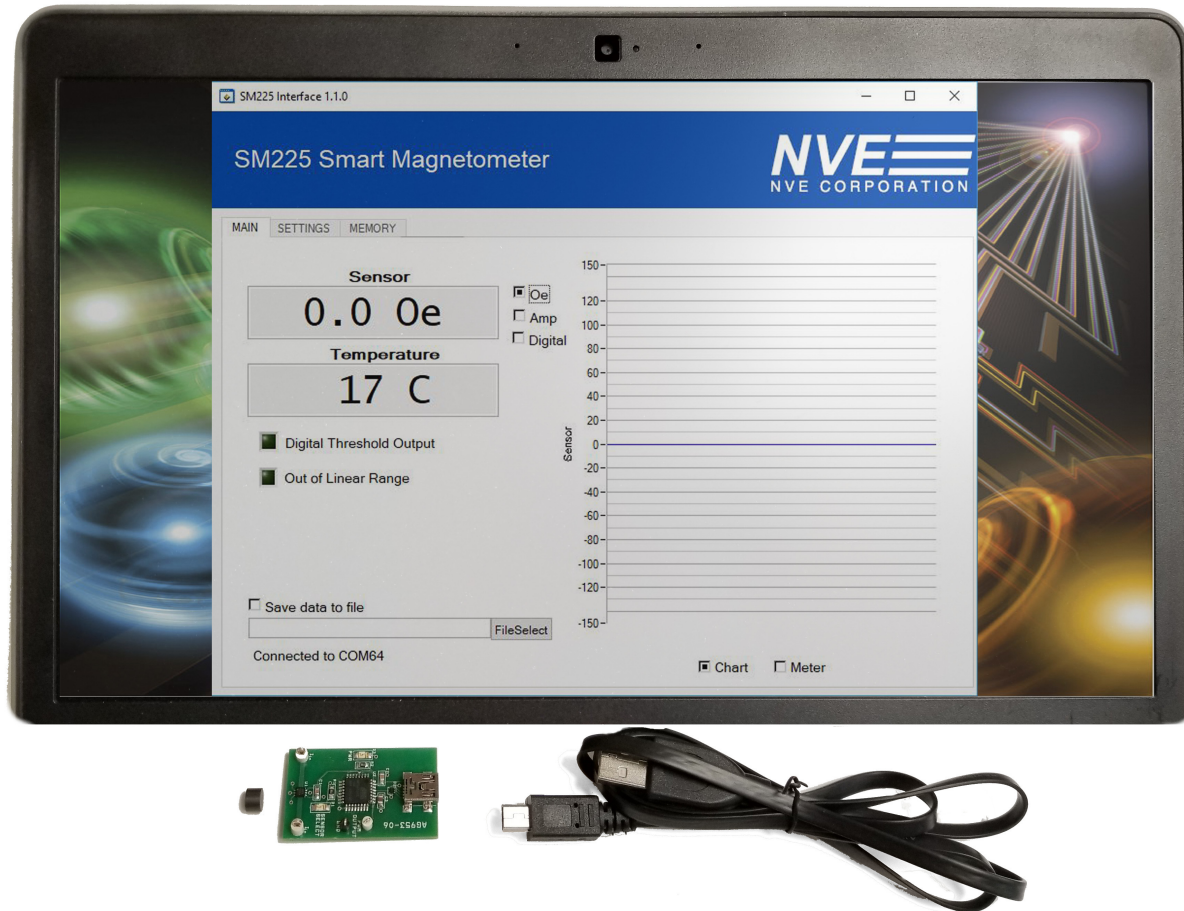


AG953: SM225 TMR SPI Smart Magnetometer Evaluation Board



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 current-carrying trace under the sensor for evaluating as a current sensor
- 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

