

## **AG969: SM228 TMR Smart I<sup>2</sup>C Magnetometer Demonstration Board**



### **Summary**

The AG969 Demonstration Board provides a sophisticated user interface for the SM228-10E Smart Magnetometer. The demonstration kit includes:

- USB-powered Demonstration Board with:
  - an SM228-10E sensor
  - a microcontroller connected to the sensor via I<sup>2</sup>C
  - a regulated 3.3 volt supply to power the SM228-10E
  - direct access to Sensor pins or jumpers for microcontroller connections
  - 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 Demonstration Board to a computer
- A powerful, intuitive graphical user interface with one-click installation

## **Contents**

---

1. Overview
2. Quick Start
3. The Demonstration Board
4. Magnets and Magnetic Operation
5. Current Sensing
6. User Interface Installation
7. User Interface Operation
  - 7.1. Main Tab
  - 7.2. Settings Tab
  - 7.3. Memory Tab
8. Troubleshooting
9. Revision History

## 1. Overview

---

### SM228-10E Features:

- Tunneling Magnetoresistance (TMR) for precision and low power
- I<sup>2</sup>C communication interface
- In-plane sensitivity—more usable than Hall effect sensors
- Factory calibrated
- Programmable offset and gain correction
- Internal temperature compensation
- 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

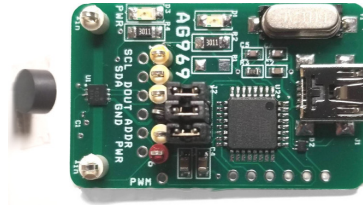
### SM228-10E Key Specifications:

- Wide 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. Run the Setup file from the USB stick if provided, or download from <https://github.com/NveCorporation> to install the User Interface on a Windows PC.
- 2.2. Click on the desktop icon to launch the User Interface application.
- 2.3. 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 SM228 Demonstration Board.**

### 3. The Demonstration Board

#### 3.1 Board Layout

The demonstration board interfaces an SM228 Smart Magnetometer via I<sup>2</sup>C with a host computer via USB:

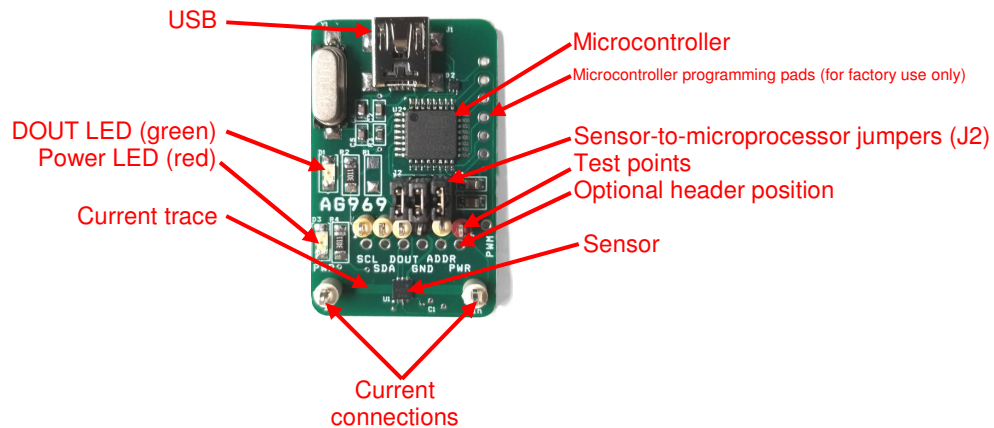


Figure 2. The Demonstration Board (actual size).

##### 3.1.1 J2 Sensor-to-Microprocessor Jumpers

For normal operation, jumpers connect the SM228 Smart Magnetometer to the microcontroller. The jumpers can be removed, however, and the pins used to connect the microcontroller to an external SM228 sensor, or to connect the on-board SM228 to external circuitry:

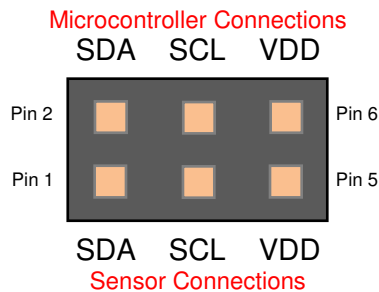


Figure 3. J2 Sensor-to-Microprocessor Jumpers.

