SM12x Smart I²C GMR Magnetometer Evaluation Board

Summary

The AG952/AG962 Evaluation Board provides an easy-to-use interface for SM12x-10E Smart Magnetometers. The evaluation kit includes:

- USB-powered Evaluation Board with:
    - an SM124-10E (1 mT) or SM125-10E (4 mT) GMR Magnetometer sensor
    - a microcontroller connected to the sensor via I²C
    - a regulated 3.3 volt supply to power the sensor
    - 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
- User interface software on a USB stick
- A disk magnet

Contents

1. Overview

This Evaluation Kit Includes:
- An evaluation board including:
  – An SM124-10E or SM125-10E Smart Magnetometer
  – A microcontroller
  – A USB computer interface

- A USB stick with easy-to-install Windows-compatible user interface software

- A disk magnet.

- USB to mini-B cable

SM12x-10E Features:
- Sensitivity to detect magnets more than 50 mm away
- Slick single-byte communication interface
- I²C and digital threshold outputs
- In-plane sensitivity more usable than Hall effect sensors
- Programmable offset and gain correction
- Single-byte addresses and parameters to simplify firmware development
- Two hardware selectable I²C addresses
- Internal temperature compensation
- Optional magnet temperature calibration
- 2.2 to 3.6 V supply
- 3.3 or 5 V compatible I²C interface
- Ultraminiature 2.5 x 2.5 x 0.8 mm TDFN6 package

SM12x-10E Key Specifications:
- 0 to 1 mT (SM124) or 0 to 4 mT (SM125) range
- High accuracy (5% over 0 to 85 °C)
- 8 bit (<1%) output resolution
- 10 kSps sample rate for fast response
- Full −40 °C to 125 °C operating temperature range
- 6 mA typical supply current for low power

2. Quick Start

2.1. Connect the Evaluation Board to a computer via the USB cable.

2.2. Apply a magnetic field with the disk magnet included in the kit and verify that the LED turns on:
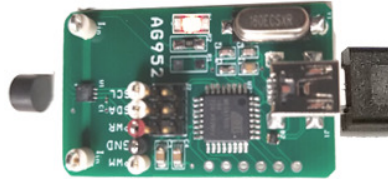

Figure 1. Activating the sensor with a disk magnet.

2.3. Run the Setup file from the USB stick if provided, or download from https://github.com/NveCorporation to install the software on a Windows PC.

2.4. Install the USB driver from "C:\Program Files (x86)\NVE folder\NVESmartSensor.inf."

2.5. Click on the desktop icon to launch the application.

2.6. The user interface will show the applied field, which can be changed by moving the magnet relative to the sensor.

3. The Evaluation Board

3.1 Board Layout

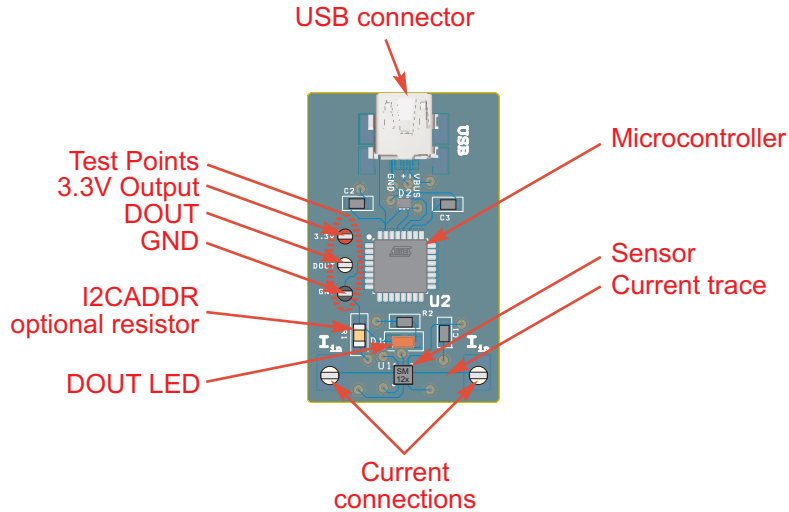The evaluation board communicates with a host computer via USB and a Smart Magnetometer via I²C:

