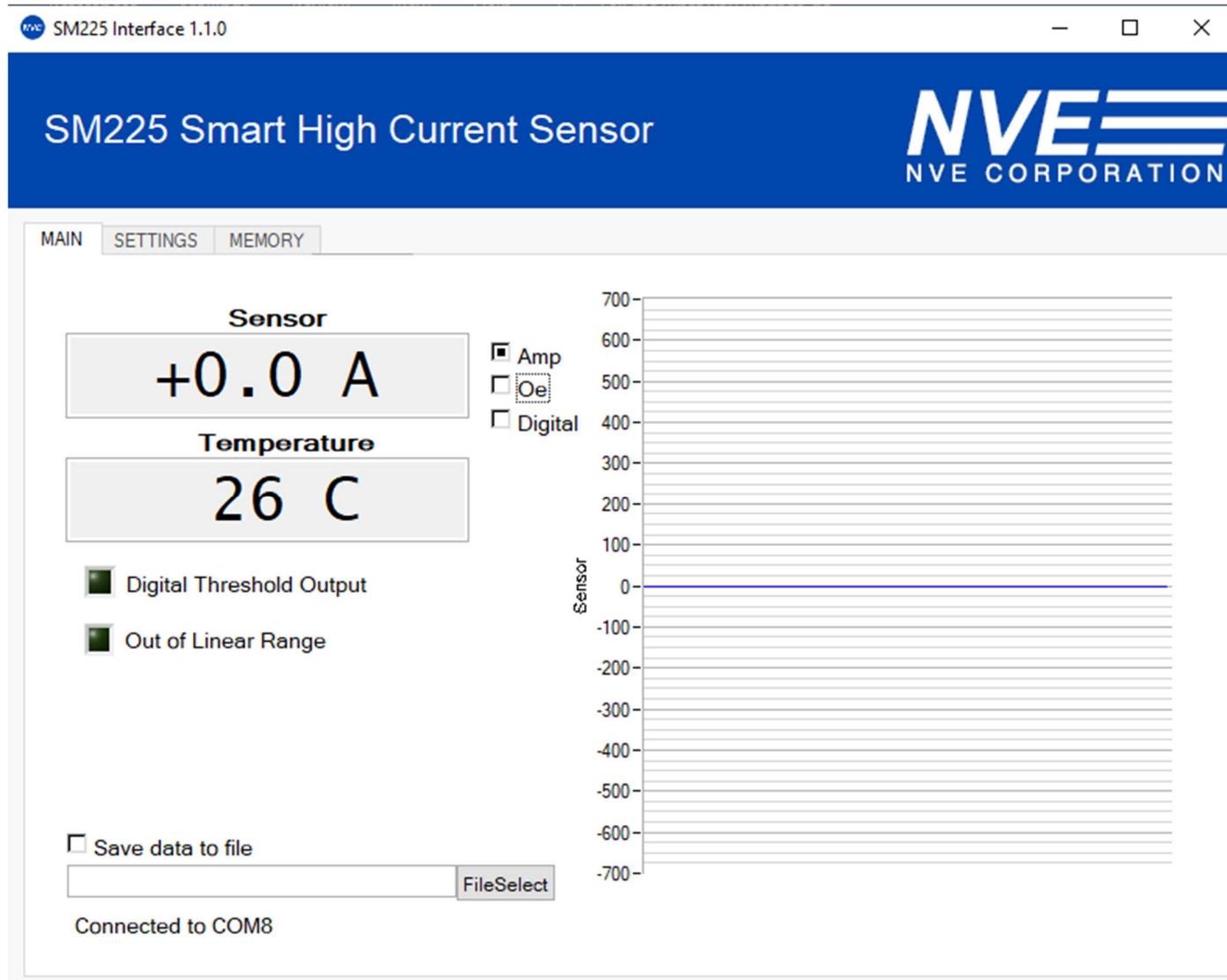
Main tab elements are described below:

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.