### 3.2 Schematic

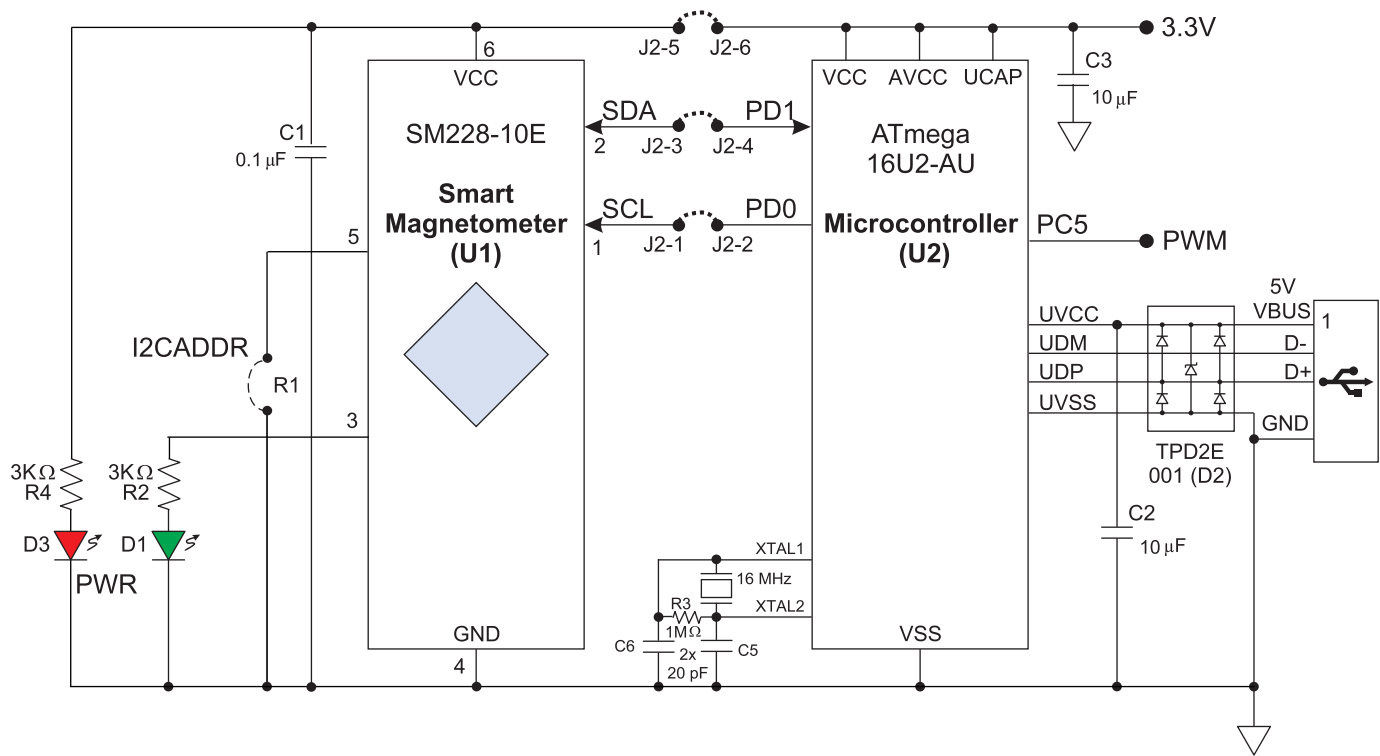


Figure 4. Demonstration Board Schematic.

Part Number	Designator	Manufacturer	Qty	Description
SM228-10E	U1	NVE	1	SMART TMR I2C MAGNETOMETER SENSOR, 15mT
ATMEGA16U2-AU	U2	Microchip Technology	1	IC MCU 8BIT 16KB FLASH 32TQFP
APT3216LSECK	D1	Kingbright	1	LED RED CLEAR 1206 SMD
APT3216LZGCK	D3	Kingbright	1	LED GREEN CLEAR 1206 SMD
	R1	Generic	1	0-OHM JUMPER (DNP) 1206
	R2, R4	Generic	1	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 SO T5
GRM033C71C104KE14D	C1	Murata Electronics	1	CAP CER 0.1UF 16V X7S 125C 0201
LMK212AB7106MG-T	C2, C3	Taiyo Yuden	1	CAP CER 10UF 10V X7R 125C 0805
CL10C200JB8NNNC	C5, C6	Samsung Electro-Mechanics	2	CAP CER 20PF 50V C0G/NP0 0603
ECS-160-20-5PX-TR	Y1	ECS Inc.	1	CRYSTAL 16.0000MHZ 2 0PF SMD
690-005-299-043	J1	EDAC Inc.	1	CONN MINI USB RCPT RA TY PE B SMD
500x	3.3V, GND, DOUT	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	N/A	NVE	1	NVE-branded USB stick with PC install file
N/A	N/A	Generic	1	3ft FLAT USB 2.0 480Mbps Type A Male to Mini-B/5-Pin Male Cable