Figure 2. The Evaluation Board (actual size).

| Part Number	Designator	Manufacturer	Qty	Description
SM124-10E	U1	NVE	1	SMART GMR I2C MAGNETOMETER SENSOR, 1 mT
ATMEGA16U2-AU	U2	Microchip Technology	1	IC MCU 8BIT 16KB FLASH 32TQFP
APT3216LSECK/J3-PRV	D1	Kingbright	1	LED RED CLEAR 1206 SMD
	R1	Generic	1	0-OHM JUMPER (DNP) 1206
	R2	Generic	1	RES 1K 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 02 01
LMK212AB7106MG-T	C2, C4	Taiyo Yuden	1	CAP CER 10UF 1 0V X7R 125C 0805
GRM21BR71C105KA01L	C3	Murata Electronics North Ame	1	CAP CER 1UF 16V X7R 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
Package-Level Components				
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

3.2 Schematic
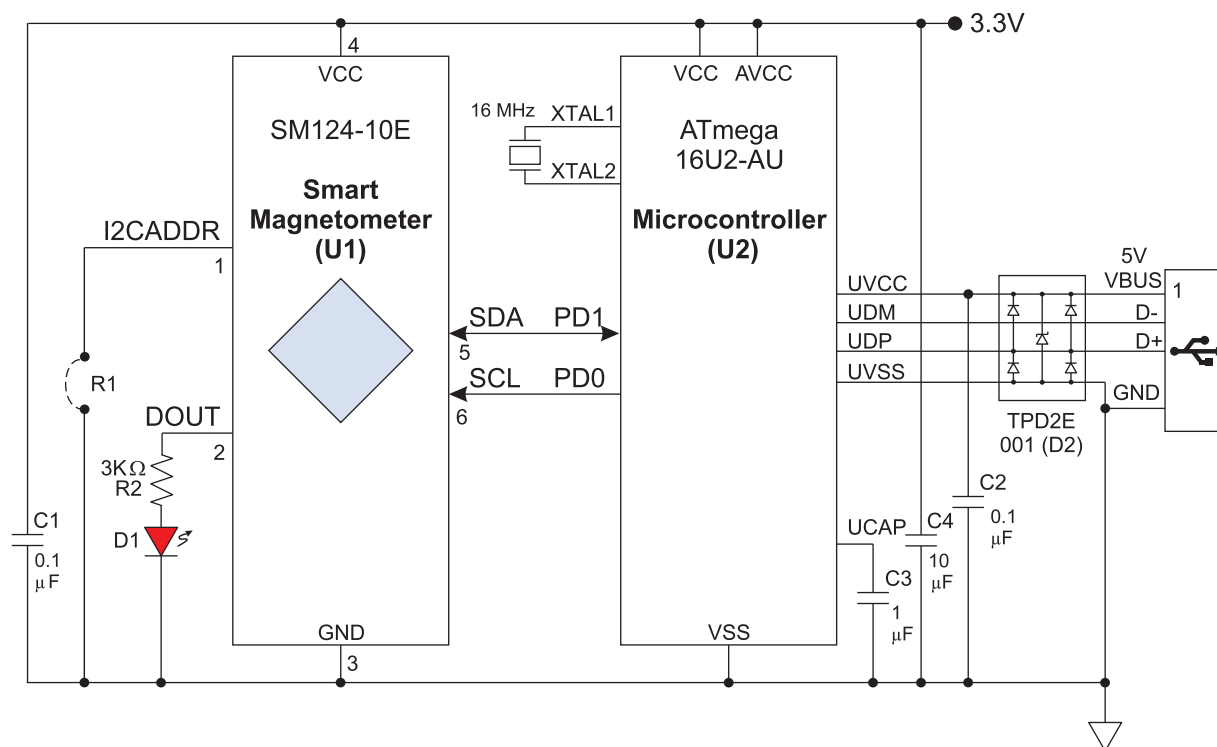
Figure 3. Evaluation Board Schematic.

3.3 Circuit Description

The Sensor
The SM12x (U1) is a six-pin component, with power (VDD and GND); I²C (SCL and SDA), the DOUT
digital threshold output, and the I2CADDR pin to set the part's slave address.