Contents

1. Overview
2. Quick Start
3. The Evaluation Board
4. Magnets and Magnetic Operation
5. Current Sensing
6. User Interface Installation
7. User Interface Operation
 - 7.1. Main
 - 7.2. Calibration
 - 7.3. Calibration Memory
 - 7.4. SPI /USB
8. Troubleshooting / FAQs
9. Revision History

1. Overview

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°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
- $\pm 2\%$ of full-scale accuracy from 0 to 125°C
- $\pm 4\%$ of full-scale accuracy for –40°C to 125°C
- Fast 15000 samples per second update rate

2. Quick Start

- 2.1. Connect the Evaluation Board to a computer via the USB cable.
- 2.2. Download the AG953 software from our GitHub repository (<https://github.com/NveCorporation>).
- 2.3. Install the software and 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:

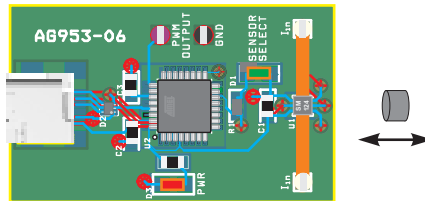


Figure1. Measuring the field from a magnet with the SM225 Evaluation Board.

3. The Evaluation Board

3.1 Board Layout

The evaluation board communicates with a host computer via USB and a Smart Magnetometer via SPI:

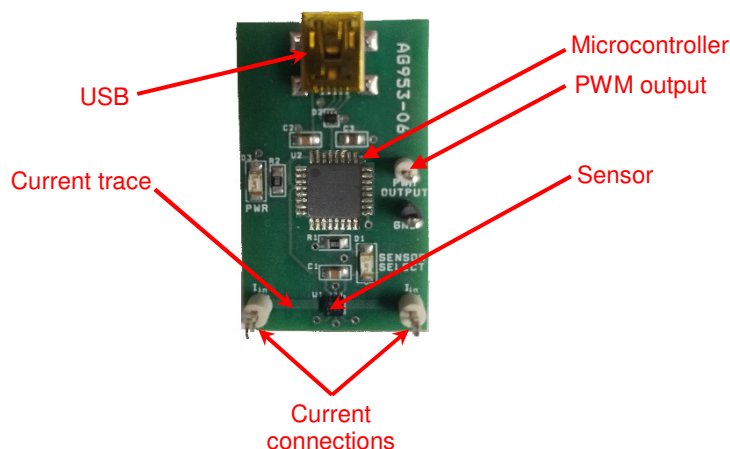


Figure 2. The Evaluation Board (actual size).

Part Number	Designator	Manufacturer	Qty	Description
Board-Level Components				
SM225-10E	U1	NVE	1	SMART TMR SPI MAGNETOMETER SENSOR
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	1	RES 3K OHM 1% 1/4W 0805
TPD2E001DRLR	D2	Texas Instruments	1	TVS DIODE 5.5V SOT5
885012207016	C2	Wurth Electronics Inc.	2	CAP CER 0.1UF 10V X7R 0805
3RM21BR71C105KA01H	C1, C3	Murata Electronics North An	1	CAP CER 1UF 16V X7R 0805
690-005-299-043	J1	EDAC Inc.	1	CONN MINI USB RCPT RA TYPE 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
Package-Level Components				
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