### 3.3 Circuit Description

#### *The Sensor*

The SM228 (U1) has six pads: power (VDD and GND), I<sup>2</sup>C (SCL and SDA), the DOUT digital threshold output, and the I2CADDR pin to set the part's slave address.

#### *Microcontroller*

The SM228 is compatible with almost any microcontroller. This board uses a popular ATMEGA16U2 8-bit microcontroller (U2), which has integrated I<sup>2</sup>C 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.

#### *I<sup>2</sup>C*

I<sup>2</sup>C links the sensor and microcontroller. The SM228 is an I<sup>2</sup>C Slave, and the microcontroller is configured as the Master. The sensor's I<sup>2</sup>C interface is compatible with 3.3 or five-volt microcontrollers. The evaluation board uses five volts (from the USB port) for the microcontroller and 3.3 volts for the sensor.

#### *Setting the I<sup>2</sup>C Address*

By default, the I2CADDR line is left unconnected (R1 unpopulated) and the default I<sup>2</sup>C address is then 72 dec (48 hex). Installing a jumper (R1) to ground changes the sensor's I<sup>2</sup>C to 16 dec (10 hex).

#### *Test Points, Connectors, and Jumpers*

Six *Test Points* are provided for each of the six I/O pads. A location for an optional header for each of the six connections is provided adjacent to the test points.

Connector J2 allows normal operation by jumpering the SM228 sensor (U1) to the microcontroller (U2), or without jumpers the Connector can be used to provide direct access to the Sensor (see Figure 3 for details).

#### *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<sub>in</sub> 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

trace is on the top of the board it is not well isolated from the sensor, so **the current trace is not recommended for line voltage or safety-critical applications.**

Since the SM228 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.

#### *LED*

Green LED D3 shows when the digital output (DOUT) is activated. A resistor (R2) sets the LED brightness.

#### *Crystal*

A crystal (Y1) provides the microcontroller time base as required for the USB interface. The sensor I<sup>2</sup>C interface operates over an extremely wide clock frequency, so crystal control is not required for the sensor itself.

#### *Decoupling Capacitors*

The board has a small (0201 / 0603 metric) 0.1  $\mu$ F ceramic capacitor (C1) close to the sensor and a 10  $\mu$ F capacitor (C4) a few millimeters away so it does not magnetically interfere with the sensor. The small capacitor is used because it contains very little ferromagnetic material.

There are also decoupling capacitors (C2 and C3) near the microcontroller as recommended by the microcontroller manufacturer.