6.2. 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.
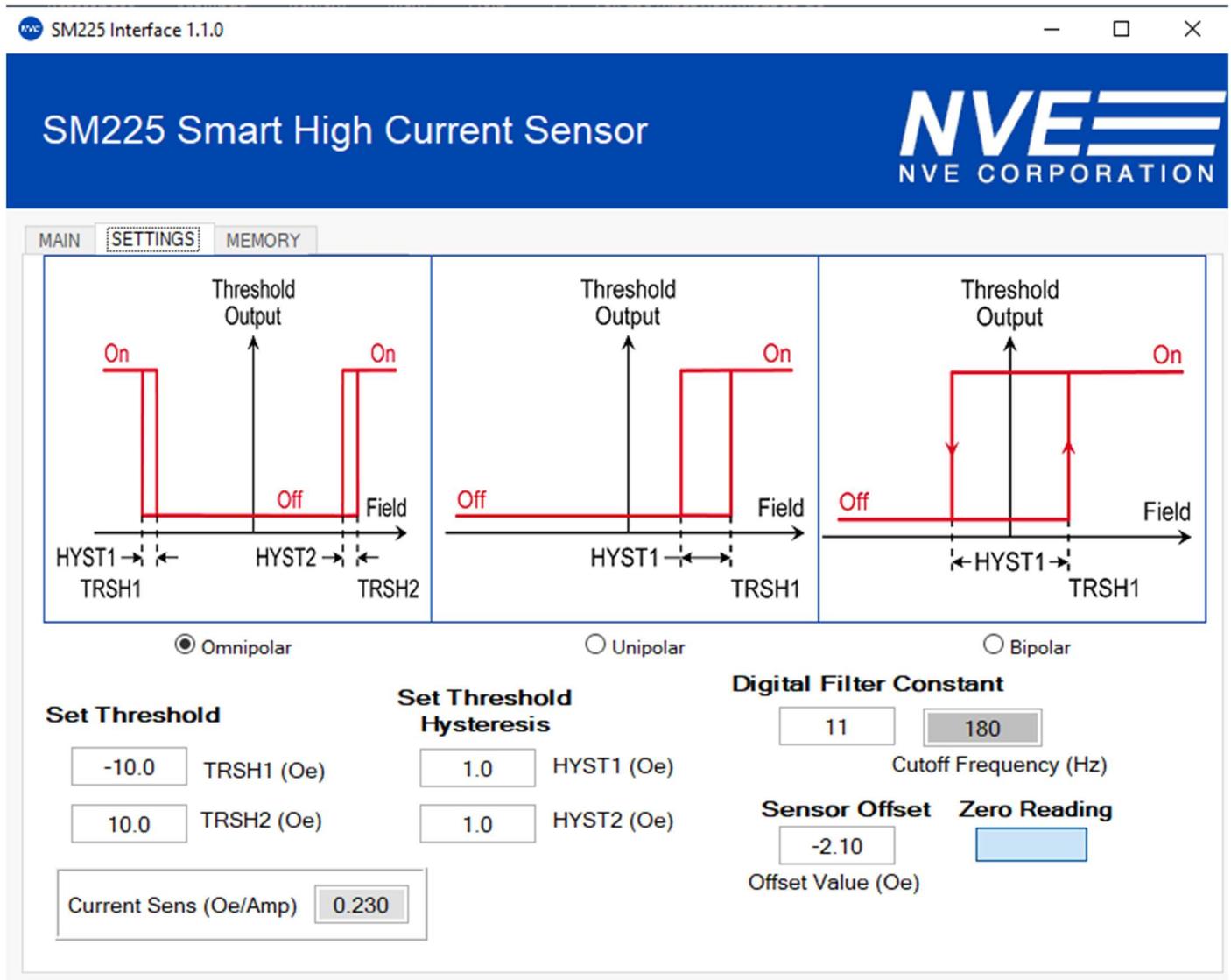
Omnipolar (the default configuration) – The output turns on when the magnitude of a field of either polarity exceeds the threshold. The field can be. Uses both TRSH and both HYST parameters.

SM225 High Current Demonstration Board

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; HYST1 > |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.