Microcontroller
The SM12x is compatible with any microcontroller. This evaluation board uses a popular ATMEGA16U2
8-bit microcontroller (U2), which has integrated I²C and USB interfaces. The microcontroller also has an
internal 3.3-volt regulator, which is used to power the sensor.

I²C
I²C links the sensor and microcontroller. The SM12x is an I²C Slave, and the microcontroller is configured
as the Master. The sensor's I²C 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 I²C Address
By default, the I2CADDR line is left unconnected (R1 unpopulated) and the default I²C address is
then 72 dec (48 hex). Installing a jumper (R1) to ground change s the sensor's I²C to 16 dec (10 hex).

Jumpers / Connector
Connector J2 allows normal operation by jumpering the sensor (U1) to the microcontroller (U2), or without
jumpers the Connector can be used to provide direct access to the Sensor.

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 referenced to board ground and
ratiometric with the 3.3 V regulated supply. It is scaled for maximum output (3.3 V) at 150% of the linear
range of 1 mT for the SM124 and 4 mT for the SM125 so, for example, the SM124 output is 2.2 V / mT or
0.22 V / Oe. PWM resolution is eight bits over 3.3 V, or about one part in 170 over the sensor's linear
range. The PWM output is generated by the microcontroller, not directly by the sensor.

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 (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 sensor is omnipolar, it provides a positive output regardless of current polarity, and therefore
provides a "full-wave rectified" output for AC currents.

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.

7

LED
Red LED D1 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 SPI 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 µF ceramic capacitor (C1) close to the sensor and a 10 µF capacitor (C3) 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 a 1 µF decoupling capacitor (C4) near the microcontroller and a 10 µF decoupling capacitor (C2) for the 5 V USB bus supply, both as recommended by the microcontroller manufacturer.

Operating Temperature
The sensor is rated for the full −40 to 125 °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 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:
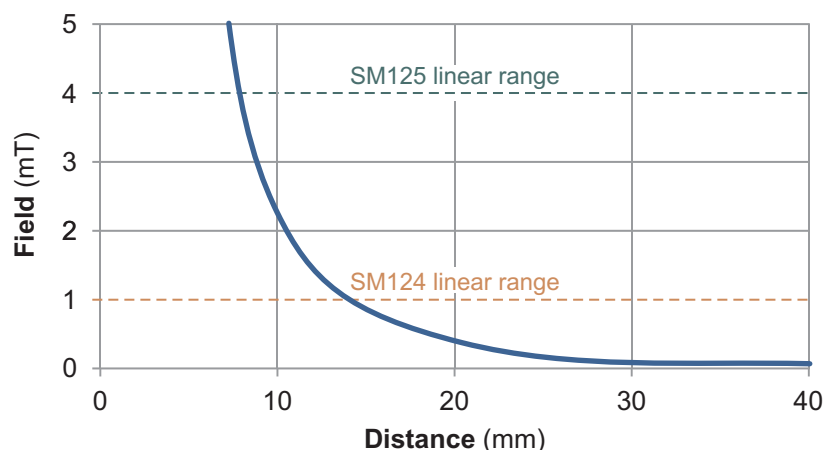

Figure 4. Magnetic field from the 6 mm dia. x 4 mm thick ferrite magnet
(referenced to the center of the sensor).

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
The default magnetic threshold is 10 Oe, and common thresholds are 4 to 10 Oe. Thresholds even lower than 4 Oe can be programmed, although care must be taken to account for the earth's magnetic field, which is typically on the order of 0.5 Oe.

The magnetic threshold is expressed as a percentage of the sensor's range, and can be changed by writing to the appropriate address in the sensor's nonvolatile memory. The magnetic hysteresis can also be set.