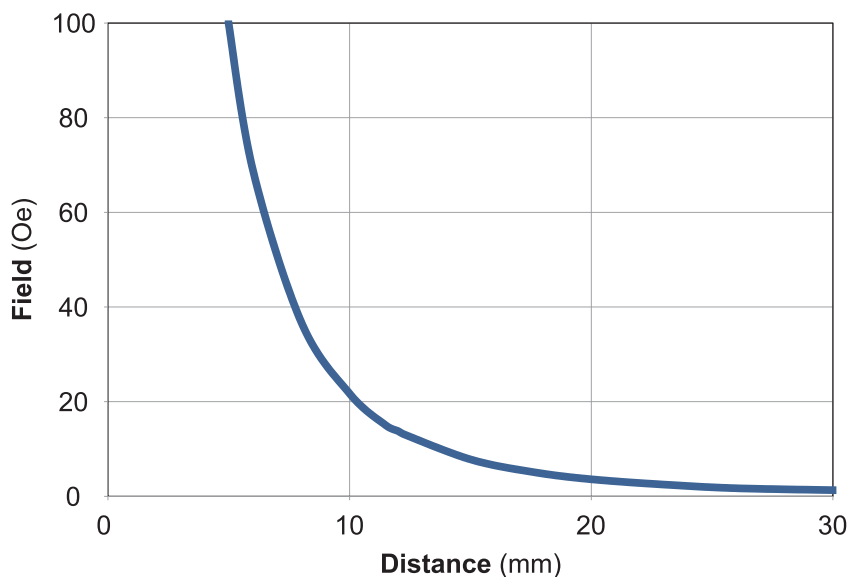
#### *Operating Temperature*

The sensor is rated for the full  $-40$  to  $125$   $^{\circ}$ C temperature range, but not all of the board components are rated for the full temperature range. Therefore the board is not recommended for environmental testing. Breakout boards are offered with the sensor and high-temperature bypass capacitors for such testing.



## 4. Magnets and Magnetic Operation

The Demonstration 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 5. 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

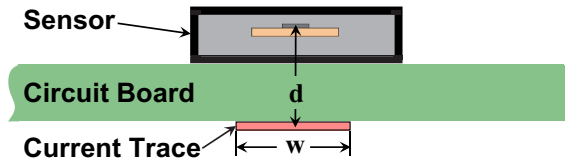
SM228-10E sensors can measure the current through a circuit board trace by detecting the magnetic field generated by the current through the trace. In this application, the digital output can be used for current threshold detection or overcurrent protection.

The demonstration board includes a current-sensing trace:



**Figure 6. 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 and higher isolation voltage. The magnetic field generated in either case can be approximated by Ampere's law:



**Figure 7. 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 (2.8 mT)	10 A
20 Oe (2 mT)	7 A
10 Oe (1 mT)	3.5 A
3 Oe (0.3 mT)	1 A

**Table 2. Typical overcurrent detection settings.**

## 6. User Interface Software Installation

---

### 6.1 System Requirements

The software system requirements are:

- 64-bit Windows 7 or later
- A USB 2.0 port

### 6.2 Software Installation

6.2.1. Run the Setup file on the USB stick if provided to begin the installation, or download the file from <https://github.com/NveCorporation>.