6.3. Memory Tab

This tab allows direct access to the sensor's internal memory:
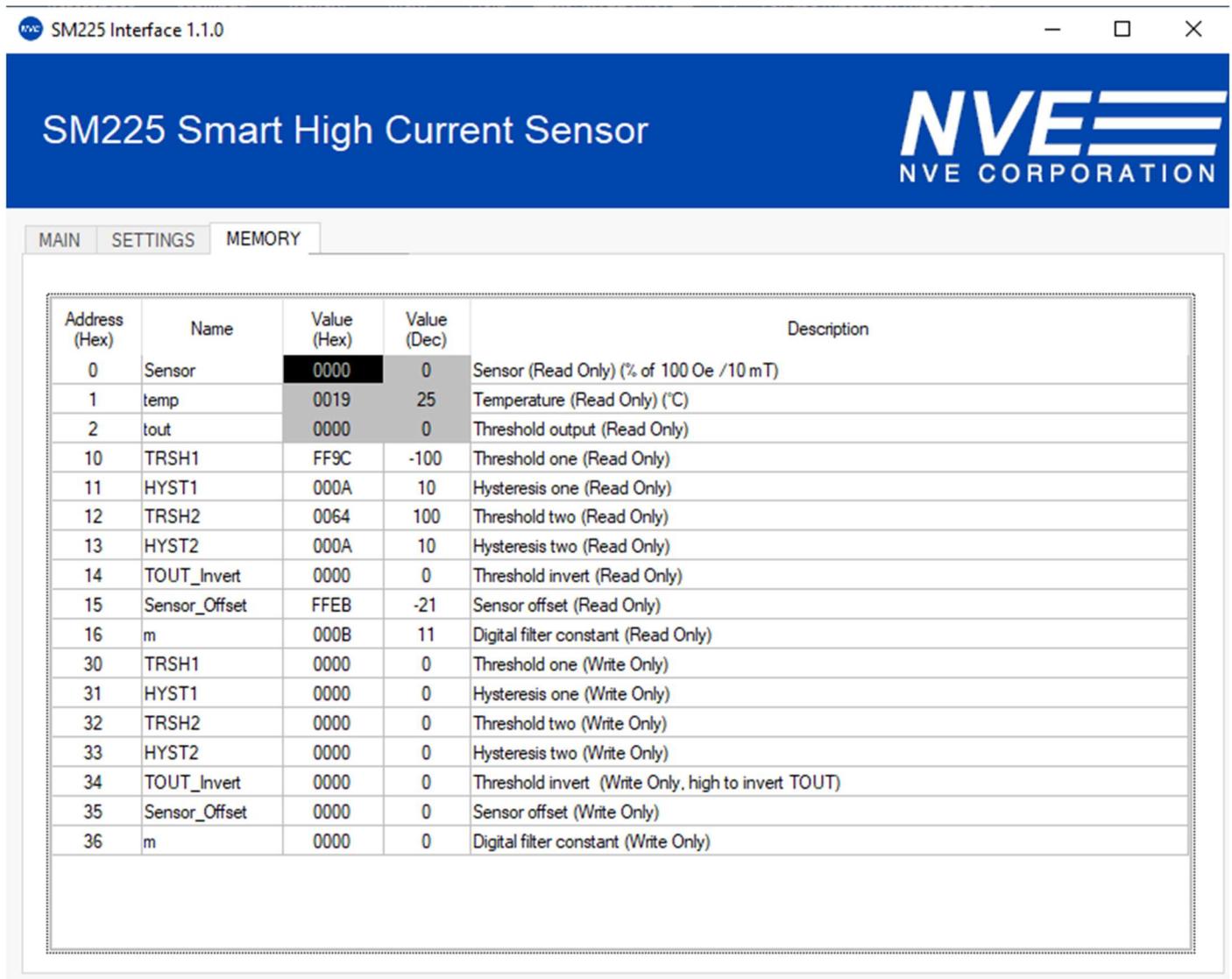
Address (Hex)	Name	Value (Hex)	Value (Dec)	Description
0	Sensor	0000	0	Sensor (Read Only) (% of 100 Oe /10 mT)
1	temp	0019	25	Temperature (Read Only) (°C)
2	tout	0000	0	Threshold output (Read Only)
10	TRSH1	FF9C	-100	Threshold one (Read Only)
11	HYST1	000A	10	Hysteresis one (Read Only)
12	TRSH2	0064	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	FFEB	-21	Sensor offset (Read Only)
16	m	000B	11	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.

7. Troubleshooting

No communications

    1. Check the USB cable.

    2. Verify the USB port under Windows Device Manager:

    3. Reinstall the USB driver.

8. Revision History

SB-00-104-C March 2020	Change • Updated graphics
SB-00-104-B February 2020	Change • Change from AG953-07H to AG95H-07E
SB-00-104-A July 2019	Change • Initial Release

Datasheet Limitations
The information and data provided in datasheets shall define the specification of the product as agreed between NVE and its customer, unless NVE and customer have explicitly agreed otherwise in writing. All specifications are based on NVE test protocols. In no event however, shall an agreement be valid in which the NVE product is deemed to offer functions and qualities beyond those described in the datasheet.

Limited Warranty and Liability
Information in this document is believed to be accurate and reliable. However, NVE does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NVE be liable for any indirect, incidental, punitive, special or consequential damages (including, without limitation, lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Right to Make Changes
NVE reserves the right to make changes to information published in this document including, without limitation, specifications and product descriptions at any time and without notice. This document supersedes and replaces all information supplied prior to its publication.

Use in Life-Critical or Safety-Critical Applications
Unless NVE and a customer explicitly agree otherwise in writing, NVE products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical devices or equipment. NVE accepts no liability for inclusion or use of NVE products in such applications and such inclusion or use is at the customer's own risk. Should the customer use NVE products for such application whether authorized by NVE or not, the customer shall indemnify and hold NVE harmless against all claims and damages.

Applications
Applications described in this datasheet are illustrative only. NVE makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NVE products, and NVE accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NVE product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customers. Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NVE does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customers. The customer is responsible for all necessary testing for the customer's applications and products using NVE products in order to avoid a default of the applications and the products or of the application or use by customer's third party customers. NVE accepts no liability in this respect.

Limiting Values
Stress above one or more limiting values (as defined in the Absolute Maximum Ratings System of IEC 60134) will cause permanent damage to the device. Limiting values are stress ratings only and operation of the device at these or any other conditions above those given in the recommended operating conditions of the datasheet is not warranted. Constant or repeated exposure to limiting values will permanently and irreversibly affect the quality and reliability of the device.

Terms and Conditions of Sale
In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NVE hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NVE products by customer.

No Offer to Sell or License
Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights.

Export Control
This document as well as the items described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

Automotive Qualified Products
Unless the datasheet expressly states that a specific NVE product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. NVE accepts no liability for inclusion or use of non-automotive qualified products in automotive equipment or applications.

In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NVE's warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NVE's specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NVE for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NVE's standard warranty and NVE's product specifications.

An ISO 9001 Certified Company

NVE Corporation
11409 Valley View Road
Eden Prairie, MN 55344-3617 USA
Telephone: (952) 829-9217
www.nve.com
e-mail: sensor-info@nve.com

SB-00-104—AG953H-07E Demonstration Board Manual   *March 2020*