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

Sensor	Parameter		Activation field	Nominal magnet distance
	Threshold	Hysteresis		
SM124	100%*	10%*	1 mT	12.5 mm
	50%	5%	0.5 mT	18 mm
	20%	2%	0.2 mT	24 mm
SM125	100%*	10%*	4 mT	8 mm
	50%	5%	2 mT	10 mm
	20%	2%	0.8 mT	14 mm

*Factory defaults

Table 1. Typical proximity-sensing settings.

4.2 Temperature Compensation

The sensor is factory calibrated and temperature compensated to accurately read magnetic field over temperature. The default reading is the temperature-compensated number. The uncompensated output can be read from a different address.

5. Current Sensing

SM12x 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:
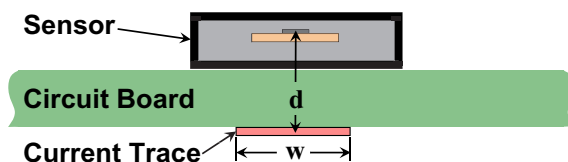

Figure 6. Current-sensing over a circuit board trace (side view).

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

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 3 Oe/A, and an SM124 sensor is linear to approximately 10 Oe or 3.5 A, and an SM125 sensor is linear to approximately 40 Oe or 14 A.

Typical parameters for overcurrent sensing are summarized in the following table:

Sensor	Parameter		Current Threshold	
	Threshold	Hysteresis	On	Off
SM124	100%	90%	3.5 A	0.35 A
	30%	27%	1 A	0.1 A
	15%	5%	0.5 A	0.35 A
SM125	71%	64%	10 A	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
- One 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 executable to install the software.

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

    6.2.4. Right click on "NVESmartSensor.inf" and click "Install."
The USB connection can be verified by checking for "NVE Smart Sensor" under "Ports (COM & LPT)" in Windows Device Manager.

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

    6.2.6. Connect the demo board to a USB port.

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 select either Simple Comparator or Window Comparator modes, and to set the digital output thresholds and hysteresis.

3. Memory – A table shows the sensor's data and calibration constants. Parameters can be changed by double-clicking on the appropriate cell, typing in a new number, and hitting "Enter."

The three tabs are described in detail in the following sections.