3.2 Schematic

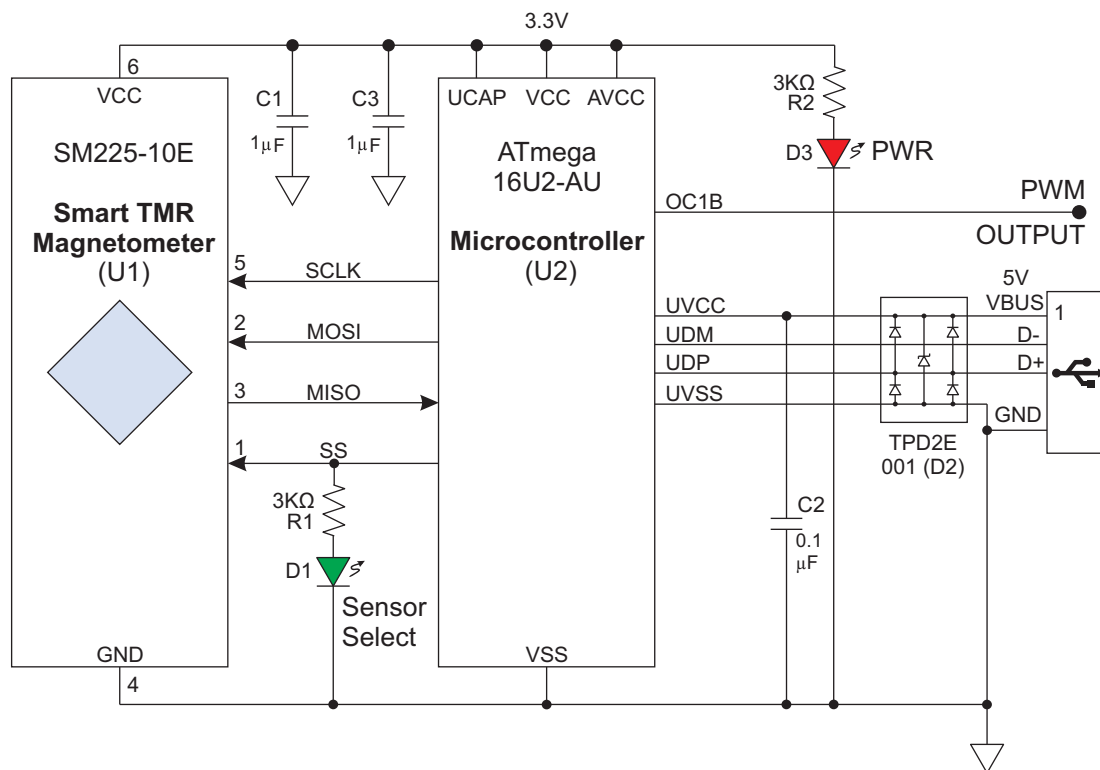


Figure 3. Evaluation Board Schematic.

3.3 Circuit Description

The Sensor

The SM225 (U1) has six pins: 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, which is used to power the board.

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 measured by the sensor, and can be connected to a multimeter or data acquisition system. The output is scaled to 0.01 volts/oersted, or 1.5 volts at the full 150 Oe linear range. The output is ratiometric with the 3.3 V regulated supply. Note that the PWM output is from the microcontroller, not directly from the sensor.

USB Interface

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 (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 with a safe temperature rise.

The sensor can be sensitive to the fields generated by clip leads, 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.

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.

Decoupling Capacitors

The board has 1 μ F decoupling capacitors (C1 and C3) as recommended for the sensor and the microcontroller. There is also a 0.1 μ 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:

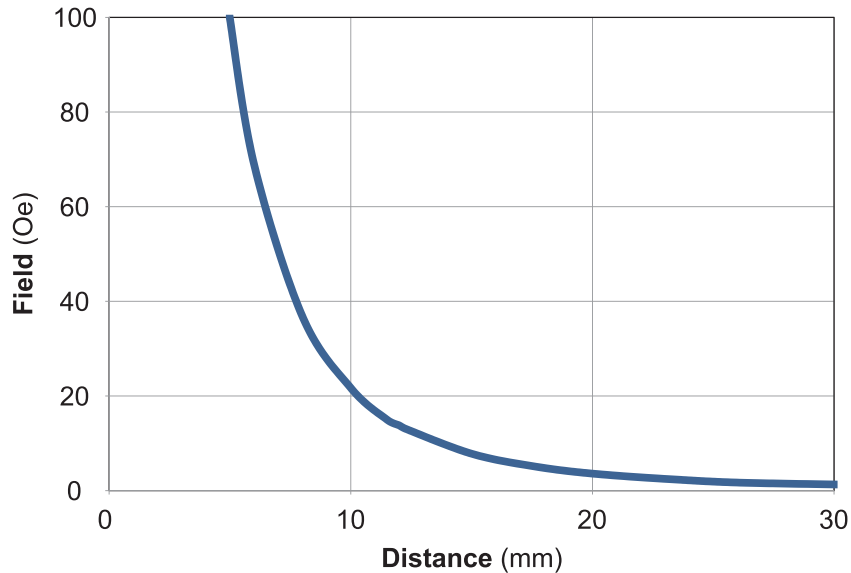


Figure 4. Magnetic field from the 6 mm dia. x 4 mm thick ferrite magnet
(referenced to the center of the sensor).

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.

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.

4.2. Magnet Temperature Compensation

In addition to sensor element temperature compensation, outputs are available that also compensate for the decrease in magnet strength at higher temperatures. Two corrections are calculated: one for low-cost ferrite magnets and another for high field rare-earth magnets.

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 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:

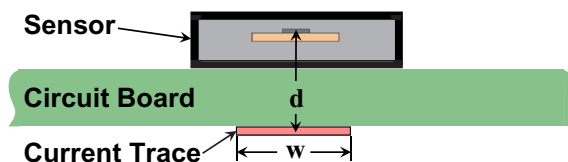


Figure 6. Current-sensing over a circuit board trace (side view).

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

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 30e/A, and is usable up to the seven amp maximum trace current.

Typical overcurrent thresholds are summarized in the following table:

Magnetic Threshold	Current Threshold
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
- One USB 2.0 port

6.2 Software Installation

6.2.1. Download the software installation package from <https://github.com/NveCorporation>

6.2.2. Run **setup.exe** to begin installation.

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

6.3 USB driver installation

6.3.1. Disconnect any AG953 boards connected to the PC.

6.3.2. Locate the USB driver **NVESmartSensor.inf** in the **drivers** folder of the installation package.

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 Windows Device Manager.