6.2.2. Run the Setup file to install the User Interface and USB driver.

6.2.3. Click on the desktop shortcut to run the software.

6.2.3. Connect the demo board to a USB port.

## **7. User Interface Operation**

---

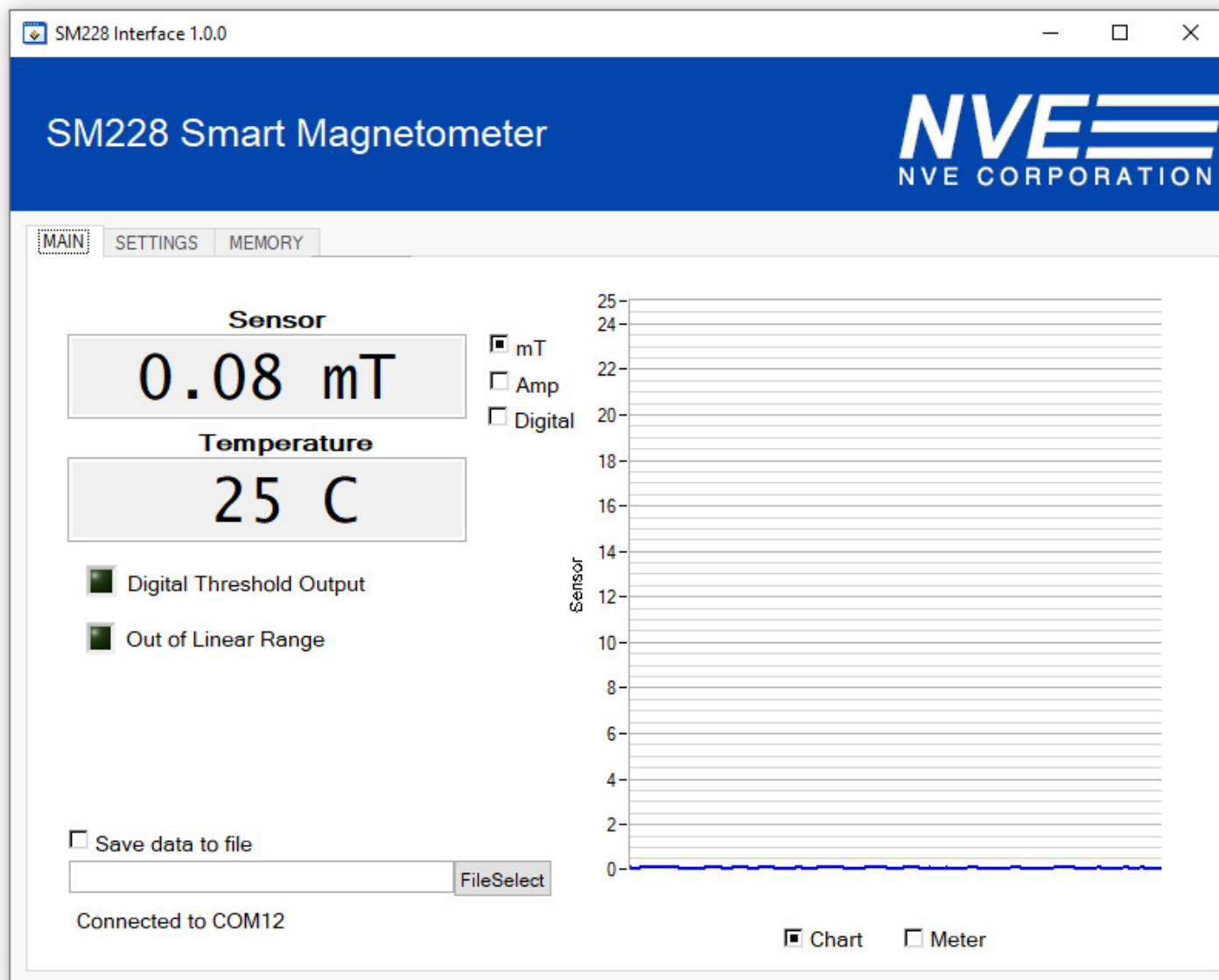
The User Interface allows reading sensor data, setting the digital output threshold parameters, and reading and writing the nonvolatile sensor parameters and calibration constants.

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 real 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** – Shows