7.1. Main Tab
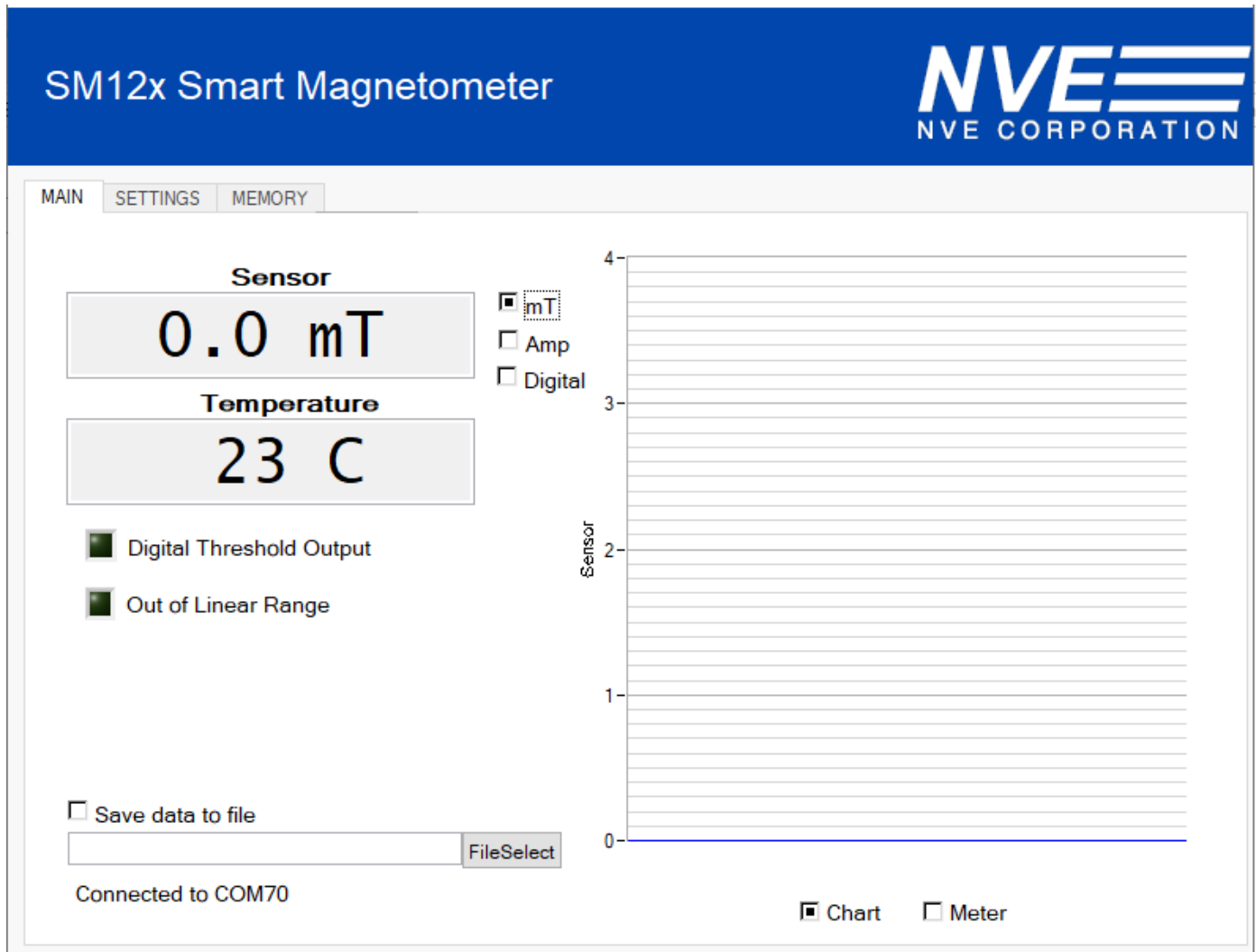
Main tab elements are described below:

Upper Digital Display – Displays the output of the device in either oersteds or amps. Double right-clicking on the display changes the precision.

Lower Digital Display – Displays the calibrated temperature from the sensor in degrees Celsius.

mT – Sets upper display to millitesla.

Amp – Sets the upper display to amps.

Digital – Sets the upper and lower displays to either hexadecimal or decimal.

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.

Digital Threshold Output – A virtual LED indicating the state of the sensor's digital threshold output (DOUT). The settings can be changed in the Settings Tab.

Out of Linear Range – Indicates the magnetic field exceeds the sensor's linear range (1 mT / 10 Oe for the SM124 and 4 mT / 50 Oe SM125).