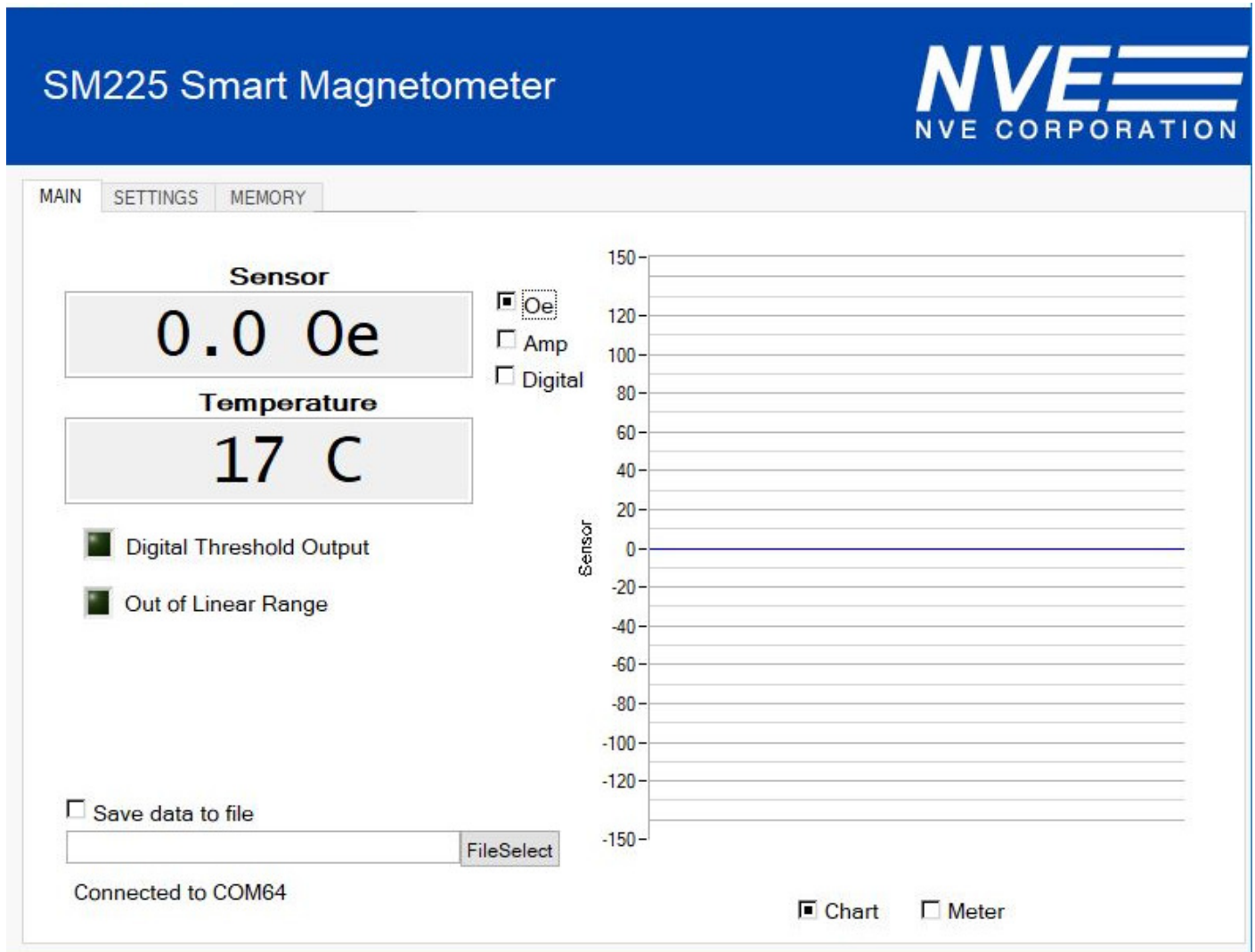
7. User Interface Operation

The User Interface allows reading sensor data, setting the digital output threshold, and reading and writing the nonvolatile sensor 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 both digital and graphical formats.
2. **Settings** – A graphical interface to change the digital output threshold, hysteresis, offset, and digital filter constant. Parameters are changed by entering a number and hitting “Enter.” This tab also allows for changes in the output type. To change between omnipolar, unipolar, and bipolar digital outputs press either the desired image or the corresponding radio button.
3. **Memory** – A table shows the sensor’s data and calibration constants. Parameters can be changed by double-clicking on the appropriate cell, typing a new number, and then hitting “Enter.”

7.1. Main Tab



Main tab elements are described below:

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

Temperature – Displays the calibrated temperature from the sensor in degrees Celsius.

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 showing the measurement on the y-axis. The chart is updated with each measurement.

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

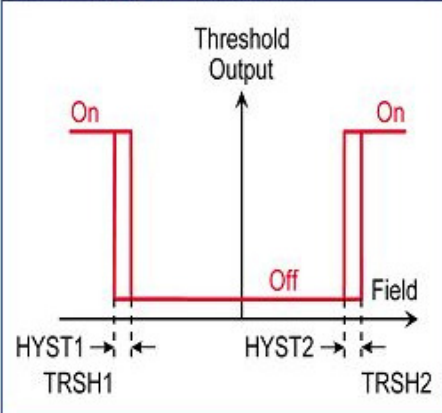
Save Data to File – Checking this box saves the datapoints to a file chosen under the *File Select* button.

File Select – Opens a pop-up window to select the data file.