the state of the sensor’s DOUT output. The DOUT 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.

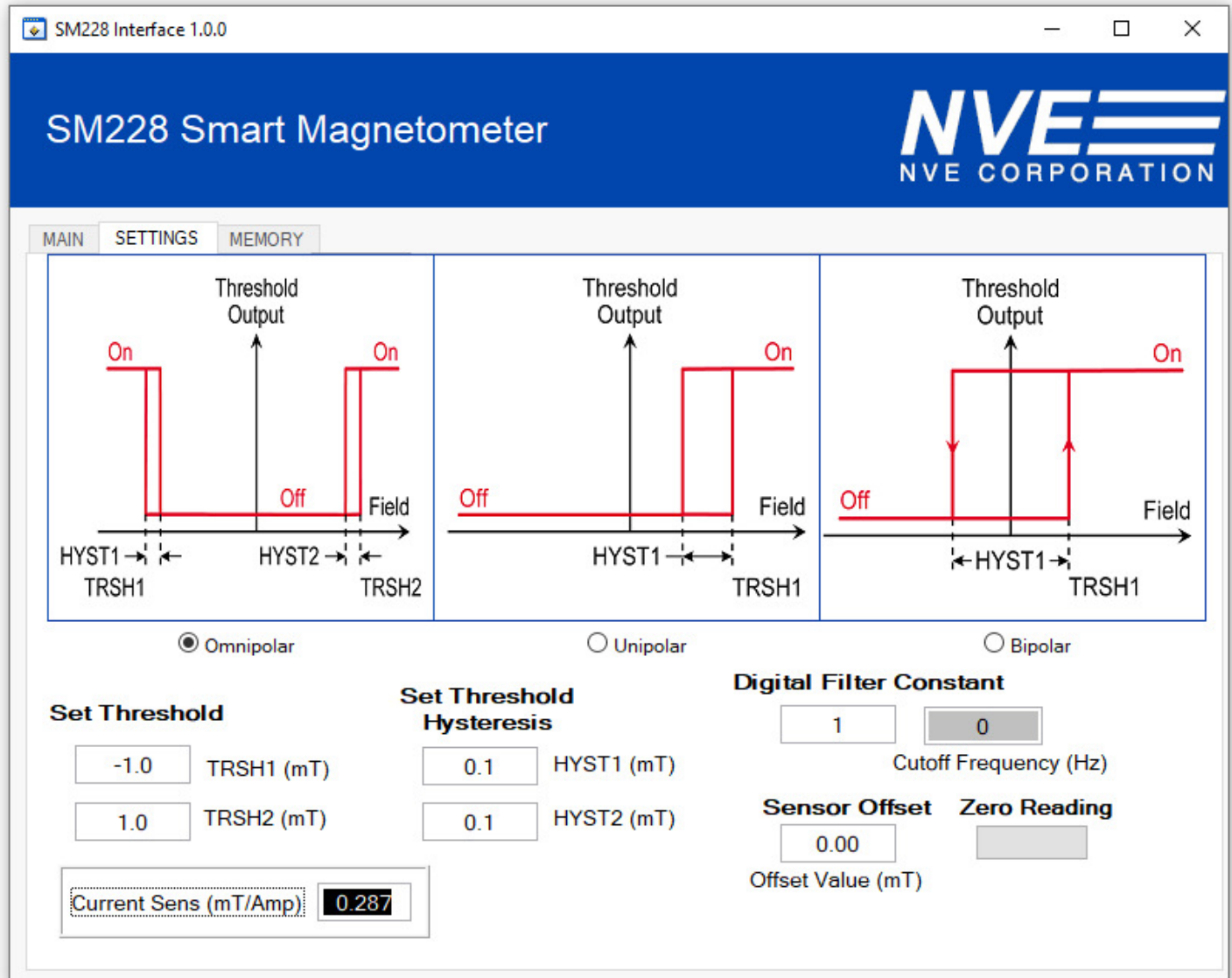
*Save Data to File* – Checking this box saves data points (date, time stamp, elapsed time, temperature, and sensor field or current output) to a file chosen under the *File Select* button. The box can be checked and unchecked while the demo is running. Data are updated every 100 milliseconds when the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