7.2. Settings Tab (simple comparator mode)
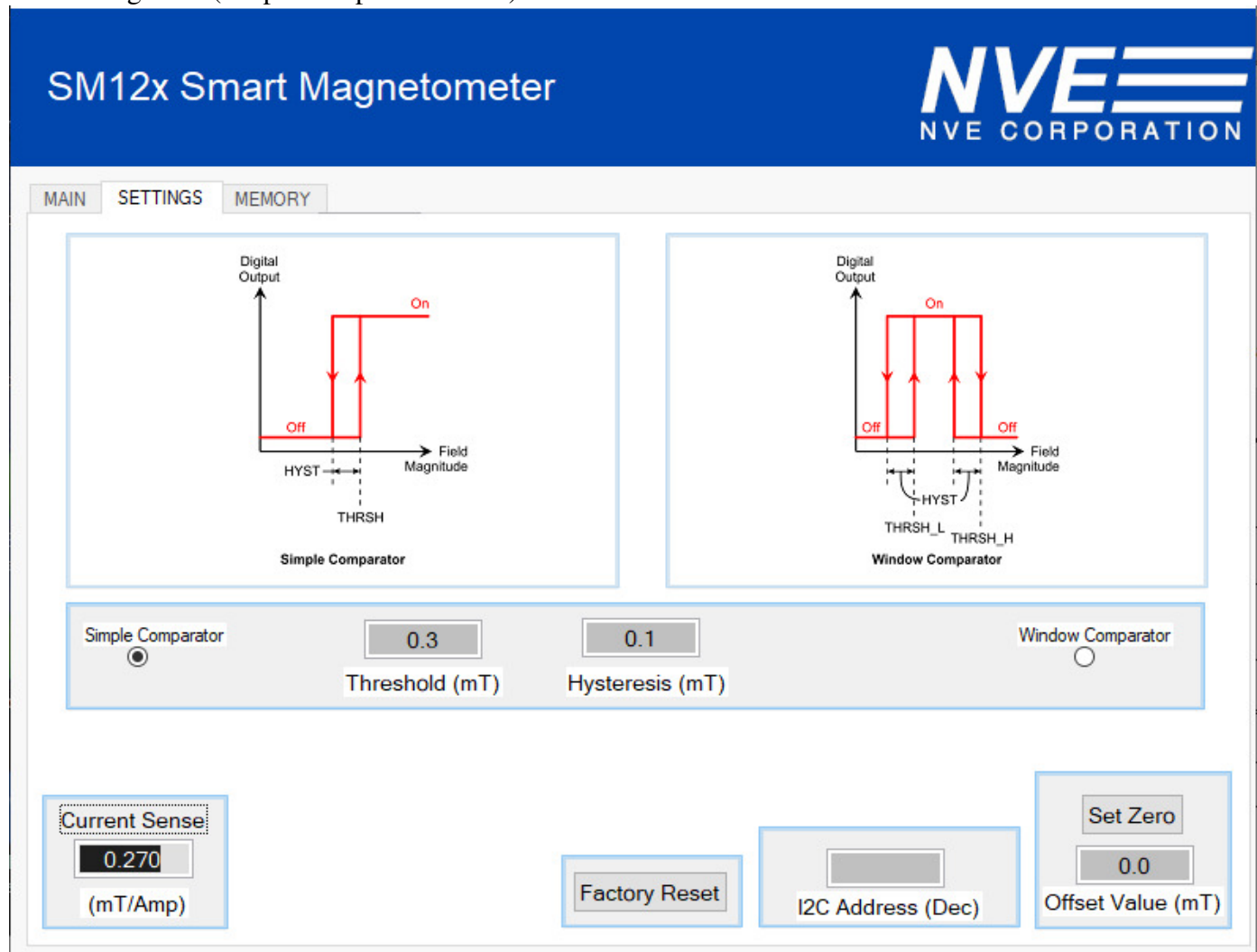
Simple Comparator – Sets the sensor Digital Threshold Output to the "Simple Comparator" mode as opposed to the "Window Comparator" mode. This is the default mode.

THRESH– Sets the sensor's digital output (DOUT) threshold, which is the threshold where DOUT turns on.