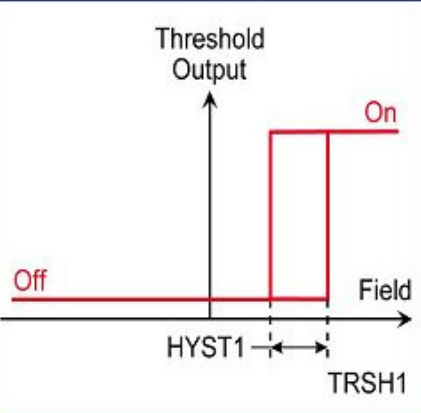
7.2. Settings Tab

SM225 Smart Magnetometer


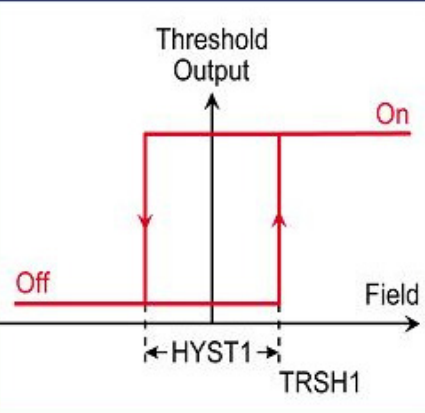
MAIN
SETTINGS
MEMORY



● 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 field magnitude exceeds the threshold. The field can be of either polarity.

Unipolar – Allows only TRSH1 and HYST1 to be set. The output will only turn on when a north pole (positive field) is applied to the sensor. It will turn off when the field is reduced or reversed.

Bipolar – Allows only TRSH1 and HYST1 to be set. The output will turn on with a north pole (positive field) applied that exceeds the threshold, then turn off when a south pole (negative field) is applied.

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


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

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

Set Threshold Hysteresis – Used to change the magnetic threshold differential located in the 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.

7.3. Memory Tab

SM225 Smart Magnetometer


MAIN
SETTINGS
MEMORY

Address (Hex)	Name	Value (Hex)	Value (Dec)	Description
0	Sensor	0000	0	Sensor (calibrated)
1	Temp	0014	20	Temperature (calibrated)
2	TOUT	0000	0	Threshold Output
10	TRSH1	FF9C	-100	Threshold 1
11	HYST1	000A	10	Hysteresis 1
12	TRSH2	0064	100	Threshold 2
13	HYST2	000A	10	Hysteresis 2
14	TOUT_invert	0001	1	Threshold Invert (set HIGH to invert TOUT)
15	Sensor_offset	00CB	203	Sensor Offset
16	m	0005	5	Digital Filter Constant (Cutoff Frequency= $[12,500/(2 \times \pi \times m)]$); 1 to disable filter

This tab allows direct access to the sensor's internal memory. Data and parameters are two-byte signed integers.

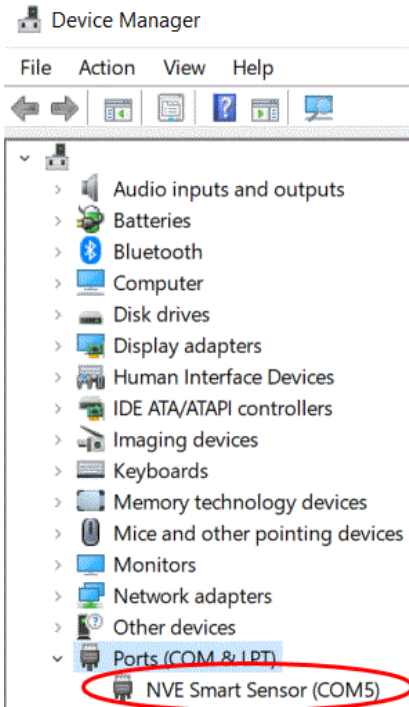
Notes:

- Calibration constants are set at the factory and vary from part to part.
- The factory default for the digital filter constant in memory location 16 (hex) is "1" (disabled). For demonstration purposes, the user interface invokes a filter constant.

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

SB-00-080-A

May 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

©NVE Corporation
All rights are reserved. Reproduction in whole or in part is prohibited without the prior written consent of the copyright owner.

SB-00-080—AG953 Evaluation Kit Manual

May 2019