**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 THRS 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 THRS1 and HYST1;  $HYST1 < |THRS1|$ .

**Bipolar** – The output will turn on when the field exceeds the threshold and off with the opposite field. Only requires THRS1 and HYST1;  $HYST1 > |THRS1|$ .

*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*.

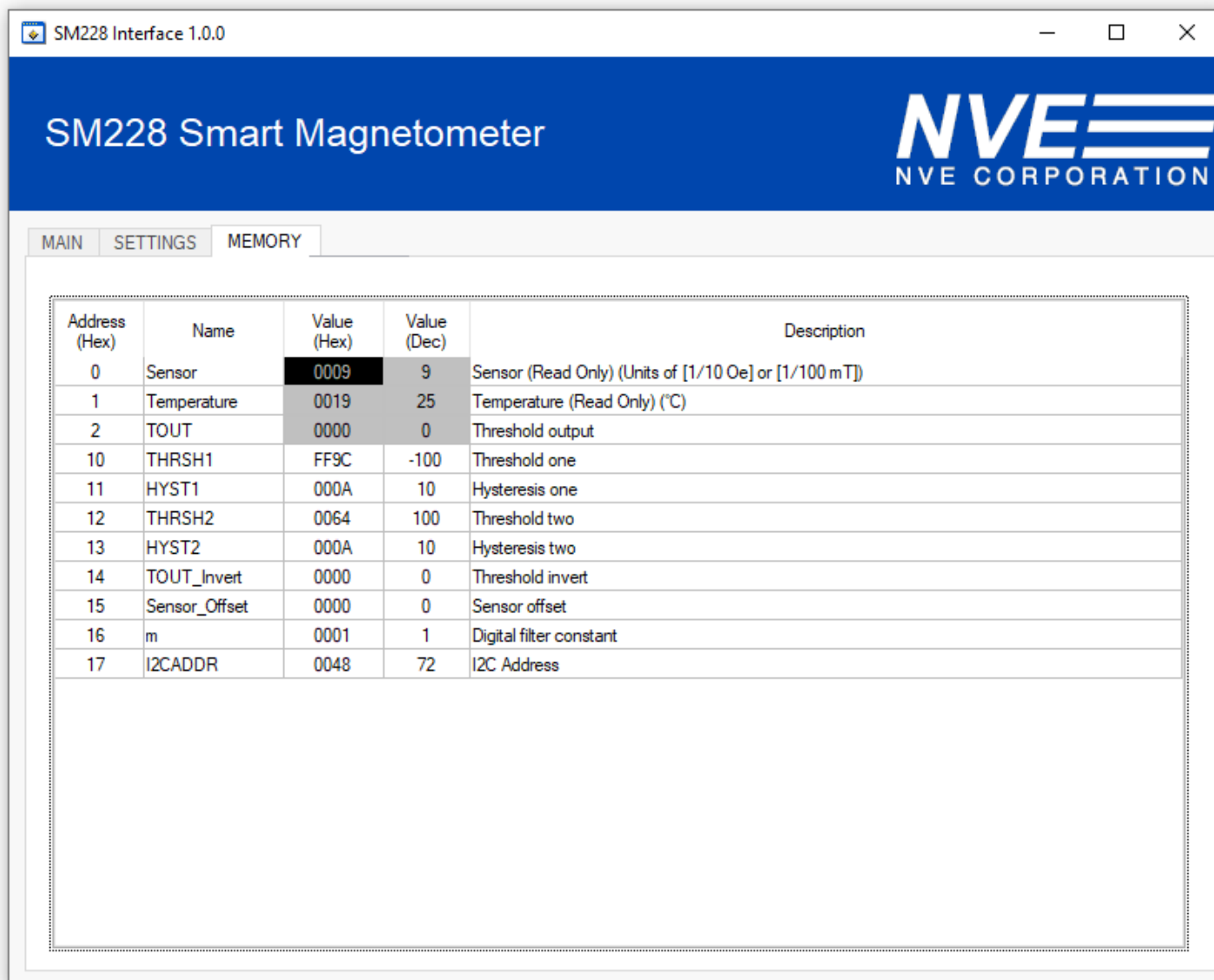
*Digital Filter Constant* – Sets the filter constant which will change the cutoff frequency of the internal filter. The cutoff frequency will be updated and displayed to the right. The range is 1 to 127 (dec). The factory-default sensor constant is "1," which disables the filter.

*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:



Address (Hex)	Name	Value (Hex)	Value (Dec)	Description
0	Sensor	0009	9	Sensor (Read Only) (Units of [1/10 Oe] or [1/100 mT])
1	Temperature	0019	25	Temperature (Read Only) (°C)
2	TOUT	0000	0	Threshold output
10	THRSH1	FF9C	-100	Threshold one
11	HYST1	000A	10	Hysteresis one
12	THRSH2	0064	100	Threshold two
13	HYST2	000A	10	Hysteresis two
14	TOUT_Invert	0000	0	Threshold invert
15	Sensor_Offset	0000	0	Sensor offset
16	m	0001	1	Digital filter constant
17	I2CADDR	0048	72	I2C Address

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.

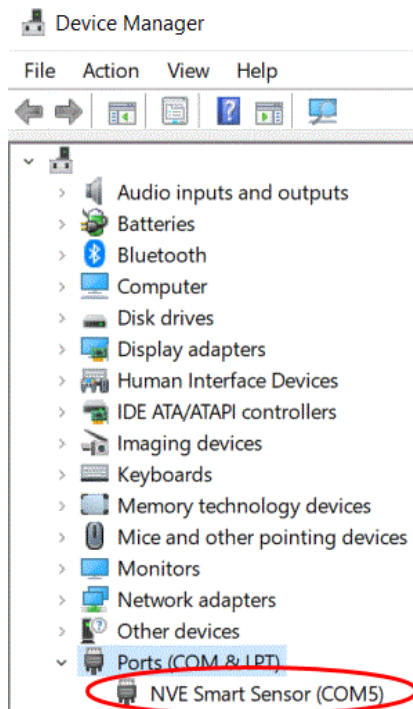
## 8. Troubleshooting

### No communication with the Sensor

1. Ensure there are jumpers on each J2 pin pair.

### No communications with the computer

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



3. Reinstall the software.

## 9. Revision History

---

**SB-00-130-A**

August 2020

**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](http://www.nve.com)  
e-mail: [sensor-info@nve.com](mailto: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-00-130—AG969 Demonstration Kit Manual

*August 2020*