HYST – Sets the threshold differential; the digital output will switch at *Thresh – HYST*.
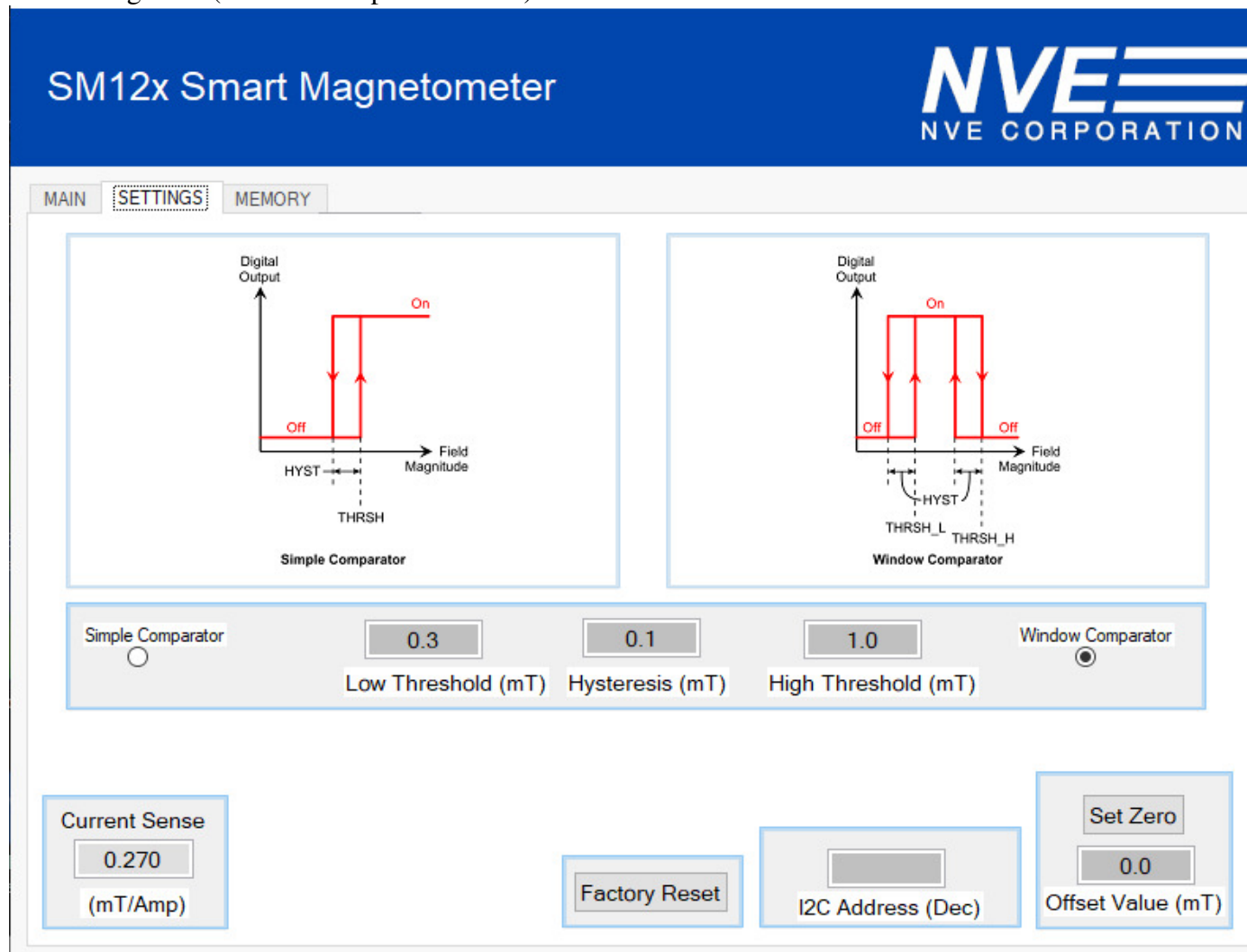
Current Sense – Sets the calibration factor for current sensing in mT/Amp.

Factory Reset – Resets the sensor to the factory defaults.

I2C Address – The sensor's I²C slave address in decimal format.

Set Zero – Sets the sensor offset to the present sensor output.

7.3. Settings Tab (window comparator mode)

Window Comparator – Sets the sensor Digital Threshold Output to the "Window Comparator" mode as opposed to the default "Simple Comparator" mode.

THRESH-L – Sets the Window Comparator "Low" threshold.

HYST – Sets the hysteresis for the switching thresholds.

THRESH-H – Sets the Window Comparator "High" threshold.

I2C Address – The sensor's I²C slave address in decimal format.

Current Sense – Sets the calibration factor for current sensing in mT/Amp.

Factory Reset – Resets the sensor to the factory defaults.

I2C Address – The sensor's I²C slave address in decimal format.

Set Zero – Sets the sensor offset to the present sensor output.

7.4. Memory Tab

SM124 Smart Magnetometer

MAIN | SETTINGS | MEMORY

| Address (Hex)	Name	Value (Hex)	Value (Dec)	Description
0	Sensor	0000	0	Sensor (calibrated) (% of 10 Oe /1 mT)
1	Sensor_Raw	0004	4	Sensor (uncalibrated)
2	Temp	0017	23	Temperature (℃)
3	DOUT	0000	0	Digital Output
4	I2CADDR	0048	72	I2C Address
20	Low Threshold	0032	50	Sensor low digital threshold (% of 10 Oe /1 mT)
21	High Threshold	0064	100	Sensor high digital threshold (% of 10 Oe /1 mT)
22	Hysteresis	000A	10	Magnetic threshold differential (% of 10 Oe /1 mT)
23	DOUT_Invert	0000	0	Digital output invert (High to invert DOUT)
24	Sensor_Offset	00FD	-3	Sensor offset (% of 10 Oe /1 mT)
25	Sensor_Sens	0064	100	Sensor sensitivity (% of spec)
26	Tempco	0064	100	Temperature coefficient of sensitivity (% of spec)
27	Temp_Offset	00FB	-5	Temperature sensor offset (℃)
28	Temp_Slope	0063	99	Temperature slope (Temp. cal. curve %)
29	m	0001	1	Digital filter constant (m=1 disables filter)
2A	I2C_Pullups	0001	1	Enable pull-ups (1=enabled, 0=disabled)
2B	Magnet_Comp	0000	0	0 = no compensation, 1 = ceramic magnet, 2 = NdFeB magnet

Notes:

- A second threshold for the optional window comparator function and related changes to the memory addresses was effective with sensor lot codes 1932xx and higher. For lot codes less that 1932xx, refer to Rev. D of this manual.

- Calibration constants are set at the factory and vary from part to part.

- The factory default for the digital filter constant in memory location 28 (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:
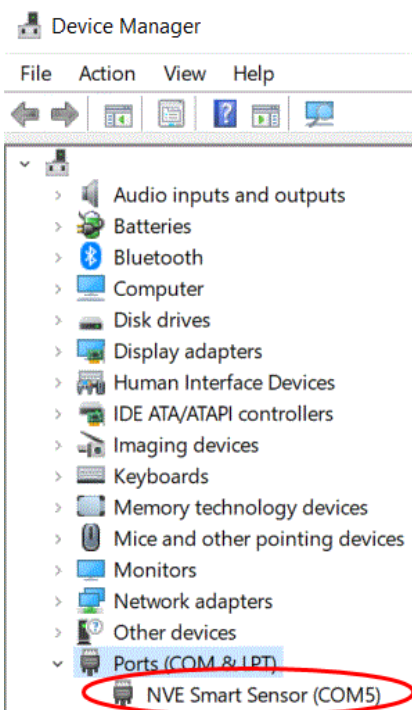
    3. Reinstall the USB driver.

9. Revision History

SB-00-076-G December 2019	**Changes** • Added SM125 (4 mT version). • Changed from oersteds to millitesla. • Single-file user interface software installation. • Added USB stick with user interface software.
SB-00-076-F November 2019	**Changes** • Added PWM output to board. • Added crystal to schematic and BOM. • Added sensor-to-microcontroller jumpers. • Updated bypass capacitors.
SB-00-076-E August 2019	**Changes** • Added window comparator function to "Settings" and "Memory" tabs. The function is implemented in sensor lot codes 1932xx and higher (refer to Rev. D of this manual for lot codes less than 1932xx). • Corrections to the Memory Tab memory table (p. 16).
SB-00-076-D June 2019	**Change** • Updated software installation instructions for simplified installation with a single executable.
SB-00-076-C April 2019	**Change** • Changed C1 (bypass capacitor) from 0.1 µF to 1 µF.
SB-00-076-B February 2019	**Change** • Simplified "Troubleshooting" section.
SB-00-076-A December 2018	**Change** • Initial Release

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